Essays on Governments, Central Banks, and Credibility

by

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Abstract

In my PhD thesis I study the motivations, policy paths, and impacts of economic and political institutions in a number of different scenarios, employing a diverse range of methods and approaches. In Chapter 2 I explore the case of a central bank attempting to deal with a consumption externality created by external consumption habits by designing an application of a New Keynesian Dynamic Stochastic General Equilibrium model. In Chapter 3 I expand on the context of the previous Chapter to examine the possibility of a central bank setting monetary policy with a present bias, and what this means for the economy as a whole. Finally, in Chapter 4 I investigate the empirical patterns of political pressure on central banks on a global level.

The main contributions of my PhD thesis are to shed more light on the consequences of external consumption habits in a context of discretionary monetary policy; to analyse the previously unexplored case of a central bank with a present bias; and to produce novel empirical findings on the topic of political pressure.

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List of Abbreviations

The following table describes the significance of various abbreviations and acronyms used throughout the thesis. The page on which each one is defined or fist used is also given.

Abbreviation	**Meaning**	**Page**
CBI	Central Bank Independence	6
CoPI	Corruption Perceptions Index	101
DPI	Database of Political Institutions	100
DSGE	Dynamic Stochastic General Equilibrium	3
ECB	European Central Bank	96
ERS	Exchange Rate Stability	116
FE	Fixed Effects	123
FO	Financial Openness	116
GEM	Global Economic Monitor	100
MI	Monetary Independence	116

1. *Overture*

Governments, Central Banks, and Credibility

The PhD journey took me on a path of reflection on what it means to build theoretical contributions through models, and led me to look at the interactions between governments and central banks through a variety of lenses. The relationship between these two institutions is not unique nor immutable. Governments, and more specifically politicians, differ from central banks in their time frame, and can also differ in their incentives. These two factors play a big role in determining whether the objectives of the two institutions will be aligned or not, and the nature of their interactions.

Sometimes governments and central banks have the same objective, yet one of them is not in the position to deliver it. In some of these cases the other policy maker can step in to aid in delivering their common policy objective. This is the case with the topic of my Chapter 2 (Overconsumption Externality): both government and central bank want to correct the welfare-reducing overconsumption externality, but as long as the central bank does not have the credibility necessary to sustain a committed policy, it will not be able to curb the externality. The government, on the other hand, can introduce a consumption tax that will, to a large extent, correct the overconsumption externality. Here the government stepped in where the discretionary central bank could not deliver. One can find more instances of governments and central banks working together towards a shared goal, e.g. the expansionary policy of Federal Reserve and U.S. Government in response to the Global Financial Crisis.

Collaboration between the two institutions happens when their interests are shared ones; otherwise, government and central bank might clash, sometimes publicly. This is indeed the case discussed in Chapter 4 (Empirical Evidence on Political Pressure): a government, motivated by short-term political gain, pressures the central bank to make choices that create economic instability, and might even lead to explosive scenarios.

The relationship between governments and central banks is partly influenced by credibility: the credibility these two policy makers possess, the credibility they seek to build, the credibility they require to reach their policy goals. Do policy makers build their credibilities by collaborating, or one's credibility grows by chipping away at the credibility of the other? The answer depends, in part, on whether their objectives are aligned or not. When the two policy makers have competing objectives, it is possible that their credibility is built at the expense of their opponent's. The tension this clash creates can be explosive.

Unless I specify otherwise, in this thesis I refer to the textbook context of separate and independent institutions: governments are in charge of fiscal policy, and central banks of monetary policy. Chapter 4 reviews the history of how this came to be the golden standard of economic policy. Yet two independent institutions can and do clash even though their remits are independent, because their tools and instruments interact, and because the objects of their policies are largely the same. Furthermore, knowing that the relationship between governments and central banks is not unique nor immutable, we must recognise the risk that continuous and excessive clashes could lead to the balance of independence being tipped. If we see the rise of protectionism, nationalism, and authoritarianism as an endogenous phenomenon, we must then recognise that the institutional design and the fragile relationships between institutions bring large contributions to the creation of politically and/or economically unstable systems. And, in turn, countries subject to chronic political and economic instability get trapped into flawed institutional settings.

What we might see as the textbook case, the end point, the ultimate balance of independence across institutions is, in fact, a stop on the evolutionary process of institutions. We may call it an equilibrium, but if we believe this equilibrium to be the best one, we must work to preserve it. Part of the work of preservation is found in gaining a deeper understanding of the forces that push us off equilibrium. Chapter 3 (Central Banks with a Present Bias) follows this path, seeking better understanding of the consequences of a central bank that sometimes sets monetary policy influenced by a present bias.

Epistemological Approach

In my PhD thesis I set to explore the implications of time frames and incentives: how they can affect the interactions between governments and central banks, and what this means for their credibilities. In order to do this, I employ different modelling approaches, according to what I believe to be the most appropriate model to tackle the specific research question. I will now briefly discuss the epistemological approach I use when developing my models.

In talking about epistemology, I must start from a key point many before me have made: the focus of social sciences is understanding, not necessarily explaining (Hausman, 1992). As even life sciences struggle to be able to afford the luxury of explanations, the luxury of unequivocal answers, the luxury of precision. These are most often out of remit for social sciences. Social sciences are often limited to understanding the phenomena we observe.

This limitation stems from the object of our studies: human nature and behaviour. To explain human (economic) behaviour with precision means to explain human nature and its causality, a task that has proven challenging for centuries (Hausman, 1992). We economists rest on the shoulder of philosophy, sociology, and psychology giants, and none of us can claim to be able to unequivocally explain human behaviour. It is possible we never will be. Economics, like all social science, has to be content with understanding: we will not explain the world, we will describe it, and in describing it we will learn more about it.

The distinction between understanding and explaining may seem like a subtle one. Yet, to do social science one must first internalise this distinction, as well as the hard constraint that will always exist on our body of work.

The way we describe and learn from the world is through our models: our models make assumptions, develop them like one develops film in a dark room, and present us with a photograph of economic phenomena. We then must hold up this photograph next to the real world, and collectively decide if it is accurate and useful. In epistemological terms, this means proceeding by falsifiability: we ought to "formulate our theories as unambiguously as we can, to expose them as clearly as possible to refutation" (Magee, 1985; p. 23).

Falsifiability can be implemented in a series of steps: formulating a theory as clearly as possible, laying the assumptions bare for any reader and researcher to see, producing clear statements with high informative content, and being open to fail the empirical test. Let me now further elaborate on these steps.

Firstly, any kind of economic model needs to be clear on what it is trying to achieve. Empirical prediction is not the same as understanding mechanisms, and different needs are better suited by different models (see, for example, Blanchard, 2017). Dynamic Stochastic General Equilibrium (henceforth: DSGE) models, by design, "have a high degree of theory coherence but a much more limited degree of data coherence" (Wren-Lewis, 2018; p. 59). DSGE's priority is not to carefully match the data, but rather to understand behaviours and propagation mechanisms. Judging a DSGE model by its empirical accuracy is, then, akin to judging a fish by its ability to climb, as the animal allegory often misattributed to Albert Einstein goes. Our misjudgement of DSGE models might make them misunderstood geniuses, to complete the allegory. Yet it is not genius I posit we ought to be interested in, but rather purpose.

Moreover, "asking a model to do more than what it was written for can be a dangerous exercise" (Ghironi, 2018; p. 3). If the first step of building an economic model is to decide which aspects of the economy are going to be modelled, one must also restrict their attention to that aspect alone. One must resist the temptation to blindly re-purpose models that successfully answer other questions. It is not by imposing models across fields that we unlock greater knowledge, because these models were not designed to fit estranged phenomena. Performance, by which I mean robustness to falsifiability, in the chosen field cannot be taken to mean ubiquity. We cannot achieve a unique economic theory of everything, nor should we struggle for it.

Choosing which phenomena the model is focusing on and being clear about what the model is trying to achieve are the key elements of formulating a theory as clearly as possible, the very first step of falsifiability.

Secondly, when constructing models, we must also pick reasonable assumption and expose them to the light. Economic models that aim to understand mechanisms and distortions essentially draw a causal link between the selected assumptions and the outcome of the model. What an economic model boils down to, when everything else is stripped away, is this: a selection of assumptions create a mechanism or distortion. This causal link between assumptions and mechanism is important because it helps us understand the workings of said mechanism and the effects of said distortion. This is why choosing assumptions that are reasonable is of the utmost importance. If a mechanism can be replicated through outlandish foundations and tricks, we have not actually understood it, and our knowledge has not progressed.

Thirdly, our models need to produce testifiable predictions. The testifiable predictions of an economic model are clear statements with high informative content. Specifically, economic models have to be empirically tested according to what their purpose is: if their aim is not to match the data but rather mechanisms, as it is for most theoretical models, they must be tested in achieving accurate mechanisms.

Finally, whenever a model unequivocally fails the empirical test, its current form has to be discarded, and the process starts over. As natural sciences know too well, and as social sciences should stop ignoring, failure is crucial in producing knowledge. In the words of Karl Popper, "[t]he wrong view of science betrays itself in the craving to be right" (Popper, 1959; p. 281).

When we test our predictions against empirical facts, we must also remember that economics can never escape the social science realm. Our experiments are rare, our data contradictory, our subjects changeable. Our answers are rarely unequivocal and we must, therefore, set reasonable objectives, as we will not achieve the theory of everything. We must choose reasonable topics, as successful models should not be re-purposed across topics and fields. We must set reasonable assumptions, as niche assumptions cannot provide a strong foundation for a model. We must use reasonable judgement when we empirically evaluate our models.

How does falsifiability ensures the creation of purposeful theory? Once again, reason, now accompanied by clarity: models with reasonable and clear purpose can create purposeful work. Purposeful work is, in my view, work that teaches how to tell a story.

The Content of This Thesis

My epistemological reflections guided the choices of theory and modelling I made in Chapters 2 and 3. In Chapter 2 I investigate the consequences of external consumption habits, and what a discretionary central bank can do to reign in these consequences. I viewed external consumption habits as a distortion, so I chose a Dynamic Stochastic General Equilibrium approach. In Blanchard (2017)'s words, a DSGE model allows to "explore the macro implications of distortions or set of distortions", so it was the obvious candidate for my research question.

External consumption habits produce an overconsumption externality, with average consumption and output levels being higher than in a context without habits, or where habits are internalised. Households over-consume and under-save. In studying the overconsumption externality I uncovered something interesting: my DSGE model showed that external consumption habits put a downward pressure on prices for a discretionary central bank. The central bank is tempted to create a disinflation surprise to slow down consumption and curb the externality. A committed central bank does not give in to the temptation, but a discretionary central bank might. Households know this, and expect prices to drop. Disinflation becomes a self-fulfilling prophecy.

A discretionary central bank dealing with external consumption habits was a story never explored before, and I tell that story in Chapter 2. It is the first of my essays about governments and central banks: a central bank that, because of its discretionary nature, cannot correct a distortion in consumption. Chapter 2 also briefly discusses how the government could be more effective in dealing with the overconsumption externality fed by habits, at least in a discretionary monetary policy setting. The government imposing a consumption tax would not completely offset the externality; it would do so in steady state and it would reduce volatility, however, which is more than the discretionary central bank can hope to achieve.

Similarly, I viewed the present bias of the central bank in Chapter 3 as a distortion to the economic system, and set out to explore its channels and mechanisms through a DSGE application. Specifically, following Laibson (1997) I model the present bias through a quasi-hyperbolic discounting function. Chapter 3 in this sense expands on Chapter 2, applying the quasi-hyperbolic discounting to a discretionary central bank in a context where households have superficial external consumption habits.

Exploring the case of a discretionary central bank that sets its monetary policy rule with a present bias exposes the trade-off created by external consumption habits: curbing the overconsumption externality is done at the expense of creating disinflation today. A central bank with a present bias values the future less and the present relatively more, and therefore prefers to create smaller inflation costs for itself. It does this even though it creates a greater habit stock to be sustained in the future. The present bias, I conclude, is linked to pressure on inflation that brings it closer to zero, motivated by the desire to minimise current inflation costs.

In Chapter 4 I empirically explore the phenomenon of political pressure. In line with the literature, I find that all central banks can be pressured by the government, irrespective of their degree of Central Bank Independence (henceforth: CBI). The likelihood of pressure is related to political checks and balances, to the political system, to party orientation, and to party nationalism. I am able to add to these: first, I find that Parties can be split into four separate clusters, based on their likelihood of pressure to ease, from nationalist right-wing and centrist Parties as the no-pressure cluster to nationalist left-wing and other Parties as the high-pressure cluster. Second, I find that central banks in the top 5% of countries for level of public debt are pressured to ease significantly more, yet central banks in the countries with above-median levels of public debt are less likely to succumb to pressure. Furthermore, political pressure to ease and the political cycle do not appear to be linked. Moreover, policy trilemma and the likelihood of pressure to ease are linked – this link is strong, non-linear, and robust to the degree of perceived corruption. This is an important result, and one that explores relationships never investigated before. My analysis indicates that the policy trilemma positioning significantly contributes to creating a context that can enable political pressure, giving policy-makers some food for thought.

Lastly, I explore the link between pressure to ease and inflation, to find that succumbing to pressure to ease is linked to higher inflation in the following quarter, confirming the economic theory predicting inflationary episodes following an interest rates cut. I also find that higher past inflation levels are linked to increased probability of pressure to ease, corroborating my conjecture that central banks with higher tolerance for inflation are more likely to be pressured.

Contribution

The main contribution of my PhD thesis is to deliver a deep dive into the mechanisms and consequences of two distortions: external consumption habits for households, and a present bias for a central bank. I am able to shed new light on these previously unexplored topics, thus providing a more rigorous context to debates relating to these issues. A further contribution of my PhD thesis is to set out a number of stylised facts regarding political pressure, facts which can be used to inform both the theoretisation of this phenomenon as well as real-world policies targeting the pressure itself as well as its consequences.

Before diving into the thesis, a passing note on syntax: I use quotation marks for direct quotes, and italic for emphasis, for variable names, for concepts I define, and for Latin.

2. Overconsumption Externality

2.1 Introduction

This chapter addresses the case of a central bank dealing with external consumption habits, with the aim of establishing if and how the consumption externality alters the behaviour of the central bank. The contribution of this chapter is a careful examination of how the discretionary central bank can deal with attempting inflation stabilisation and the curbing of the overconsumption externality, shedding light on a topic that has not received extensive attention thus far.

I consider a context of discretionary monetary policy, i.e. a situation where the monetary authority is not in a position where it can credibly commit to and enforce the optimal policy, but rather has to set policy for the current period, every period. I introduce external consumption habits to this context: households' level of consumption is linked to aggregate past consumption, and consuming below this aggregate level gives households extremely low utility. I compare it to the commitment case, which I use as a benchmark, yet the chapter focuses on the case of a discretionary central bank. In my analysis I focus on qualitative effects and the importance of various channels, rather than on empirical magnitudes.

I show that, in this context, external habits lead to an overconsumption externality: the policy maker's objective to maximise household welfare translates into a need to contain the overconsumption externality. In an effort to do that the policy maker wants to surprise households with falling prices to encourage them to postpone consumption. Households, however, foresee the central bank's behaviour and expect negative inflation. The result is considerable downward pressure on inflation. This negative inflation comes with no benefit for consumption: households still overconsume. While the discretionary central bank's inability to credibly make promises about the future results in a positive inflation bias in the externality-free context, here the situation is reversed and the inflation bias is negative.

I also show that in the face of a technology shock it is necessary for the central bank to change nominal interest rate by more than it would absent external consumption habits, which in turn makes the economy more volatile. As consumption habits introduce persistence, the policy maker is forced to generate bigger changes in the nominal interest rate when accommodating the shock.

Because of the negative inflation bias the nominal interest rate set optimally by the discretionary central bank is in most cases negative, and in the case of higher degrees of external consumption habit it is well below zero. In practice, the nominal interest rate would often breach the Zero Lower Bound.

I investigate the mechanisms creating this strong negative inflation bias by adding a production subsidy and a consumption tax to the model. The production subsidy offsets the monopolistic distortion which generates the traditional positive inflation bias, and allows me to isolate the effect of the external consumption habits. The consumption tax is designed to offset the externality in steady state, though it cannot achieve the same when out of steady state. I observe that the distortion created by the habits is large and often much stronger than the one created by monopolistic competition, and that a consumption tax can curb the externality and reduce volatility.

The two key ingredients of the model here presented are, indeed, external consumption habits and discretionary monetary policy. On the one hand, there is both micro and macro evidence of consumers being subject to habits. The numbers vary across studies (see Smets and Wouters, 2003; Ravina, 2005; and Leith, Moldovan, and Rossi, 2012), but their size is clearly non-negligible. Moreover, consumption habits are becoming increasingly popular in Dynamic Stochastic General Equilibrium (DSGE) modelling, as a realistic microfoundation that helps capture and recreate the persistence that generates hump-shaped dynamics (e.g. Smets and Wouters, 2007, or Leith, Moldovan, and Rossi, 2012).

On the other hand, it is possible that discretion is a better description of reality than commitment, at least in some cases. Kirsanova and le Roux (2013) find that the Bank of England's policies since its independence (1992:1–2008:2) are best described by a discretionary scenario, not a commitment one. Givens (2012) and Coroneo, Corradi, and Santos Monteiro (2018) make the same consideration about the US Federal Reserve for the Volcker-Bernanke era (1979–2014). In general, it is undeniable that a thorough understanding of discretionary scenarios is essential.

Independently relevant on their own, the two ingredients of this paper gain even more relevance when combined. For completion, I compare my results to the commitment case as well as to internal habits where appropriate.

This particular model builds on the familiar New Keynesian DSGE model, with the explicit aim of singling out the effects of the consumption habit. The model, therefore, only considers essential players — households, producers, and the central bank. There are no further distortions or mechanisms other than habits and the familiar monopolistic power in the intermediate production sector. The goal is to investigate the externality in a discretionary scenario. The results speak to the magnitude of the externality, and the changes it induces in monetary policy.

The model, albeit parsimonious, has an important feature: it is fully non-linear. Much of the existing research studying optimal monetary policy in the presence of habits is based on linear or log-linearised models (see e.g. Leith and Malley, 2005; Ravn, Schmitt-Grohé, and Uribe, 2006; Smets and Wouters, 2007; Ravn, Schmitt-Grohé, Uribe, and Uuskula, 2010; and Leith, Moldovan, and Rossi, 2012). While avoiding the non-linearity surely makes the model easier to to solve (non-linear models rarely have closed-form solutions), it also has some important drawbacks. First, the role risk aversion has to play is ignored, as that is connected with volatility and second moments in general, which are erased in a linear or linearised model. Risk aversion is an important element that helps explain the mechanism that brings the externality to affect discretionary monetary policy. A linear model would overlook that entirely. Linearised models also miss aspects of the generalised Euler equation for discretionary policy. Second, post-crisis literature has extensively discussed how poorly linear and linearised models perform at the zero lower bound (Christiano and Takahashi, 2018). I discuss the Zero Lower Bound and possible implications whenever appropriate. In much of what follows, however, I do not impose any Zero Lower Bound restrictions on the model. Third, models are generally linearised around a zero-inflation steady state. Inflation need not be zero in steady state — in fact, within my discretionary monetary policy model, it is not, except for some specific circumstances.

Section 2.2 briefly discusses the relevant literature for the two main ingredients of the model, discretionary monetary policy and consumption habits. Section 2.3 presents the model: the individual choices of representative household and firms, which are then aggregated, and the problem faced by the central bank. I discuss the problem for both committing and discretionary central bank. The main and general results are presented and discussed in Section 2.4. Section 2.5 provides a comparison between external and internal consumption habits. Section 2.6 explores the source of the negative inflation bias by isolating the effects of consumption externalities and monopolistic distortion. Section 2.7 discusses how the externality can be offset. Finally, Section 2.8 concludes.

2.2 Literature Review

There exists plenty of literature on optimal monetary policy: the most relevant results are summarised in the first part of this literature review. The second part discusses the literature on consumption habits.

2.2.1 Monetary Policy

While there exist literature that looks at simple rules, like Taylor-type instrument or target rules (see e.g. Svensson, 1997a; Judd and Rudebusch, 1998; Clarida, Galí, and Gertler, 1999 and 2000; and Woodford, 2003), a large portion of the vast modern literature on monetary policy in a New Keynesian setting is devoted to credibility. The starting point of this literature can be found in Kydland and Prescott (1977), which can be credited for introducing the idea that monetary policy is "a game against rational economic agents" (Kydland and Prescott, 1977; p. 473). Kydland and Prescott build on the distinction between commitment to a rule and discretion, arguing that the issue of time inconsistency makes commitment the best alternative, based on the fact it avoids the inflationary bias connected with discretion.

In a commitment scenario the benevolent, welfare-maximising central bank can exploit its reputation and commit to optimal policy, and the economy enjoys the benefits in the form of lower and more stable inflation. This type of optimal policy, however, is time inconsistent: the policy maker faces the temptation to create surprise inflation, which boosts employment and output in the short run, but compromises long run inflation and the ability to commit to a rule. A policy maker that gives in to temptation and creates an inflationary surprise once is no longer able to make believable promises relating to future policies: it can only set policy for the current period. This is the discretionary scenario.

Under discretion the central bank's credibility problem gives rise to two types of bias, namely inflation bias and stabilisation bias. Commonly, the central bank will be tempted to create higher inflation to boost production in the short term; agents anticipate higher inflation when making their consumption-leisure choice, hence effectively creating the rise in prices. The mechanism just described implies a positive inflation bias. Because of this inflation bias discretionary policy results in higher inflation in equilibrium, with no benefits for either employment or output (Kydland and Prescott, 1977, Calvo, 1978, Barro and Gordon, 1983b, and Schaumburg and Tambalotti, 2007). The stabilisation bias, on the other hand, means that discretionary policy cannot stabilise the economy as well as commitment policy does in response to shocks. In the discretionary case, the policy maker no longer has access to the most favourable trade-off between output gap and inflation stabilisation. The inflation level observed under commitment is no longer achievable.

The key for a central bank to be able to stick to commitment, and avoid the time inconsistency problem introduced by Kydland and Prescott (1977), is to equip the policy maker with commitment technology – in other terms, with an enforceable rule that eliminates the inflation bias. Barro and Gordon (1983a, 1983b) argue that the solution is to make the announced rule credible to economic agents by using reputation as a commitment tool. This allows policy makers to reach a reputational equilibrium which, unlike enforced commitment to time-inconsistent rules, is sustainable in a repeated game.

Rogoff (1985), instead, introduces the idea of strategic delegation. He proposes to reduce the inflation bias under discretion by delegating monetary policy to a conservative central banker. Rogoff adds that a flexible target is to be preferred to constraining central bankers to precisely hitting a target, in order to preserve credibility. Rogoff's proposition is an important contribution to the idea of independent central banks. His solution, however, suffers from a democratic problem: the conservative central banker would need to have markedly different preferences from those of the general public, yet require their support to continue operating in the long run (Le Heron & Carré, 2006).

A further contribution to the credibility literature for monetary policy comes from Walsh (1995), Svensson (1997b), and Woodford (2003). Walsh (1995) frames the problem faced by the central bank in terms of the principal-agent model: he argues that an optimal incentive contract can be considered the best institutional design for credibility, and the institution can be seen as an incentive structure. In this framework, rules are therefore replaced by contracts. Svensson (1997b), on the other hand, proposes to focus on the accountability of the central bank, proposing a mix between Rogoff (1985)'s weight-conservative central bank and Walsh (1995)'s inflation-target-conservative central bank. Finally, Woodford (2003) develops a commitment strategy with history-dependent variables, where the central bank sets policy following an optimal interest rate feedback rule. Woodford prescribes interest rate inertia as optimal policy rule, and this is indeed the approach most often favoured by monetary policy makers (Masciandaro, 2017).

Drazen (2000, p. 166) presents two distinct concepts about credibility: the credibility of the policy maker and the credibility of the policy. The credibility of the policy maker means that "the policymaker will attempt to do exactly what he says". The credibility of the policy, instead, "could be thought of as the expectation that policy will be carried out". Furthermore, the credibility of the policy depends on the credibility of the policy maker, as well as the policy maker's reputation.

Reputation is built through actions, and is used by the households to form expectations about the policy makers' future behaviour. For example, a central bank builds a reputation of being tough on inflation by strongly reacting to changes in prices fluctuations. As it gains a reputation for being tough on inflation, the central bank strengthens the credibility of enforcing a stable price environment.

In their historical overview of central bank credibility, Bordo and Siklos (2015) find that credibility changes over time are frequent and can be significant. They also find that institutional factors affect credibility, and specifically that central bank independence improves credibility.

Inflation targeting regimes are generally found to be better for central bank credibility (Walsh, 2009). By clearly stating the inflation target and communicating how they intend to maintain it, inflation-targeting central banks can be more successful at anchoring expectations, which improves their credibility. Measuring credibility as the squared difference between observed and target inflation and comparing this across central banks with different regimes, Bordo and Siklos (2014) find that central banks with inflation targeting appear to have succeeded in anchoring inflation at lower levels.

Financial crises tend to be a testing time for central bank credibility. The Global Financial Crisis in particular revived older conversations on central bank credibility by interrogating what the unprecedented actions of central banks — targeting financial stability, aggressive quantitative easing, etc. — could mean for their credibility. One of the issues discussed was indeed whether adding a target for financial stability was going to take away from the central bank's main mandate of price stability (Bordo & Siklos, 2014). This is because there can be some level of trade-off between financial and price stability, and because macro-prudential tools can complicate the central bank's mission and actions, thus making transparency harder to achieve.

Another area of discussion is whether the close cooperation between central banks and the financial policy arm of governments (in the form of Treasuries or Finance Ministries) observed in the aftermath of the Great Financial Crisis is desirable or not. Critics of this close cooperation, e.g. Meltzer (2009), argue that in the U.S. case this close cooperation risks sacrificing much of the independence the US Federal Reserve had gained over the decades by yielding to political pressure. Blinder (2012), on the other hand, distinguishes 'normal times' from during and after a serious financial crisis. In normal times central banks should be conducting monetary policy in a manner that is transparently independent of governments. Financial crises, however, make cooperation more natural and desirable: during the crisis period central bank and government find themselves more aligned in time horizons and objectives, the line between monetary and fiscal policy becomes blurred, and the government lends the actions of the central bank political legitimacy as well as, if needed, financial backing. After the crisis, the central bank can gradually re-establish its monetary independence. The credibility of the central bank is not necessarily put at risk by closer cooperation with the government during a crisis because anti-inflation credibility is only one aspect of credibility: promising and then delivering to handle a financial crisis well contributes to successfully building credibility for the future.

"[C]redibility and reputation can considerably improve the effectiveness of monetary policies since they increase the confidence of the agents on expectations regarding future central banks' actions" (Montes, 2009; p. 680): the ability to credibly commit to a particular policy path and hence influence inflation to a greater extent normally makes commitment desirable for a central bank. Committing to a policy rule increases welfare, and is to be preferred to a discretionary policy rule. As mentioned in the introduction, however, discretion might sometimes better describe reality. The already cited Kirsanova and le Roux (2013) posits that discretion better fits the Bank of England's policies since its independence (1992:1–2008:2). Givens (2012) and Coroneo, Corradi, and Santos Monteiro (2018) find the same about the Federal Reserve for the Volcker-Bernanke era (1979–2014). Furthermore, discretion can be superior to commitment with relatively impatient households, a high preference of policy makers for output stabilisation, a deviation from steady state (Sauer, 2007), or important nominal and real rigidities (Dennis, 2010). In this chapter I will be focusing on the case of no credibility and use commitment as a benchmark case.

2.2.2 Consumption Habits

Consumption habits introduce a link between past and current consumption. The existence of consumption habits is supported by psychological studies (Ouellette and Wood, 1998). It traces its microfoundations to Duesenberry (1949), with applications dating back to the 1970s (see e.g. Ryder and Heal, 1973), and became an integral component of New Keynesian models in the 2000s (see e.g. Luttmer, 2005, as well as the many examples cited below).

Habits can be either internal (Fuhrer, 2000, Amato and Laubach, 2004, Christiano, Eichenbaum, and Evans, 2005, and Leith and Malley, 2005) or external (Smets and Wouters, 2007), depending on whether the household's consumption is contingent on his own past consumption or aggregate past consumption. Another distinction that can be drawn is between superficial and deep habits. Superficial habits are formed at the level of the overall consumption basket, whilst deep habits are at the level of individual goods (Ravn, Schmitt-Grohé, and Uribe, 2006, Ravn, Schmitt-Grohé, Uribe, and Uuskula, 2010, and Leith, Moldovan, and Rossi, 2015). Consumption habits have been used to study growth (Ryder and Heal, 1973; and Carroll, Overland, and Weil, 2000), asset prices and stock market behaviour (Abel, 1990; Constantinides, 1990; and Campbell and Cochrane, 1999), and the business cycle (Boldrin, Christiano, and Fisher, 2001; and Dennis, 2009).

The literature consistently finds that including consumption habits qualitatively changes the short-run dynamics: habit formation is key in introducing endogenous persistence and plays a critical role in creating hump-shaped dynamics (Fuhrer, 2000). Consumption habits add a backward looking term in the Phillips curve, which is essential in generating sluggish adjustment to shocks (Ravn, Schmitt-Grohé, Uribe, and Uuskula, 2010). Impulse responses are now hump-shaped, an observed feature that the New Keynesian model absent consumption habits struggles to replicate.

Furthermore, deep external habits can radically alter the fiscal policy transmission mechanism: this type of habits leads to mark-ups being counter-cyclical, which can result in government spending crowding-in rather than crowding-out private consumption in the short run. Leith, Moldovan, and Rossi (2015) find that, despite the rise in government spending multipliers implied by deep habits, government spending is relative impotent in stabilising private consumption and output gaps.

I choose to focus on superficial consumption habits, discussing external habits at length and comparing them to internal habits. At an aggregate level, there exists an externality associated with external habits, which introduces an additional challenge for monetary policy. Consumers cannot fully internalise the effect that their current consumption choices have on creating a habit stock for the future, and they end up overconsuming. This has important implications for optimal monetary policy: the usual desire to stabilise inflation is traded against the new overconsumption externality (Leith, Moldovan, and Rossi, 2012). A policy aimed at stabilising inflation would not be able to curb the overconsumption. External consumption habits, specifically, force the committing central bank to respond less aggressively to shocks: the monetary authority instead creates higher inflation to counterbalance the effects of the externality and curb the overconsumption induced by the habits.

How the discretionary central bank deals with attempting inflation stabilisation and the curbing of the overconsumption externality – a key topic of this chapter – has not received much attention. It was briefly discussed in Leith, Moldovan, and Rossi (2012): they find that external consumption habits exacerbate the gap between commitment and discretion. Not being able to commit to future policies leads to a significantly different path for inflation, and higher welfare costs. They conclude that external habits in consumption make commitment even more desirable.

2.3 The External Habits Model

The model is a New Keynesian Dynamic Stochastic General Equilibrium model in discrete time, with superficial external habits in consumption. Households consume and supply labour to intermediate-good producing firms; the goods these firms produce are then assembled into final goods by retail firms, employing no labour. As intermediate goods are used in the production of final goods, only final goods are consumed. The final-good market is perfectly competitive, whilst the intermediate-good one is monopolistically competitive. Households can transfer wealth across periods (i.e. borrow/save) through a risk-free, one-period nominal bond that is traded among households. The bond is in zero net supply. The return on the bond is given by the nominal interest rate, which is set by the central bank. The central bank manipulates the interest rate with the aim of maximising welfare. Finally, as is common in the New Keynesian literature, there are nominal rigidities in the form of price stickiness in the intermediate sector: intermediate-good firms face a Rotemberg (1982) rigidity in setting prices.

2.3.1 Households

The household's habit-adjusted consumption is given by $c_t - \theta \cdot C_{t-1}$, where c_t is current individual consumption, C_{t-1} is last period's aggregate consumption, and $\theta \in [0,1)$ is the degree of habit. Similar functional forms for external habits can be found, for example, in Ravn, Schmitt-Grohé, Uribe, and Uuskula (2010) and Leith, Moldovan, and Rossi (2012). Households are not conscious of the impact that their consumption choices have on aggregate consumption. They do not internalise their contribution to the level of aggregate consumption, and the consequences that has in terms of a habit to be sustained. External consumption habits give rise to an externality whereby households overconsume, as discussed in Section 2.2.

Households choose consumption, labour, and the quantity of bonds: $\{c_t, h_t, b_t\}_{t=0}^{\infty}$. They seek to maximise the expected discounted sum of utilities

$$E_0 \sum_{t=0}^{\infty} \beta^t \cdot \left[\frac{(c_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-h_t)^{1-\psi} - 1}{1-\psi} \right], \tag{2.1}$$

subject to the flow budget constraint

$$c_t + \frac{b_t}{P_t} = w_t \cdot h_t + \frac{b_{t-1}}{P_t} \cdot (1 + R_{t-1}) + D_t. \tag{2.2}$$

P_t is the price of the final good at time t, w_t is the real wage, R_{t-1} is the interest rate earned on bonds bought at time t-1, and D_t is the dividends from the firms. $\beta \in (0,1)$ is the time discount factor, σ and ψ are the time substitutability of habit-adjusted consumption and leisure respectively, $\sigma, \psi > 0$, and χ is the weight on utility from leisure, $\chi > 0$.

Households get their income from labour, bonds, and dividends, and spend it on consumption and new bonds. The Lagrangian is

$$\begin{aligned}\mathscr{L}_t = E_0 \sum_{t=0}^{\infty} \beta^t \cdot \Bigg[& \frac{(c_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-h_t)^{1-\psi} - 1}{1-\psi} \\ & - \mu_t \cdot \left[c_t + \frac{b_t}{P_t} - w_t \cdot h_t - \frac{b_{t-1}}{P_t} \cdot (1 + R_{t-1}) - D_t \right] \Bigg],\end{aligned} \tag{2.3}$$

with first order conditions

$$\frac{\partial \mathscr{L}_t}{\partial c_t} : \quad (c_t - \theta \cdot C_{t-1})^{-\sigma} - \mu_t = 0, \tag{2.4}$$

$$\frac{\partial \mathscr{L}_t}{\partial h_t} : \quad -\chi \cdot (1-h_t)^{-\psi} + \mu_t \cdot w_t = 0, \tag{2.5}$$

$$\frac{\partial \mathscr{L}_t}{\partial b_t} : \quad -\mu_t \cdot \frac{1}{P_t} + \beta \cdot E_t \left[\mu_{t+1} \cdot \frac{1+R_t}{P_{t+1}} \right] = 0. \tag{2.6}$$

Substituting the Lagrange multiplier μ_t out, combining equations (2.4) and (2.5), rearranging, and defining inflation as $\pi_t \equiv \frac{P_t}{P_{t-1}} - 1$ we get

$$w_t = \chi \cdot \frac{(1-h_t)^{-\psi}}{(c_t - \theta \cdot C_{t-1})^{-\sigma}} \tag{2.7}$$

and

$$(c_t - \theta \cdot C_{t-1})^{-\sigma} = \beta \cdot E_t \left[\frac{1+R_t}{1+\pi_{t+1}} \cdot (c_{t+1} - \theta \cdot C_t)^{-\sigma} \right]. \tag{2.8}$$

By equation (2.7) the representative household chooses the optimal amount of labour to supply to equate the marginal benefit of labour to the marginal cost. If the household works one unit more then they earn real wage w_t, the marginal benefit. The disutility from working more detracts from overall utility; by working (and earning) more the household is however able to afford more consumption, which adds to overall utility. The ratio between marginal disutility from labour and marginal utility from extra consumption, weighted by χ the relative weight of leisure, is the marginal cost of labour in terms of final goods.

Equation (2.8) compares the expected marginal costs and marginal benefits of the inter-temporal dynamic consumption choice problem, and is referred to as the consumption Euler equation. The left-hand side is the marginal benefit of current consumption, while the right-hand side is the discounted marginal benefit of future consumption in real terms. In equilibrium these two equations must be respected because the household will be choosing optimal labour and consumption. This means that they will choose a level of labour where marginal costs of labour are equal its marginal benefits; and a level of consumption that is inter-temporally optimal, so they have no desire to consume more (less) now in exchange for consuming less (more) later. Note that the consumption externality is present in both conditions: the representative household is aware that the consumption habit needs to be sustained. What households fail to internalise is how their own consumption choice affects aggregate consumption and hence the consumption habits.

2.3.2 Final-Good Producers

Final good producers operate in a perfectly competitive market. The final good firm chooses intermediate inputs Y_{jt} to maximise profits (distributed to households as dividends)

$$P_t \cdot Y_t - \int_0^1 P_{jt} \cdot Y_{jt} dj \tag{2.9}$$

given the production technology

$$Y_t = \left(\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2.10}$$

where $\varepsilon > 1$ is the elasticity of substitution between any two intermediate inputs, Y_t denotes final output, and $j \in [0,1]$ refers to the indexing of each particular intermediate good, with the assumption that each good is only produced by a single firm. Final good producers do not employ any labour: their production process can be thought of as a reassembling of intermediate goods into final goods.

Substituting the production equation into the maximisation problem we get

$$\max_{Y_{jt}} \left[P_t \cdot \left(\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_{jt} \cdot Y_{jt} dj \right]. \tag{2.11}$$

Taking the derivative of equation (2.11) with respect to Y_{jt} gives the equation for the amount of intermediate goods final-good producers demand in order to maximise their profits,

$$\begin{aligned} P_t \left(\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{1}{\varepsilon-1}} \cdot Y_{jt}^{-\frac{1}{\varepsilon}} - P_{jt} &= 0, \\ \Leftrightarrow P_t \cdot Y_t^{\frac{1}{\varepsilon}} \cdot Y_{jt}^{-\frac{1}{\varepsilon}} - P_{jt} &= 0, \\ \Leftrightarrow \left(\frac{Y_{jt}}{Y_t} \right)^{-\frac{1}{\varepsilon}} - \frac{P_{jt}}{P_t} &= 0, \end{aligned}$$

which gives the demand equation for inputs

$$Y_{jt} = \left(\frac{P_{jt}}{P_t}\right)^{-\varepsilon} \cdot Y_t \quad \forall j. \tag{2.12}$$

Intermediate goods are demanded based on their price relative to the one of the final good. Substitute the demand equation (2.12) into the production function to get

$$\begin{aligned} Y_t &= \left[\int_0^1 \left(\left(\frac{P_{jt}}{P_t}\right)^{-\varepsilon} \cdot Y_t\right)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}, \\ &= \left[\int_0^1 \left(\frac{P_{jt}}{P_t}\right)^{1-\varepsilon} \cdot Y_t^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}, \\ &= Y_t \cdot \left[\int_0^1 \left(\frac{P_{jt}}{P_t}\right)^{1-\varepsilon} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}, \end{aligned}$$

which implies

$$\left[\int_0^1 \left(\frac{P_{jt}}{P_t}\right)^{1-\varepsilon} dj\right]^{\frac{\varepsilon}{\varepsilon-1}} = 1. \tag{2.13}$$

It follows that profits from the final firm are zero, and that

$$P_t = \left[\int_0^1 P_{jt}^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}}, \tag{2.14}$$

so that the prices of the intermediate good are aggregated into the price of the final good according to the elasticity of substitution between intermediate goods. Note that the consumption habit does not directly affect the supply of final goods, only the demand. This is because the final producer's problem is static.

2.3.3 Intermediate-Good Producers

To solve the intermediate-good producer's problem and characterise their behaviour, we first find the amount of labour that minimises production costs. This gives a demand for labour and an equation for real marginal costs. We then set up the problem of inter-temporal profit (i.e. value of the firm) maximisation.

The j'th intermediate-good producer chooses h_{jt} to minimise real costs

$$w_t \cdot h_{jt}, \tag{2.15}$$

subject to the production function

$$Y_{jt} = A_t \cdot h_{jt}. \tag{2.16}$$

Labour is the only factor of production employed by intermediate-good producers. A_t is a time-varying exogenous technology factor, and technology follows the AR(1) process $\ln A_{t+1} = \rho_A \cdot \ln A_t + \eta_{t+1}$, with $\eta_t \sim i.i.d.N(0,\sigma^2)$. The Lagrangian is

$$\mathscr{L}_{jt} = w_t \cdot h_{jt} + \omega_{jt} \cdot [Y_{jt} - A_t \cdot h_{jt}], \tag{2.17}$$

with first order conditions

$$\frac{\partial \mathscr{L}_{jt}}{\partial h_{jt}} : \quad w_t - \omega_{jt} \cdot A_t = 0, \tag{2.18}$$

$$\frac{\partial \mathscr{L}_{jt}}{\partial \omega_{jt}} : \quad Y_{jt} - A_t \cdot h_{jt} = 0, \tag{2.19}$$

which give the demand for labour

$$h_{jt} = \frac{Y_{jt}}{A_t}, \tag{2.20}$$

and real marginal costs

$$\omega_{jt} = \frac{w_t}{A_t}. \tag{2.21}$$

Intermediate-good producers have market power and face quadratic costs when changing prices (Rotemberg, 1982), with parameter $\phi > 0$ measuring price adjustment costs. Since intermediate-good producers are symmetrical in their costs and production, the prices they set optimally will also be symmetrical in equilibrium. Specifically, they choose P_{jt} in order to maximise

$$V_j = E_0 \sum_{t=0}^{\infty} \beta^t \cdot \frac{\mu_t}{\mu_0} \cdot \left[\left(\frac{P_{jt}}{P_t} - \omega_t \right) \cdot Y_{jt} - \frac{\phi}{2} \cdot \left(\frac{P_{jt}}{P_{jt-1}} - 1 \right)^2 \cdot Y_{jt} \right] \tag{2.22}$$

subject to the demand for inputs as given by equation (2.12). Substituting the constraint (2.12) into the maximisation problem, letting $p_t \equiv \frac{P_{jt}}{P_t}$, and using the definition $1 + \pi_t \equiv \frac{P_t}{P_{t-1}}$ we obtain

$$V_j = E_0 \sum_{t=0}^{\infty} \beta^t \cdot \frac{\mu_t}{\mu_0} \cdot \left[(p_t - \omega_t) \cdot p_t{}^{-\varepsilon} \cdot Y_t - \frac{\phi}{2} \cdot \left(\frac{p_t \cdot (1+\pi_t)}{p_{t-1}} - 1 \right)^2 \cdot p_t{}^{-\varepsilon} \cdot Y_t \right]. \tag{2.23}$$

All firms choose the same optimal relative price, as they face the same real marginal costs and the same price adjustment costs, so in equilibrium it is true that $P_{jt} = P_t$ as we are choosing to look at a symmetric equilibrium. Taking the derivative with respect to p_t and simplifying we get the New

Keynesian Phillips Curve (NKPC),

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t{}^2 = \frac{1-\varepsilon}{\phi} + \frac{\varepsilon}{\phi} \cdot \omega_t + \beta \cdot E_t \left[\frac{c_{t+1} - \theta \cdot C_t}{c_t - \theta \cdot C_{t-1}} \cdot \frac{Y_{t+1}}{Y_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right], \quad (2.24)$$

which gives the relationship between inflation and real marginal costs. Inflation is positively related to real marginal costs and expectations of future inflation. It is also positively related to future expected marginal utility from consumption and output, but negatively related to their current realisations.

2.3.4 Aggregation

Aggregating across households gives the equation for labour-leisure choice (or labour supply)

$$w_t = \chi \cdot \frac{(1-H_t)^{-\psi}}{(C_t - \theta \cdot C_{t-1})^{-\sigma}}, \quad (2.25)$$

and the Euler equation for consumption

$$(C_t - \theta \cdot C_{t-1})^{-\sigma} = \beta \cdot E_t \left[\frac{1+R_t}{1+\pi_{t+1}} \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma} \right]. \quad (2.26)$$

Given that intermediate-good firms are have the same cost-structure and set the same prices, in equilibrium real marginal costs are homogeneous across such firms

$$\omega_t = \frac{w_t}{A_t}, \quad (2.27)$$

along with the already mentioned NKPC

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 = \frac{1-\varepsilon}{\phi} + \frac{\varepsilon}{\phi} \cdot \omega_t + \beta \cdot E_t \left[\left(\frac{C_{t+1} - \theta \cdot C_t}{C_t - \theta \cdot C_{t-1}} \right)^{-\sigma} \cdot \frac{Y_{t+1}}{Y_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right]. \quad (2.28)$$

The NKPC shows that consumption habit affects marginal costs through its effect on labour supply and the real wage.

Furthermore, we have the aggregate production function

$$Y_t = A_t \cdot H_t, \quad (2.29)$$

and combining the household budget constraint (2.2) with the definition of profits (2.9) we obtain the aggregate resource constraint

$$C_t = \left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot Y_t. \tag{2.30}$$

Because of the costs associated with inflation some of the goods that could otherwise be consumed are instead wasted by the price-adjustment process. As mentioned before, technology follows the AR(1) process

$$\ln A_{t+1} = \rho_A \cdot \ln A_t + \eta_{t+1}, \tag{2.31}$$

with $\eta_t \sim i.i.d. N(0, \sigma_A^2)$.

2.3.5 Discretionary Central Bank

The discretionary central bank does not have the ability to credibly commit to optimal policy, and therefore cannot today set policy for future periods. When deciding on current monetary policy the discretionary central bank knows it will have to make a similar decision in every subsequent period, and takes that into account.

The central bank maximises current welfare (i.e. the habit-adjusted utility) subject to the behaviour of the private sector. The following equation is the Bellman equation which summarises the discretionary central bank's optimal policy problem:

$$\begin{aligned} V(A_t, C_{t-1}) = \max_{\{C_t, H_t, \pi_t\}} E_t \Bigg[& \frac{(C_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-H_t)^{1-\psi} - 1}{1-\psi} \\ & + \beta \cdot V(A_{t+1}, C_t) + \gamma_t \cdot \left[\left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot A_t \cdot H_t - C_t \right] \\ & - \lambda_t \cdot \Bigg[\left(\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 - \frac{1-\varepsilon}{\phi} \right) \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t \cdot H_t \\ & - \frac{\varepsilon}{\phi} \cdot \chi \cdot (1-H_t)^{-\psi} \cdot H_t - \beta \cdot G(A_{t+1}, C_t) \Bigg] \Bigg]. \end{aligned} \tag{2.32}$$

The future values of habit-adjusted consumption, labour and inflation have been grouped in a single term,

$$G(A_{t+1}, C_t) \equiv (C_{t+1} - \theta \cdot C_t)^{-\sigma} \cdot A_{t+1} \cdot H_{t+1} \cdot \pi_{t+1} \cdot (1 + \pi_{t+1}). \tag{2.33}$$

$G(A_{t+1}, C_t)$ is not independent of today's policy, because the consumption habit provides a link between periods.

The first order conditions are

$$
\begin{aligned}
\frac{\partial V(A_t,C_{t-1})}{\partial C_t}: \quad & (C_t-\theta\cdot C_{t-1})^{-\sigma}+\beta\cdot E_tV_2(A_{t+1},C_t)-\gamma_t \\
& +\sigma\cdot\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon}{2}\cdot\pi_t^2-\frac{1-\varepsilon}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma-1}\cdot A_t\cdot H_t\cdot\lambda_t \\
& +\beta\cdot E_tG_2(A_{t+1},C_t)\cdot\lambda_t=0, \qquad (2.34) \\
\frac{\partial V(A_t,C_{t-1})}{\partial H_t}: \quad & -\chi\cdot(1-H_t)^{-\psi}+\gamma_t\cdot\left(1-\frac{\phi}{2}\cdot\pi_t^2\right)\cdot A_t \\
& -\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon}{2}\cdot\pi_t^2-\frac{1-\varepsilon}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot\lambda_t \\
& +\frac{\varepsilon}{\phi}\cdot\chi\cdot\left[\psi\cdot(1-H_t)^{-\psi-1}\cdot H_t+(1-H_t)^{-\psi}\right]\cdot\lambda_t=0, \qquad (2.35) \\
\frac{\partial V(A_t,C_{t-1})}{\partial \pi_t}: \quad & -\phi\cdot\gamma_t\cdot\pi_t-\big(1+2\cdot\pi_t+(1-\varepsilon)\cdot\pi_t\big)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot\lambda_t=0. \qquad (2.36)
\end{aligned}
$$

From equation (2.34), a marginal increase in consumption gives the benefits of positive marginal utility and of the resource constraint being relaxed on the margin, but at the same time it has the costs of decreasing marginal value for the following period (because of the higher habit stock that must be sustained), placing current policy stricter, and giving even stricter constraints on future policy.

From equation (2.35), a marginal increase in labour brings costs in terms of marginal disutility (because of reduced leisure) and by tightening the resource constraint. At the same time, it has benefits in that it relaxes the relationship between output and inflation on the margin.

Last, from equation (2.36), a marginal increase in inflation tightens the resource constraint but relaxes the NKPC.

2.3.6 Committing Central Bank

I now discuss the decision problem for a central bank that sets monetary policy with commitment. The central bank will select the policy path that maximises the infinite discounted stream of utility, announce its policy, and commit to it. As the interest rate can be later determined based on optimal consumption, labour and inflation paths, the central bank effectively chooses $\{C_t,H_t,\pi_t\}_{t=0}^{\infty}$ to maximise welfare

$$
E_0\sum_{t=0}^{\infty}\beta^t\left[\frac{(C_t-\theta\cdot C_{t-1})^{1-\sigma}-1}{1-\sigma}+\chi\cdot\frac{(1-H_t)^{1-\psi}-1}{1-\psi}\right] \qquad (2.37)
$$

subject to

$$C_t = \left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot A_t \cdot H_t, \tag{2.38}$$

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 = \frac{1-\varepsilon}{\phi} + \frac{\varepsilon}{\phi} \cdot \chi \cdot \frac{(1-H_t)^{-\psi}}{(C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t}$$
$$+ \beta \cdot E_t \left[\frac{(C_{t+1} - \theta \cdot C_t)^{-\sigma} \cdot A_{t+1} \cdot H_{t+1}}{(C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t \cdot H_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right]. \tag{2.39}$$

The Lagrangian is

$$\mathscr{L}_t = E_0 \left[\sum_{t=0}^{\infty} \beta^t \cdot \left[\frac{(C_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-H_t)^{1-\psi} - 1}{1-\psi} \right.\right.$$
$$+ \gamma_t \cdot \left[\left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot A_t \cdot H_t - C_t \right]$$
$$- \lambda_t \cdot \left[\left(\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 - \frac{1-\varepsilon}{\phi} \right) \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t \cdot H_t \right.$$
$$\left.\left.\left. - \frac{\varepsilon}{\phi} \cdot \chi \cdot (1-H_t)^{-\psi} \cdot H_t - \beta \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma} \cdot A_{t+1} \cdot H_{t+1} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right]\right]\right] \tag{2.40}$$

with first order conditions

$$\frac{\partial \mathscr{L}_t}{\partial C_t} : \ (C_t - \theta \cdot C_{t-1})^{-\sigma} - \gamma_t$$
$$- \sigma \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma-1} \cdot A_t \cdot H_t \cdot \pi_t \cdot (1+\pi_t) \cdot \lambda_{t-1}$$
$$+ \sigma \cdot \left(\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 - \frac{1-\varepsilon}{\phi} \right) \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma-1} \cdot A_t \cdot H_t \cdot \lambda_t$$
$$+ \sigma \cdot \theta \cdot \beta \cdot E_t \left[(C_{t+1} - \theta \cdot C_t)^{-\sigma-1} \cdot A_{t+1} \cdot H_{t+1} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right] \cdot \lambda_t$$
$$- \theta \cdot \beta \cdot E_t \left[(C_{t+1} - \theta \cdot C_t)^{-\sigma} \right]$$
$$- \sigma \cdot \theta \cdot \beta \cdot E_t \left[\left(\pi_{t+1} \cdot (1+\pi_{t+1}) + \frac{1-\varepsilon}{2} \cdot \pi_{t+1}^2 - \frac{1-\varepsilon}{\phi} \right) \right.$$
$$\left. \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma-1} \cdot A_{t+1} \cdot H_{t+1} \cdot \lambda_{t+1} \right] = 0 \tag{2.41}$$

$$\frac{\partial \mathscr{L}_t}{\partial H_t} : \ (C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t \cdot \pi_t \cdot (1+\pi_t) \cdot \lambda_{t-1} - \chi \cdot (1-H_t)^{-\psi} + \gamma_t \cdot \left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot A_t$$
$$- \left(\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 - \frac{1-\varepsilon}{\phi} \right) \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t \cdot \lambda_t$$
$$+ \frac{\varepsilon}{\phi} \cdot \chi \cdot \left[\psi \cdot (1-H_t)^{-\psi-1} \cdot H_t + (1-H_t)^{-\psi} \right] \cdot \lambda_t = 0 \tag{2.42}$$

$$\frac{\partial \mathscr{L}_t}{\partial \pi_t} : \ (C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot (1 + 2 \cdot \pi_t) \cdot \lambda_{t-1} - \gamma_t \cdot \phi \cdot \pi_t$$
$$- \left[1 + 2 \cdot \pi_t + (1-\varepsilon) \cdot \pi_t \right] \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot \lambda_t = 0 \tag{2.43}$$

with $\lambda_{-1} = 0$.

The first order conditions give costs and benefits of a marginal increase in consumption, labour and inflation, respectively. In equilibrium, marginal costs should equal marginal benefits. Extra consumption brings marginal utility and relaxes the resource constraint, but it makes the New-Keynesian Phillips Curve (NKPC), i.e. equation (2.39), a stricter constraint. Extra labour gives marginal disutility, tightens the resource constraint but relaxes the NKPC. Extra inflation makes the resource constraint more binding, and the NKPC less binding.

Current optimal policy is linked to past policy through the multiplier λ_{t-1}, which essentially binds the central bank to keep its promises. The fact that $\lambda_{-1} = 0$ means that the first order conditions different from period 0 to period 1-onwards; this implies that the central bank will commit to a optimal policy in period 0 and then, having its constraints changed in the following period, will be tempted to "cheat" on its promises. The Lagrange multiplier reflects indeed the time inconsistency of commitment.

In the presence of consumption habits, the committing central bank needs to be aware of the repercussions its current choices have on future policy-making, through aggregate consumption. A current marginal increase in consumption comes at the extra cost of creating a higher habit stock to be sustained in the future, a fact that policy makers have to take into account when formulating monetary policy.

2.3.7 Model Parameterisation

Table 2.1 reports the value given to each parameter. A time discount factor of 0.99 is in line with an annual real interest rate of 4%. Setting $\varepsilon = 11$ implies a steady state mark-up of 10%, as in Leith, Moldovan, and Rossi (2012). Similar values for the inverse of inter-temporal elasticity of substitution for consumption, σ, and the substitutability of labour, ψ, can be found in Leith, Moldovan, and Rossi (2012) and Ravn, Schmitt-Grohé, Uribe, and Uuskula (2010), while a similar value for the Rotemberg price adjustment cost ϕ can be found in Ireland (2001). The weight on utility from leisure χ is calibrated to imply labour around 0.4 in the benchmark model, i.e. roughly 9 hours of work per day, or close to 50 per week, after excluding 8 hours per day for sleep.

Finally, the baseline value for the degree of consumption habit, θ, is set to 0.60 following Leith et al., as it "falls within the range of estimates identified in the literature" (Leith, Moldovan, and Rossi, 2012; p. 421). Macro estimates vary from 0.59 (Smets and Wouters, 2003) to 0.98 (Bouakez, Cardia, and Ruge-Murcia, 2005), while micro estimates are in the lower range 0.29–0.50 (Ravina, 2005). The technology parameters ρ_A and σ_A are in line with the RBC literature (e.g. King and

Rebelo, 1999).

Table 2.1: Baseline Parameters

Description	Parameter	Value
Subjective discount factor	β	0.99
Inverse of inter-temporal elasticity of substitution	σ	2.00
Leisure demand elasticity	ψ	4.00
Weight on leisure in utility	χ	2.50
Elasticity of subst. between intermediate goods	ε	11.00
Rotemberg price adjustment cost	ϕ	80.00
Degree of consumption habit	θ	0.60
Persistence of technological innovations	ρ_A	0.95
Standard deviation of technological innovations	σ_A	0.008

The table gives parameter values used in the numerical solution and simulation.

2.4 Results

In this section I will first provide a comparison between the discretionary and the commitment case. The latter serves as a benchmark, to be able to first observe the different impact that external consumption habits have when they interact with discretionary monetary policy. I will then give an overview of how the stochastic steady state with discretionary monetary policy changes as consumption habits get stronger. Finally, in this section I will investigate how the presence of external consumption habits alter the reaction of the discretionary central bank to a productivity shock, by comparing it to the standard case without habits.

The model is solved numerically using value function iteration. The numerical solution is then used to simulate the economy for 1,000,000 periods. A detailed description of the algorithm can be found in Appendix A.1.

2.4.1 Commitment vs Discretion

Table 2.2 compares the steady states with a committing and a discretionary central bank, without and with external consumption habits. The Table reports average outcomes, and volatilies in brackets. The comparison between the second and fourth columns illustrates the difference between commitment and discretion without any consumption habits. These columns show that discretion produces average outcomes for consumption, labour, output, real rate, and wage that are the same

Table 2.2: Stochastic Steady States by Regime and Degree of External Habit θ

	Commitment		**Discretion**	
Degree of habit (θ)	0.00	0.60	0.00	0.60
Inflation	0.000	0.000	1.007	-7.386
	(0.001)	(0.095)	(0.005)	(0.177)
Consumption	0.298	0.452	0.298	0.447
	(0.006)	(0.009)	(0.006)	(0.009)
Labour	0.298	0.452	0.298	0.453
	(0.002)	(0.003)	(0.002)	(0.003)
Output	0.298	0.452	0.298	0.453
	(0.006)	(0.009)	(0.006)	(0.009)
Real rate	4.013	3.971	4.013	3.974
	(0.754)	(2.214)	(0.752)	(2.240)
Nominal rate	4.013	3.972	5.031	-3.483
	(0.754)	(2.174)	(0.750)	(2.296)
Wage	0.909	0.909	0.909	0.896
	(0.023)	(0.023)	(0.023)	(0.022)
Welfare	-393.24	-876.81	-393.32	-886.06
$\|\|$Euler error$\|\|_\infty$	1.80E-4	5.63E-5	5.16E-5	5.40E-5

The table presents stochastic steady state values and standard deviations for all variables, for the commitment and discretionary regimes, in the cases with no habits and with external consumption habits. Note: Inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

as commitment, and average outcomes for inflation and the nominal interest rate that are higher than commitment. Because the discretionary central bank does not have the credibility to be able to resist the time inconsistency temptation, the households expect it to create an inflationary surprise that would boost output; the households therefore make their allocation choices assuming inflation is going to be positive, which makes inflation happen. The inflationary bias of a discretionary central bank is a product of the nature of inflation being a self-fulfilling prophecy, which emerges because of the lack of credibility (Clarida, Galí, and Gertler, 1999; Gärtner, 2000; and Woodford, 2003).

Absent external consumption habits, the private sector expects the central bank to lower interest rates in order to boost output, which results in the positive inflation bias shown in the fourth column. As the comparison between the second and fourth columns of Table 2.2 shows, the inflationary bias of the discretionary central bank is not associated with a boost in output, or any variation in consumption or labour. All other variables are essentially unaffected by the discretionary inflation bias, with the exception of nominal interest rate which is higher than in commitment, reflecting higher inflation. The nominal interest rate in equilibrium follows the Fisher equation, which states that the nominal interest rate is given by the real interest rate plus the inflation rate: with real rate being the same across the two cases and inflation being higher under discretion, the nominal interest rate has to be higher too.

The addition of external consumption habits to the commitment case increases the steady state values of consumption, labour, and output: this is the overconsumption externality created by the habits. With external consumption habits households are willing to work more at the same wage to be able to afford to consume more. Inflation remains at the same level as without habits: the presence of external consumption habits does not affect the ability of the central bank to credibly commit and deliver zero inflation.

Looking at the discretionary case, just as for the commitment case, the presence of external consumption habits means that households are willing to supply more work in order to sustain their consumption habits. Unlike in the commitment case, however, now the increased supply of labour pushes down the real wage: labour (and output) are much higher. This is a reverse of the traditional, no-habit case, where instead output is inefficiently low due to the monopolistic distortion.

The monopolistic distortion is discussed in more detail in Section 2.6.1, where I introduce a production subsidy to offset the effect of the monopolistic distortion originating from intermediate-good producers having some degree of market power and therefore being able to produce a smaller quantity of intermediate good that they would if the market was perfectly competitive, and charge a higher price than the one of perfect competition. The fact that the market for intermediate goods is monopolistically competitive leads to intermediate-good producers under-producing compared tot the efficient competitive scenario, and ultimately to inefficiently low output. It should be noted that the model discussed here does not include a production subsidy, and therefore there exist a downward pressure on output due to the monopolistic distortion. The fact that output is higher when external consumption habits are introduced (i.e. from the fourth to the fifth column) indicates that the upward pressure introduced by the overconsumption externality trumps the downward pressure of the monopolistic distortion. I investigate this issue further in Section 2.6.

To bring down output, and curb the externality, the central bank would be tempted to create falling prices, which would slow down production. The households expect a discretionary central bank to increase the interest rate and create negative inflation with the aim of lowering output. The households therefore make their allocation choices assuming inflation is going to be negative, which indeed makes deflation happen. Furthermore, inflation being negative and large pushes down the nominal interest rate, which in the case presented in the table is also negative.

Table 2.2 also shows that external consumption habits make the economy more volatile, under both monetary policy regimes. In particular, the volatility of inflation, real interest rate, and nominal interest rate increase dramatically. Without habits inflation is about 5 times as volatile as in the discretionary case compared to the commitment case, but when habits are introduced inflation is over 18 times as volatile in the discretionary case. External consumption habits exacerbate the stabilisation bias of discretionary monetary policy, making it increasingly harder for the central bank to stabilise the economy following a shock.

Table 2.3: Likelihood of Breaching the ZLB by Regime and Degree of Habit θ

	Commitment	Discretion
θ=0.00	0.00%	0.00%
θ=0.60	3.11%	93.27%

The table gives the likelihood of breaching the ZLB calculated as the percentage of time in the 1,000,000-period simulation where the nominal interest rate is set below zero.

Table 2.3 shows that, as expected, neither central bank would be at risk of breaching the ZLB in the case without external consumption habits ($\theta = 0.00$). The addition of habits drastically increases the likelihood of the discretionary central bank setting an interest rate below zero — in the case considered with degree of habit $\theta = 0.60$, the nominal interest rate is negative and large enough that it is negative for the vast majority of the time. With the same degree of habit $\theta = 0.60$ the committing central bank sets a positive nominal interest rate, but the increased volatility created by the external habits results in the central bank setting a negative interest rate a small portion of the time. With larger variations in nominal interest rate, even the committing central bank becomes more likely to breach the ZLB.

It should be noted that the likelihood of a nominal interest rate below zero as presented here is calculated in the absence of the ZLB constraint imposed as an explicit constraint on the model. Introducing the ZLB as a hard constraint on the optimal choices of the central bank — in other words, preventing the central bank from setting a negative nominal interest rate, would change the behaviour of the central bank and could potentially alter the results quite significantly. The behaviour of a discretionary central bank with a ZLB is a potential venue for future research.

2.4.2 Discretion: Comparative Statics

As the previous section showed, external consumption habits have a bigger impact under a discretionary regime for monetary policy compared to commitment. As discussed in Section 2.2, the combination of external consumption habits and discretionary central bank has not received much attention in the literature. I therefore focus the rest of the Chapter on analysing the case of a discretionary central bank.

Averaging out the values over the simulation period gives the stochastic steady states reported in Table 2.4. Specifically, the columns of Table 2.4 show what happens to the stochastic steady state as consumption habits get stronger (standard deviations, in brackets, are in percentage points).

Table 2.4: Stochastic Steady States by Degree of External Habit θ (Discretionary Regime)

Degree of habit (θ)	**0.00**	**0.20**	**0.40**	**0.60**	**0.80**
Inflation	1.007	-1.286	-4.037	-7.386	-10.938
	(0.005)	(0.013)	(0.055)	(0.177)	(0.556)
Consumption	0.298	0.334	0.382	0.447	0.552
	(0.006)	(0.006)	(0.007)	(0.009)	(0.011)
Labour	0.298	0.334	0.382	0.447	0.552
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Output	0.298	0.334	0.382	0.447	0.552
	(0.006)	(0.006)	(0.008)	(0.009)	(0.012)
Real rate	4.013	4.006	3.994	3.974	3.945
	(0.752)	(1.055)	(1.601)	(2.240)	(2.258)
Nominal rate	5.031	2.707	-0.082	-3.483	-7.089
	(0.750)	(1.062)	(1.616)	(2.296)	(2.902)
Wage	0.909	0.909	0.905	0.896	0.880
	(0.023)	(0.023)	(0.023)	(0.022)	(0.020)
Welfare	-393.32	-473.29	-608.58	-886.06	-1,762.60
$\lVert$Euler error$\rVert_\infty$	5.16E-5	5.42E-5	5.67E-5	5.40E-5	5.52E-5

The table presents stochastic steady state values and standard deviations for all variables for the discretionary regime, for varying degrees of external consumption habits.
Note: inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

As the degree of habit increases inflation decreases, while consumption, labour, and output all increase. Stronger habits are also related to higher volatility for most variables, and especially for inflation.

Result 2. 1 *With discretionary monetary policy, external consumption habits generate a strong negative inflation bias, that opposes and dominates the positive inflation bias associated with monopolistic competition.*

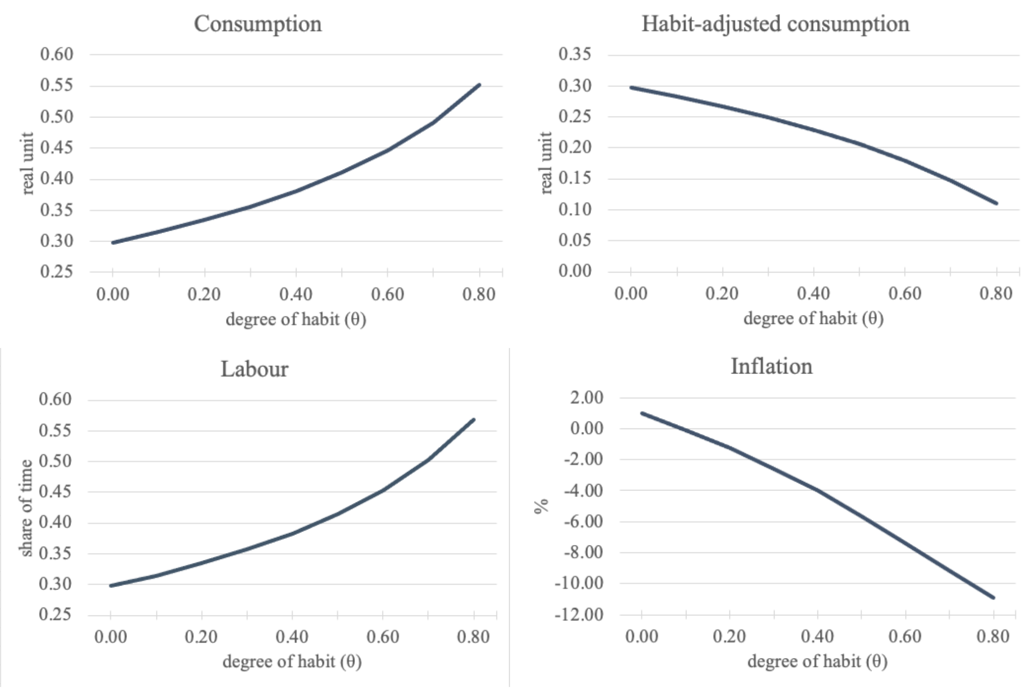
With any degree of habit, the more households consume today the bigger the habit stock to be sustained in the future is. As consumers give themselves a habit that needs to be accommodated, they supply levels of labour that increase in the degree of habit θ: the stronger the habit, the larger share of steady-state consumption is driven by the habit, pushing consumption to higher levels which require more hours worked to be sustained. As households supply increasing levels of labour, the real wage decreases, pushing down the price of labour.

Stronger habits give rise to higher levels of consumption and output in steady state. As discussed above to address the overconsumption the central bank is tempted to create a deflationary surprise that dampens the inefficiently high output: the bigger the positive output gap is, the bigger the deflationary surprise needed to return output and consumption to their efficient levels. With a discretionary central bank, this time inconsistency gives rise to a negative inflation bias. The size of the negative inflation bias increases in θ, thus creating larger negative numbers for steady state inflation (as seen in Table 2.4).

Because the inefficiency associated with monopolistic competition should generate a positive inflation bias, the fact that average inflation is negative in Table 2.4 indicates that the negative inflation bias due to the overconsumption externality is powerful, dominating the bias from monopolistic competition. I investigate this later in Section 2.6, where I show that the large negative inflation bias linked to the external consumption habits is so large that it trumps the usual positive inflation bias normally associated with discretionary monetary policy.

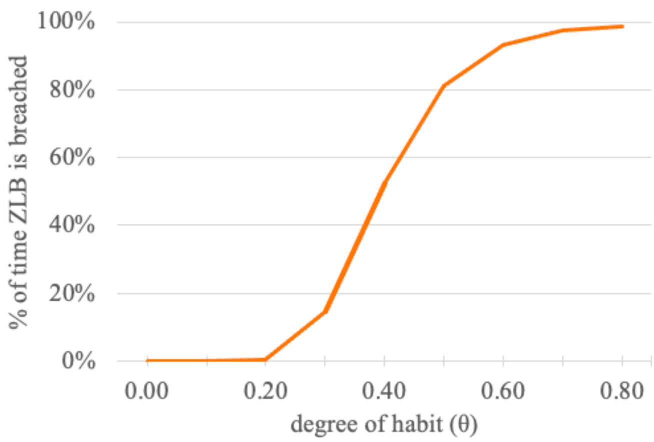
Figure 2.1 shows the deterministic steady states of consumption, habit-adjusted consumption, labour, and inflation for degrees of external consumption habit going from $\theta = 0.00$ to $\theta = 0.80$. From Figure 2.1 we see that consumption increases as habits get stronger, and habit-adjusted consumption $C_t - \theta \cdot C_{t-1}$ decreases. Households have to work more in order to be able to sustain the lifestyle established by their habits, and therefore labour increases. One can deduce that, with increasing labour and decreasing habit-adjusted consumption, welfare (i.e. utility) must be decreasing as the degree of habit increases. This finding is indeed confirmed by Table 2.4. Furthermore, as households supply more labour, higher degrees of habit formation see wages decrease, as discussed. Economies with stronger external consumption habits will therefore see households work longer hours at a lower wage in order to sustain a habit that ultimately lowers welfare, all because households fail to internalise the impact of their consumption choices.

Figure 2.1: Steady State Values by Degrees of Habit θ (Discretionary Regime)



The figure shows the deterministic steady states of consumption, habit-adjusted consumption, labour, and inflation for varying degrees of external consumption habit.
Note: inflation is annualised, while consumption and labour are quarterly.

Figure 2.2: Likelihood of Breaching the ZLB by Degree of External Habit θ (Discretionary Regime)



The figure shows the likelihood of breaching the ZLB for varying degrees of external consumption habit, calculated as the percentage of time in the 1,000,000-period simulation where the nominal interest rate is set below zero.

Inflation being large and negative pushes down the nominal interest rate: Table 2.4 indicates that, for my set of parameters, the average nominal interest rate becomes negative for a level of habits between $\theta = 0.20$ and $\theta = 0.40$. With degree of external habits equalling $\theta = 0.20$ the nominal interest rate can be set at negative rates after very large positive technology shocks: in fact, at this level of external habits the nominal interest rate breaches the ZLB 0.5% of the time. With degree of external habits equalling $\theta = 0.40$, and average nominal interest rate is negative, and outcomes for the nominal interest rate breach the ZLB 52.39% of the time. As Figure 2.2 shows, the stronger the external habit the more likely the nominal interest rate is to be below zero — and at high levels of θ negative nominal interest rates are almost a certainty.

2.4.3 Discretion: Comparative Dynamics

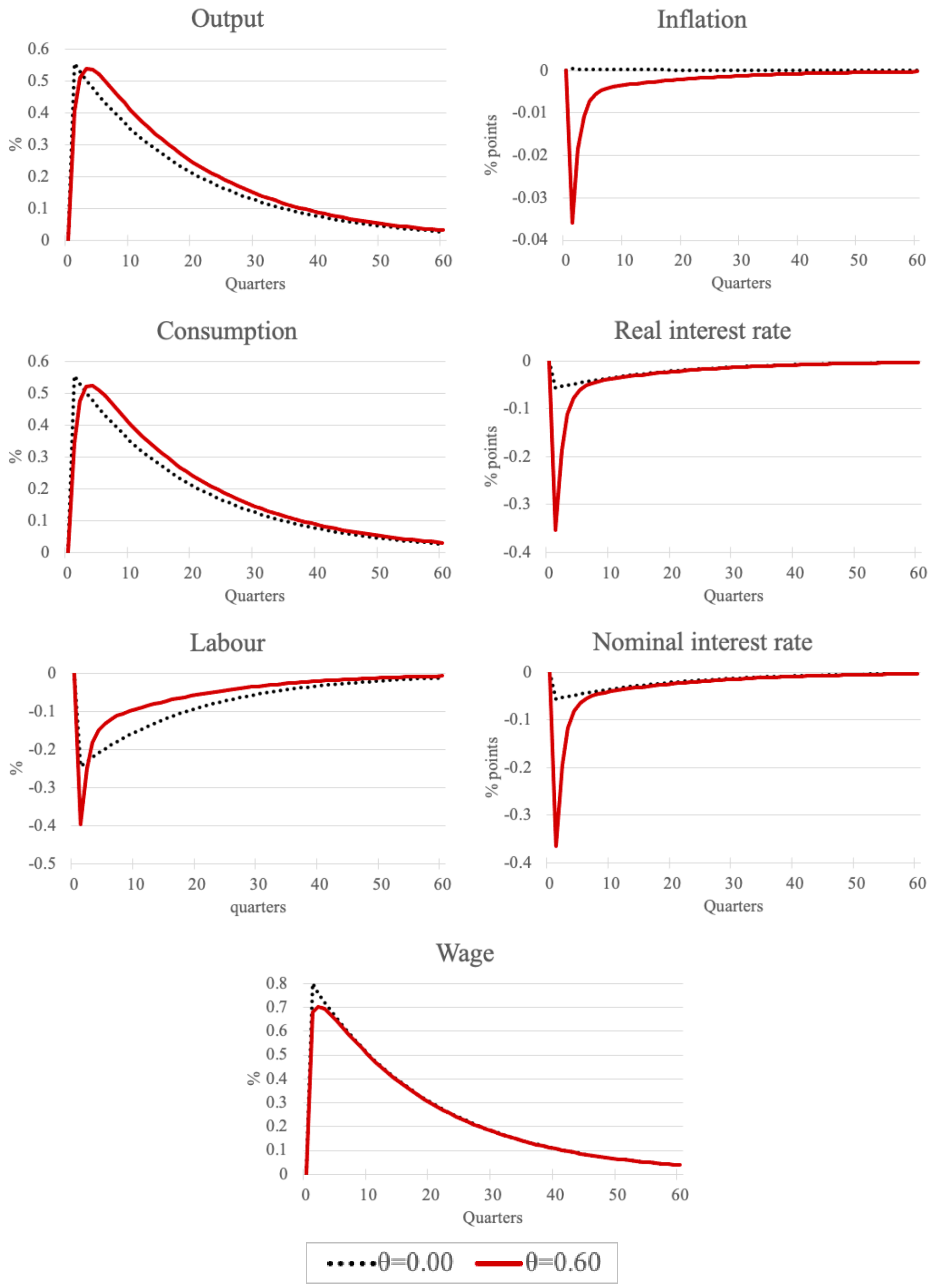
Result 2. 2 *Higher degrees of habit make the economy more volatile.*

As previously noted in relation to Table 2.4, Figure 2.3 confirms that increasing the degree of external consumption habits, θ, causes inflation and the nominal interest rate, in particular, to become more volatile. The figure compares the response to a positive technology shock in the New Keynesian model without consumption habits to the model with external habits. In both cases the positive shock makes production more efficient, causing output to increase. Since labour productivity has improved wages also increase. Now households can afford to consume more and work less; this increased consumption drives up prices and creates positive inflation. The discretionary central bank tightens monetary policy in an effort to stabilise inflation. Consumption and output therefore return to steady state values, and so do wages, which makes household increase their labour supply back to steady state levels.

In the presence of habits the impact on consumption is smaller, but the effect is more persistent. This increased persistence is generated by the habits, which strengthen the desire to smooth consumption. At the same time the initial effect on labour is stronger: as wages increase, households substitute away from labour and towards leisure, more than in the case without habits. External habits exacerbate substitution effects. Following the initial larger drop in labour, with the consumption externality labour transitions back to equilibrium more quickly: labour supply increases faster, as households need to sustain their consumption habit.

Figure 2.3 shows that in the case with external consumption habits the initial increase in consumption is smaller compared to the case without external consumption habits, though it is more protracted in time. As mentioned in Section 2.2, consumption habits introduce hump-shaped dynamics. Looking at the real interest rate, however, we see that it is more heavily affected in the case with external consumption habits, decreasing by much more following a positive productivity shock. The real interest rate drop on impact is significantly larger with habits, and the transition back to equilibrium more gradual in the first few quarters. Following the plunge of real interest rate, the discretionary central bank is forced to lower the nominal interest rate accordingly in order to accommodate the shock. The impact on consumption is somewhat weaker and the one on real

Figure 2.3: Generalised Impulse Response Functions to a Positive Technology Shock (Discretionary Regime)



The figure shows the generalised impulse response functions to a positive technology shock of output, consumption, labour, inflation, real and nominal interest rates, and wage, comparing the case with no habits to the case with habits.
Note: % deviation from relative no-shock path.

interest rate stronger because of risk aversion motives.

Whilst the discretionary central bank is successful in stabilising inflation absent habits, in the presence of habits it is not. In the first case there is no significant change in inflation. In the second, instead, inflation drops on impact, and then slowly recovers, followed by the nominal interest rate. The central bank creates a bigger drop in nominal interest rate to prevent consumption (and output) from increasing too much, and this creates deflationary pressure on prices.

To summarise, subject to the same AR(1) technology shocks a scenario with stronger consumption habits will see more volatility. The discretionary central bank is forced to create bigger swings in nominal interest rate (see Figure 2.3), and this volatility propagates to the rest of the economy: this can be seen in standard deviations for almost all variables of Table 2.4 increasing in the degree of habit, θ. Specifically, as habits get stronger consumption becomes more volatile, which makes the risk-averse households want to save more to insure themselves against said volatility. The real interest rate and risk aversion are related, and scenarios where households demand more insurance see their real interest rate driven down: the real rate decreases as habits gets stronger.

Robustness to changes in risk aversion and inter-temporal substitutability of labour are shown in Appendix D.1. Risk-aversion motives have quantitative influence on the results, while the substitutability of labour has a largely negligible effect.

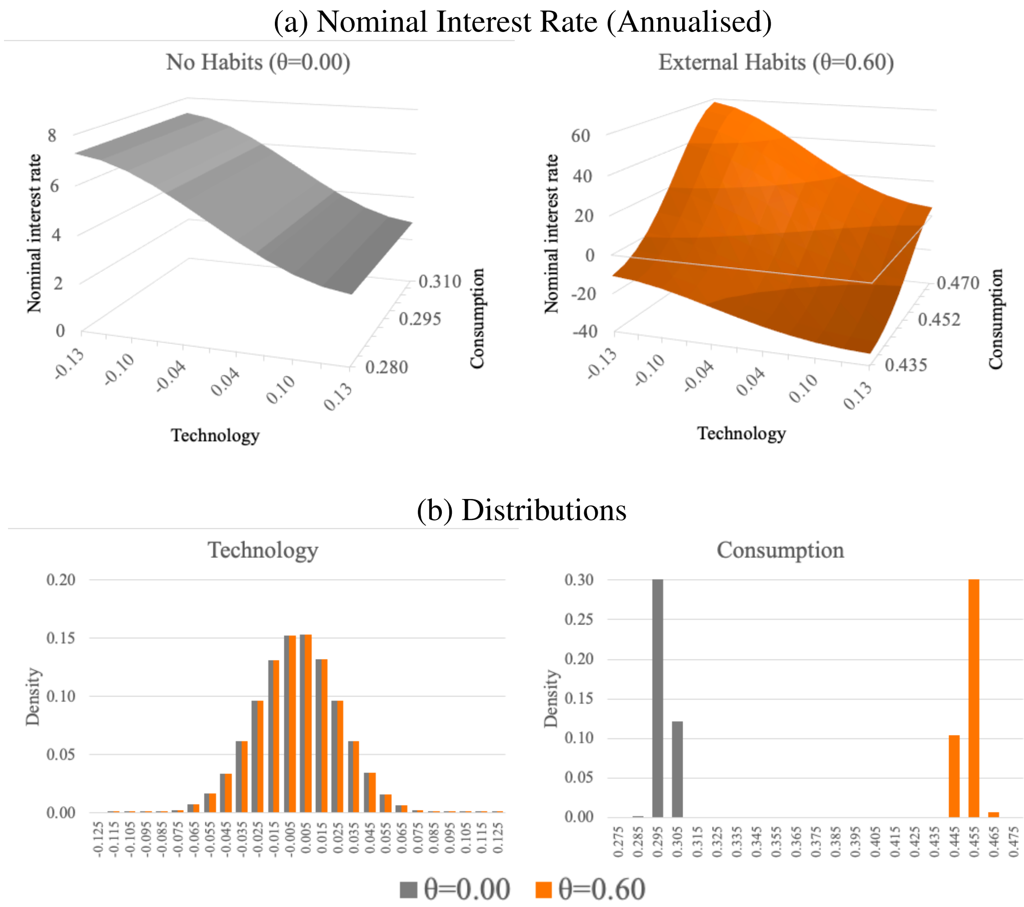
Result 2. 3 *The discretionary central bank has to create bigger changes in the nominal interest rate. Often, in practice, these changes would breach the Zero Lower Bound (ZLB).*

Part (a) of Figure 2.4 shows how the policy rule, i.e. nominal interest rate, varies across different values for the two states technology A_t and past consumption C_{t-1}. The policy rule is a function of the two states, and hence I can calculate how it varies as the values for technology and past consumption change.

The range for technology and consumption for the plots in part (a) were chosen based on the distributions of these variables from the simulation, as shown in part (b) of the Figure. The distribution for technology does not differ between the case of no habits and the case of external habits of degree $\theta = 0.60$: technology is distributed normally around a zero mean. This is because, as outlined in equation (2.31), technology follows an AR(1) process with shocks distributed normally, $\eta_t \sim i.i.d.N(0, \sigma^2)$, and as the steady state value of technology is $A = 1$ then the distribution is centred around $lnA = 0$. As external habits affect the level of consumption, the range of its distribution varies as habits get stronger. The distribution of consumption absent habits ranges approximately from 0.28 to 0.31, while the distribution of consumption with external habits of degree $\theta = 0.60$ ranges approximately from 0.435 to 0.470. These two ranges for consumption are used for part (a) of the Figure.

Absent habits (left-hand side of Figure 2.4, panel (a)), the nominal interest rate does not respond to past consumption, as the link provided by habits is absent. Higher levels of technology have a lower nominal interest rate. This inverse relationship between technology and nominal interest rate is much more pronounced with habits: on the right-hand side of Figure 2.4 panel (a) we see

Figure 2.4: Policy Rule (Discretionary Regime)



Part (a) of the figure shows the 3D surface graph of the annualised nominal interest rate on the grid of technology and consumption, for the cases with no habits and with external consumption habits. Part (b) of the figure shows the distributions of technology and consumption for the cases with no habits and with external consumption habits, obtained from the simulation.

that as technology increases, the nominal interest rate drops by much more than it does in the absence of habits. The nominal interest rate, on the other hand, has a direct relationship with lagged consumption: the nominal rate increases in consumption. Lower levels of past consumption see much lower nominal interest rate, and as the level of past consumption increases the nominal interest rate rises.

In analysing Figure 2.4 panel (a) it should be remembered that technology and consumption are not independent of each other: higher levels of technology are associated with higher levels of consumption. The relevant portion of plot on the right-hand side is that around the diagonal from the low-technology and low-consumption corner, where the nominal interest rate is 7.279, to the high-technology and high-consumption corner, where the nominal interest rate is 2.813. The relevant range for the nominal interest rate is therefore more moderate than the plot in Figure 2.4 panel (a) suggests, although the variation in nominal interest rate in response to changes in technology and consumption is still much stronger than in the case without habits, as discussed in relation to Table 2.4. We can furthermore deduce that the effect of technology prevails over the effect of consumption, as interest rate and degree of habit are inversely related in Table 2.4.

The reason for bigger changes in the nominal interest rate is that the discretionary central bank has to manipulate the policy instrument by more, because it is forced to accommodate bigger changes in the real interest rate. As discussed, the combination of low/negative nominal interest rate and larger changes means that, in practice, the ZLB is often breached.

2.5 Comparison with the Internal Habits Case

I have so far discussed the case of external superficial habits, in relation to both a committing and a discretionary central bank. It is useful to compare the scenario of external superficial habits to the scenario of internal superficial habits, to better understand the effect that the externality has on the economy studied here, and specifically on optimal monetary policy. I focus on discretionary monetary policy because external habits had a bigger effect under this regime, and therefore this comparison is more illustrative of the externality. It is worth noting that the distortion originating from monopolistic competition is still present.

2.5.1 The Model

Superficial internal habits are formed on the level of the household consumption basket c_{t-1} instead of the aggregate consumption basket C_{t-1}. Contrarily to the external habits case studied in Section 2.3, now households fully internalise the effects of their consumption habits and there is no externality.

The households choose $\{c_t, h_t, b_t\}_{t=0}^{\infty}$ to maximise utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(c_t - \theta \cdot c_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-h_t)^{1-\psi} - 1}{1-\psi} \right]$$

subject to the budget constraint

$$c_t + \frac{b_t}{P_t} = w_t \cdot h_t + \frac{b_{t-1}}{P_t} \cdot (1 + R^i_{t-1}) + D_t.$$

Final-good firms and intermediate-good firms operate in exactly the same way as in the external-habit case.

The aggregated equilibrium is now described by

$$w_t = \chi \cdot \frac{(1-H_t)^{-\psi}}{(C_t - \theta \cdot C_{t-1})^{-\sigma} - \theta \cdot \beta \cdot E_t (C_{t+1} - \theta \cdot C_t)^{-\sigma}}, \tag{2.44}$$

$$(C_t - \theta \cdot C_{t-1})^{-\sigma} - \theta \cdot \beta \cdot E_t \left[(C_{t+1} - \theta \cdot C_t)^{-\sigma} \right] = \beta \cdot E_t \left[\frac{1+R_t^i}{1+\pi_{t+1}} \cdot \left[(C_{t+1} - \theta \cdot C_t)^{-\sigma} - \theta \cdot \beta \cdot (C_{t+2} - \theta \cdot C_{t+1})^{-\sigma} \right] \right], \tag{2.45}$$

$$\omega_t = \frac{w_t}{A_t}, \tag{2.46}$$

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 = \frac{1-\varepsilon}{\phi} + \frac{\varepsilon}{\phi} \cdot \omega_t + \beta \cdot E_t \left[\frac{[(C_{t+1} - \theta \cdot C_t)^{-\sigma} - \theta \cdot \beta \cdot (C_{t+2} - \theta \cdot C_{t+1})^{-\sigma}] \cdot Y_{t+1}}{[(C_t - \theta \cdot C_{t-1})^{-\sigma} - \theta \cdot \beta \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma}] \cdot Y_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right] \tag{2.47}$$

$$Y_t = A_t \cdot H_t, \tag{2.48}$$

$$C_t = (1 - \frac{\phi}{2} \cdot \pi_t^2) \cdot Y_t. \tag{2.49}$$

Equations (2.46), (2.48), and (2.49) replicate the equations of Section 2.3.4, specifically equations (2.27), (2.29), and (2.30) respectively. Equations (2.44), (2.45), and (2.47), on the other hand, contain extra terms compared to equations (2.25), (2.26), and (2.28) of Section 2.3.4. Because households are conscious of the role that their current consumption level will have in creating a consumption habit to be sustained in the next period, we have that in the equilibrium conditions the term $(C_t - \theta \cdot C_{t-1})^{-\sigma}$ has been substituted with $(C_t - \theta \cdot C_{t-1})^{-\sigma} - \theta \cdot \beta \cdot E_t(C_{t+1} - \theta \cdot C_t)^{-\sigma}$, and similarly the term $E_t[(C_{t+1} - \theta \cdot C_t)^{-\sigma}]$ has been substituted with $E_t[(C_{t+1} - \theta \cdot C_t)^{-\sigma} - \theta \cdot \beta \cdot (C_{t+2} - \theta \cdot \cdot C_{t+1})^{-\sigma}]$.

The discretionary central bank maximises welfare subject to the behaviour of the private sector, hence their problem is

$$\begin{aligned} V(A_t, C_{t-1}) = \max E_0 \Bigg[& \frac{(C_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-H_t)^{1-\psi} - 1}{1-\psi} \\ & + \beta \cdot V(A_{t+1}, C_t) + \gamma_t \cdot \left[\left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot A_t \cdot H_t - C_t \right] \\ & - \lambda_t \cdot \Bigg[\left(\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 - \frac{1-\varepsilon}{\phi} \right) \cdot \big[(C_t - \theta \cdot C_{t-1})^{-\sigma} \\ & - \theta \cdot \beta \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma} \big] \cdot A_t \cdot H_t \\ & - \frac{\varepsilon}{\phi} \cdot \chi \cdot (1-H_t)^{-\psi} \cdot H_t - \beta \cdot G(A_{t+1}, C_t) \Bigg] \Bigg]. \end{aligned}$$

The future values of habit-adjusted consumption, labour and inflation are in a single term,

$$G(A_{t+1},C_t) \equiv \left[(C_{t+1}-\theta\cdot C_t)^{-\sigma}-\theta\cdot\beta\cdot(C_{t+2}-\theta\cdot C_{t+1})^{-\sigma}\right]\cdot A_{t+1}\cdot H_{t+1}\cdot\pi_{t+1}\cdot(1+\pi_{t+1}). \tag{2.50}$$

As for the equilibrium conditions described above, in equation $G(A_{t+1},C_t)$ the value of habit-adjusted consumption now includes the effect of today's consumption on tomorrow's habits.

The first order conditions for discretionary central bank in the case of superficial internal habits are

$$\begin{aligned}
\frac{\partial V(A_t,C_{t-1})}{\partial C_t}:\quad & (C_t-\theta\cdot C_{t-1})^{-\sigma}+\beta\cdot V_2(A_{t+1},C_t)-\gamma_t \\
& +\sigma\cdot\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon}{2}\cdot\pi_t^2+\frac{\varepsilon}{\phi}\right)\cdot\Big[(C_t-\theta\cdot C_{t-1})^{-\sigma-1} \\
& +\theta^2\cdot\beta\cdot E_t\left[(C_{t+1}-\theta\cdot C_t)^{-\sigma-1}\right]\Big]\cdot A_t\cdot H_t\cdot\lambda_t \\
& -\beta\cdot E_t G_2(A_{t+1},C_t)\cdot\lambda_t-\theta\cdot\beta\cdot E_t\left[(C_{t+1}-\theta\cdot C_t)^{-\sigma}\right] \\
& +\theta\cdot\beta\cdot E_t\Bigg[\left(\pi_{t+1}\cdot(1+\pi_{t+1})+\frac{1-\varepsilon}{2}\cdot\pi_{t+1}^2+\frac{\varepsilon}{\phi}\right) \\
& \cdot(C_{t+1}-\theta\cdot C_t)^{-\sigma-1}\cdot A_{t+1}\cdot H_{t+1}\cdot\lambda_{t+1}\Bigg]=0,
\end{aligned} \tag{2.51}$$

$$\begin{aligned}
\frac{\partial V(A_t,C_{t-1})}{\partial H_t}:\quad & -\chi\cdot(1-H_t)^{-\psi}+\gamma_t\cdot\left(1-\frac{\phi}{2}\cdot\pi_t^2\right)\cdot A_t \\
& -\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon}{2}\cdot\pi_t^2+\frac{\varepsilon}{\phi}\right)\cdot\Big[(C_t-\theta\cdot C_{t-1})^{-\sigma-1} \\
& +\theta^2\cdot\beta\cdot E_t\left[(C_{t+1}-\theta\cdot C_t)^{-\sigma-1}\right]\Big]\cdot A_t\cdot\lambda_t \\
& +\frac{\varepsilon}{\phi}\cdot\chi\cdot\left[\psi\cdot(1-H_t)^{-\psi-1}\cdot H_t+(1-H_t)^{-\psi}\right]\cdot\lambda_t=0,
\end{aligned} \tag{2.52}$$

$$\begin{aligned}
\frac{\partial V(A_t,C_{t-1})}{\partial \pi_t}:\quad & -\phi\cdot\gamma_t\cdot\pi_t-[1+2\cdot\pi_t+(1-\varepsilon)\cdot\pi_t]\cdot\Big[(C_t-\theta\cdot C_{t-1})^{-\sigma} \\
& -\theta\cdot\beta\cdot E_t\left[(C_{t+1}-\theta\cdot C_t)^{-\sigma}\right]\Big]\cdot\lambda_t=0.
\end{aligned} \tag{2.53}$$

Comparing these first order conditions with equations (2.34), (2.35) and (2.36) we see that, once again, the impact of current consumption on creating future consumption habits to be sustained is explicitly taken into account by the discretionary central bank when setting its optimal policy, because households are now aware of the effect of habits.

2.5.2 Results

Table 2.5 shows a comparison between the cases of no habits, external habits, and internal habits under a discretionary regime. As before, the steady state values are calculated as the averages across a simulation period of 1,000,000 quarters.

Table 2.5: Stochastic Steady States by Type of Habit (Discretionary Regime)

	No habits	**External habits**	**Internal habits**
Degree of habit (θ)	0.00	0.60	0.60
Inflation	1.007	-7.386	0.540
	(0.005)	(0.177)	(0.005)
Consumption	0.298	0.447	0.374
	(0.006)	(0.009)	(0.007)
Labour	0.298	0.453	0.374
	(0.002)	(0.003)	(0.003)
Output	0.298	0.453	0.374
	(0.006)	(0.009)	(0.007)
Real rate	4.013	3.974	4.122
	(0.752)	(2.240)	(2.241)
Nominal rate	5.031	-3.483	4.668
	(0.750)	(2.296)	(2.241)
Wage	0.909	0.896	0.895
	(0.023)	(0.022)	(0.023)
Welfare	-393.32	-886.06	-825.10
$\|\|$Euler error$\|\|_\infty$	5.16E-5	5.40E-5	3.52E-5

The table presents stochastic steady state values and standard deviations for all variables for the discretionary regime, in the cases with no habits, with external consumption habits, and with internal consumption habits. Note: Inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

The case of external consumption habits has been discussed in the previous Section: households decide to overwork to sustain their consumption habits. The increased supply of labour pushes down the real wage, while output and consumption increase. The time inconsistency problem faced by the central bank is reversed by the presence of strong-enough habits. The central bank now finds output inefficiently high, the opposite of the no-habit case where the monopolistic distortion generates inefficiently low output. The central bank would therefore be tempted to create a deflationary surprise by cutting the nominal interest rate in order to slow down production and reduce output (and consumption) levels. With a discretionary central bank, the households expect this and behave as if deflation is going to happen, which forces the central bank to cut interest rates and create deflation, with no benefit to output and consumption. Deflation, for a discretionary central bank facing external consumption habits, is the self-fulfilling prophecy.

Internal habits create persistence in consumers' behaviour in the same way that external habits did, but as discussed above the consumers now take into account the impact that current consumption choices will have on future behaviour, being aware that they create a habit to be sustained in the future. Consumers with internal consumption habits internalise the effect of their habits. As a result, the steady state of internal habits stands somewhere in between the case of no habits and the one of external habits (as presented in Table 2.5).

Like external habits, internal habits lead to increased levels of consumption, labour, and output, and reduced wages. The mechanism is analogous to the one described for the external habits case: households supply more labour in order to be able to consume more, which reduces wages and increases output. The increase in output, however, is smaller than in the external habits case, because consumers with internal habits foresee the effect of creating a habit stock, and balance out the utility from consumption adjusted to a habit they are fully aware of against the utility from leisure — in other words, they do not over-commit themselves to high consumption levels that require sacrificing too much leisure time to be sustained.

On the other hand, the internal habits case is similar to the case of no habits in the sense that the inflation bias is positive. An economy with internal habits and a discretionary central bank would show the usual positive inflation bias: the central bank no longer needs to curb overconsumption, hence is no longer tempted to create falling prices. Instead, it is tempted to create positive inflation to boost output and offset the monopolistic distortion, exactly like in the habit-free model. With the addition of a production subsidy that corrects the monopolistic distortion the steady state would be efficient, and inflation would be zero.

Lacking the consumption externality, the habit stock is not unforeseen and the effects of their consumption choices on said stock are fully known and accounted for. The real interest rate and the degree of habit do not have the same strong inverse relationship as with external habits. With internal consumption habits, there is no downward pressure on inflation.

With the inflation bias being positive, the nominal interest rate in the case of internal habits is positive. While this reduces the likelihood of breaching the ZLB, it does not make it impossible. Habits, whether external or internal, create more volatility in the nominal interest rate. As a result, the nominal interest rate can still be negative — however, this occurs less frequently than in the external habits case. As Table 2.6 shows, with internal habits the nominal interest rate would breach

Table 2.6: Likelihood of Breaching the ZLB by Type of Habit (Discretionary Regime)

No habits	External habits	Internal habits
θ=0.00	θ=0.60	θ=0.60
0.00%	93.27%	1.68%

The table gives the likelihood of breaching the ZLB calculated as the percentage of time in the 1,000,000-period simulation where the nominal interest rate is set below zero.

the ZLB only 1.68% of the time, compared to 93.27% of the time for the case with external habits of the same degree.

2.6 Investigating the Inflation Bias

In this Section I investigate in detail the sign and size of the inflation bias by introducing first a consumption tax and then a production subsidy. For simplicity I assume that any distortionary consumption taxes/production subsidies are financed/remitted lump-sum. The consumption tax offsets the externality, the production subsidy offsets the monopolistic distortion. This allows me to investigate and discuss the relative magnitudes of the two distortions on the inflation bias. The results confirm that it is indeed the consumption externality is significantly stronger than the monopolistic distortion, creating the negative inflation bias and exacerbating the stabilisation bias.

2.6.1 Production Subsidy

Intermediate-good firms are monopolistically competitive, which results in underproduction (and, in combination with Rotemberg price-adjustment costs and discretionary policy, creates inflation). Firms can be incentivised to increase production and obtain an efficient outcome through a production subsidy. With a production subsidy in place, and absent any other distortion or externality, there is no inflation in steady state.

The production subsidy therefore idntifies the effect of the consumption externality by correcting the distortion created by the market power of intermediate-good firms.

The production subsidy is set to $-\frac{1}{\varepsilon-1}$, which is the level that offsets the monopolistic competition distortion in steady state. With the optimal production subsidy in place and in the absence of external consumption habits, the NKPC equation of Section 2.3 (equation (2.28)) becomes

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 = -\frac{\varepsilon}{\phi} + \frac{\varepsilon}{\phi} \cdot \omega_t + \beta \cdot E_t \left[\left(\frac{C_{t+1} - \theta \cdot C_t}{C_t - \theta \cdot C_{t-1}} \right)^{-\sigma} \cdot \frac{Y_{t+1}}{Y_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right] \tag{2.54}$$

which, alongside equations (2.25) – (2.27), (2.29) and (2.30) now describes the aggregate equilibrium.

As mentioned above, in the case of internal consumption habits a production subsidy would make the steady state efficient. Imposing the production subsidy $-\frac{1}{\varepsilon-1}$ on intermediate-good producers, the Euler consumption equation of Section 2.5 (equation 2.47) becomes

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon}{2} \cdot \pi_t^2 = -\frac{\varepsilon}{\phi} + \frac{\varepsilon}{\phi} \cdot \omega_t$$
$$+\beta \cdot E_t \left[\frac{[(C_{t+1} - \theta \cdot C_t)^{-\sigma} - \theta \cdot \beta \cdot (C_{t+2} - \theta \cdot C_{t+1})^{-\sigma}] \cdot Y_{t+1}}{[(C_t - \theta \cdot C_{t-1})^{-\sigma} - \theta \cdot \beta \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma}] \cdot Y_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right]. \quad (2.55)$$

In this case inflation would be zero, and hence we have that $\bar{C} = \bar{H} = \bar{Y}$, $\bar{\omega} = \bar{w} = 1$, and

$$\frac{(\bar{C} - \theta \cdot \bar{C})^{\sigma}}{(1-\bar{C})^{\psi}} = \chi \cdot \frac{1}{1-\theta \cdot \beta} \quad (2.56)$$

This result will be used in the next Section to determine the tax on consumption when the habit formation is external that mimics the steady state level of consumption when the habit formation is internal.

Table 2.7 shows the effect of introducing a production subsidy in the case of no habits and external habits of degree $\theta = 0.60$.

Comparing the second and fourth column we can see that adding a production subsidy to the model with no habits offsets the distortion originating from market power. With a production subsidy output, consumption, and labour are higher, the wage is increased, and inflation is zero. Because the monopolistic distortion inefficiently suppressed output, introducing a production subsidy that offsets this distortion brings output to its efficient level. This removes the temptation for the central bank to create an inflationary surprise, because an output boost is no longer needed. Therefore, the time inconsistency is resolved and the inflationary bias is removed, allowing the steady state to be efficient.

Adding the production subsidy on the case with external habits, then, offsets the effect of the monopolistic distortion and allows to isolate any other distortion present in the model, in the present case the consumption externality. As the fifth column of Table 2.7 shows, it is the external consumption habits that increase output, consumption, and labour above their efficient level, that reduce the wage, and that put a sizeable downward pressure on prices.

The production subsidy has limited effect on volatility: in the economy with external consumption habits and a production subsidy all variables remain highly volatile. While inflation

Table 2.7: Effect of the Production Subsidy by Degree of External Habit (Discretionary Regime)

Production subsidy	**No**		**Yes**	
Degree of habit (θ)	0.00	0.60	0.00	0.60
Inflation	1.007	-7.386	0.000	-7.416
	(0.005)	(0.177)	(0.000)	(0.173)
Consumption	0.298	0.447	0.305	0.455
	(0.006)	(0.009)	(0.006)	(0.009)
Labour	0.298	0.453	0.305	0.462
	(0.002)	(0.003)	(0.002)	(0.003)
Output	0.298	0.453	0.305	0.462
	(0.006)	(0.009)	(0.006)	(0.009)
Real rate	4.013	3.974	4.013	3.972
	(0.752)	(2.240)	(0.757)	(2.320)
Nominal rate	5.031	-3.483	4.013	-3.515
	(0.750)	(2.296)	(0.757)	(2.370)
Wage	0.909	0.896	1.000	0.986
	(0.023)	(0.022)	(0.026)	(0.025)
Welfare	-393.32	-886.06	-392.84	-899.93
$\|\|$Euler error$\|\|_\infty$	5.16E-5	5.42E-5	5.22E-5	5.59E-5

The table presents stochastic steady state values and standard deviations for all variables for the discretionary regime, in the cases with no habits and with external consumption habits, and without or with production subsidy.
Note: Inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

Table 2.8: Likelihood of Breaching the ZLB by Degree of External Habit and Production Subsidy (Discretionary Regime)

	No prod. subsidy	Prod. subsidy
θ=0.00	0.00%	0.00%
θ=0.60	93.27%	92.83%

The table gives the likelihood of breaching the ZLB calculated as the percentage of time in the 1,000,000-period simulation where the nominal interest rate is set below zero.

is marginally less volatile after the addition of the production subsidy, nominal and real interest rate are more volatile. This increased volatility means that the nominal interest rate, despite being negative, has a slightly larger chance of rising above zero. It does, however, continue to breach the ZLB for the majority of the time, as shown in Table 2.8.

2.6.2 Consumption Tax

The consumption tax, by replicating the efficient, internal-habits steady state, identifies the effects of the monopolistic distortion on the economy in general, and inflation in particular.

The overconsumption externality arises because consumers fail to internalise the effects their current consumption choices have in creating a habit to be sustained in the future. If the habits were of the internal type, instead, consumers would fully internalise the effects of their habit, and no externality would materialise. I construct a tax that replicates the internal-habit steady state, where the externality is absent. The purpose of this exercise is twofold: it allows me to observe the monopolistic distortion by itself, and to study the size of the tax necessary to offset the consumption externality.

With consumption subject to the proportional tax, τ, which is redistributed to households in the form of lump-sum subsidy T_t, the household now maximises

$$E_0 \sum_{t=0}^{\infty} \beta^t \cdot \left[\frac{(c_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-h_t)^{1-\psi}}{1-\psi} \right] \tag{2.57}$$

subject to

$$(1+\tau) \cdot c_t + \frac{b_t}{P_t} = w_t \cdot h_t + \frac{b_{t-1}}{P_t} \cdot (1+R_{t-1}) + D_t + T_t. \tag{2.58}$$

As previously, one can find the first order conditions and combine them to get an equation for wage. Aggregated, that becomes

$$w_t = \chi \cdot (1+\tau) \cdot \frac{(1-H_t)^{-\psi}}{(C_t - \theta \cdot C_{t-1})^{-\sigma}} \tag{2.59}$$

which replaces equation (2.25), and alongside equations (2.26) – (2.30) describes the aggregate equilibrium. The labour market-clearing wage is the one that equates the marginal benefit of labour to the marginal cost, as before, with the difference that now the marginal cost includes the consumption tax.

The consumption tax is calibrated so that consumption and all other variables match the steady state value of an economy with internal habits and a production subsidy. By comparing the efficient steady state of internal consumption habits with production subsidy to the steady state of the external habits with a tax I can find an equation that links the size of the tax to the degree of habit. From the steady state equations for the external case, we get

$$\frac{(\bar{C} - \theta \cdot \bar{C})^{\sigma}}{(1-\bar{C})^{\psi}} = \chi \cdot (1+\tau)$$

Combining this with equation (2.56) we get the equation for the consumption tax

$$\tau = \frac{1}{1-\beta \cdot \theta} - 1, \tag{2.60}$$

which is clearly increasing in the degree of habit, θ. The higher the degree of habit, the higher the tax; the higher the tax, the higher the equilibrium wage. The effect of the degree of consumption habit on wages discussed in Section 2.4.2 is balanced out.

With a consumption tax that mimics the steady state of the internal consumption habits with a production subsidy, the steady state will be efficient. However, the consumption tax completely corrects the overconsumption only in steady state. Outside of the steady state the externality will not be efficiently taxed.

Setting $\beta = 0.99$ (i.e. quarterly time horizon) the size of the consumption tax is shown in Table 2.9. The size of the tax increases exponentially, amounting to a striking 146.3% of consumption for the baseline value of $\theta = 0.60$. The size of the tax is linked to the size of the externality that needs to be offset, and Table 2.9 suggests that the size of the externality is important.

Table 2.9: Size of Consumption Tax

Degree of habit (θ)	**Tax** (% of consumption)
0.00	0.0
0.10	11.0
0.20	24.7
0.30	42.2
0.40	65.6
0.50	98.0
0.60	146.3
0.70	225.7
0.80	380.8

1

Table 2.10 shows the effect of introducing a consumption tax in the case of no habits and external habits of degree $\theta = 0.60$. The consumption tax, as seen in Table 2.9, is linked to the degree of habit, and in the case of no consumption habits there is no consumption tax, i.e. $\tau = 0$ when $\theta = 0.00$. The fourth column of Table 2.10, therefore, simply replicates the second column, and is presented for completion.

We can see from the fourth column of Table 2.10 that adding a consumption tax decreases

Table 2.10: Effect of the Consumption Tax by Degree of External Habit $\theta = 0.60$ (Discretionary Regime)

Consumption tax	**No**		**Yes**	
Degree of habit (θ)	0.00	0.60	0.00	0.60
Inflation	1.007	-7.386	1.007	0.819
	(0.005)	(0.177)	(0.005)	(0.039)
Consumption	0.298	0.447	0.298	0.375
	(0.006)	(0.009)	(0.006)	(0.007)
Labour	0.298	0.453	0.298	0.375
	(0.002)	(0.003)	(0.002)	(0.003)
Output	0.298	0.453	0.298	0.375
	(0.006)	(0.009)	(0.006)	(0.007)
Real rate	4.013	3.974	4.013	3.979
	(0.752)	(2.240)	(0.752)	(2.118)
Nominal rate	5.031	-3.483	5.031	4.807
	(0.750)	(2.296)	(0.750)	(2.145)
Wage	0.909	0.896	0.909	0.369
	(0.023)	(0.022)	(0.023)	(0.009)
Welfare	-824.96	-886.06	-824.96	-824.98
$\|\|$Euler error$\|\|_\infty$	5.16E-5	5.40E-5	5.33E-5	5.06E-5

The table presents stochastic steady state values and standard deviations for all variables for the discretionary regime, in the cases with no habits and with external consumption habits, and without or with consumption tax.

Note: Inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

consumption, output, and labour in steady state. These steady state values are indeed close to those found for the case of internal habits, as in Table 2.5. The consumption tax acts to curb the overconsumption, thus reducing output and the demand for labour. This undoes the negative inflationary bias created by the external habits. Now, like in the case of a discretionary central bank facing internal habits or no habits, the level of output is inefficiently low and the discretionary central bank would be tempted to create an inflationary surprise to boost output. This creates inflationary expectations which come true, and in the fourth column of Table 2.5 steady state inflation is indeed positive.

As the consumption tax reduces demand and output, firms demand less labour. Now the supply of labour outstrips demand, bringing the real wage down even further. Households oversupply labour led by their desire to over-consume, and with the addition of the consumption tax consuming now is even more expensive. Households cannot afford to consume more, and therefore the consumption tax is successful in reducing consumption and output. Undoing the negative inflation bias is achieved at the expense of low wages.

Table 2.11: Likelihood of Breaching the ZLB by Degree of External Habit and Consumption Tax (Discretionary Regime)

	No consumption tax	Consumption tax
θ=0.00	0.00%	0.00%
θ=0.60	93.27%	1.11%

The table gives the likelihood of breaching the ZLB calculated as the percentage of time in the 1,000,000-period simulation where the nominal interest rate is set below zero.

Because inflation is positive, so is the steady state nominal interest rate. This means that the chances of breaching the ZLB are extensively reduced: the nominal interest rate is negative only following large technology shocks, which as Table 2.11 shows happens 1.11% of the time.

2.6.3 Comparing and Combining Production Subsidy and Consumption Tax

Table 2.12 partially reprises on previous results by showing side to side what the effect is of adding the production subsidy or the consumption tax on the economy facing external consumption habits of degree $\theta = 0.60$ and under a discretionary regime. Table 2.12 also shows how the steady state changes when both production subsidy and consumption tax are added.

Column (2) shows how adding the production subsidy to the benchmark case, i.e. column (1), increases consumption, output, and labour. The positive output gap is wider now, giving rise to a larger negative inflation bias and therefore a larger negative value for inflation. Inflation is less volatile, but real and nominal interest rate are more volatile. Introducing the production subsidy slightly decreases the likelihood of breaching the ZLB, from 93.27% to 92.83%, as shown in Table 2.13.

Column (3) shows how adding the consumption tax decreases output, consumption, and labour compared to the benchmark case of column (1). The consumption tax offsets the consumption externality created by the habits in steady state, and therefore the economy is now characterised by the inefficiently low output levels created by the monopolistic distortion. The inefficiently low output leads to an positive inflationary bias for a discretionary central bank, and indeed inflation in column (3) is positive. Introducing the production subsidy drastically reduces the likelihood of breaching the ZLB to 1.11%.

Table 2.12: Stochastic Steady States with Discretionary Regime and Degree of External Habit $\theta = 0.60$

	(1) Benchmark	(2) Prod. subsidy	(3) Consumption tax	(4) Both
Inflation	-7.386	-7.416	0.819	-0.002
	(0.177)	(0.173)	(0.039)	(0.047)
Consumption	0.447	0.455	0.375	0.383
	(0.009)	(0.009)	(0.007)	(0.007)
Labour	0.453	0.462	0.375	0.383
	(0.003)	(0.003)	(0.003)	(0.003)
Output	0.453	0.462	0.375	0.383
	(0.009)	(0.009)	(0.007)	(0.007)
Real rate	3.974	3.972	3.979	3.978
	(2.240)	(2.230)	(2.118)	(2.178)
Nominal rate	-3.483	-3.515	4.807	3.976
	(2.296)	(2.370)	(2.145)	(2.205)
Wage	0.896	0.986	0.369	0.406
	(0.022)	(0.025)	(0.009)	(0.010)
Welfare	-886.06	-899.93	-824.96	-824.40
$\|\|\text{Euler error}\|\|_\infty$	5.40E-5	5.59E-5	5.33E-5	5.51E-5

The table presents stochastic steady state values and standard deviations for all variables for the discretionary regime and with external consumption habits, for the cases with production subsidy, consumption tax, or both compared to the case with neither (i.e. benchmark).
Note: Inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

Comparing the effects of production subsidy and consumption tax we can see that they work in opposite directions. This is because they act to offset two opposing distortions: the distortion of monopolistic competition in intermediate-good markets is antagonist to the externality of external consumption habits. The former decreases output, while the latter increases it. As the benchmark case shows, and as discussed above, for the specification chosen here and in particular for a degree of habit $\theta = 0.60$ we have that the externality overpowers the monopolistic distortion, resulting in negative and large inflation, and high output, consumption, and labour.

Finally, column (4) of Table 2.12 presents the stochastic steady state values when both monopolistic distortion and externality are offset. Having compensated for these two competing distortions, now the steady state values of output, consumption, and labour are efficient. The consumption tax offsets the effect of the consumption externality only in steady state and not when the economy deviates from the steady state, leading to an average value for inflation obtained through a stochastic process that is close to but not exactly equal to zero.

Table 2.13: Likelihood of Breaching the ZLB with Discretionary Regime and Degree of External Habit $\theta = 0.60$

	No consumption tax	Consumption tax
No prod. subsidy	93.27%	1.11%
Prod. subsidy	92.83%	3.35%

The table gives the likelihood of breaching the ZLB calculated as the percentage of time in the 1,000,000-period simulation where the nominal interest rate is set below zero.

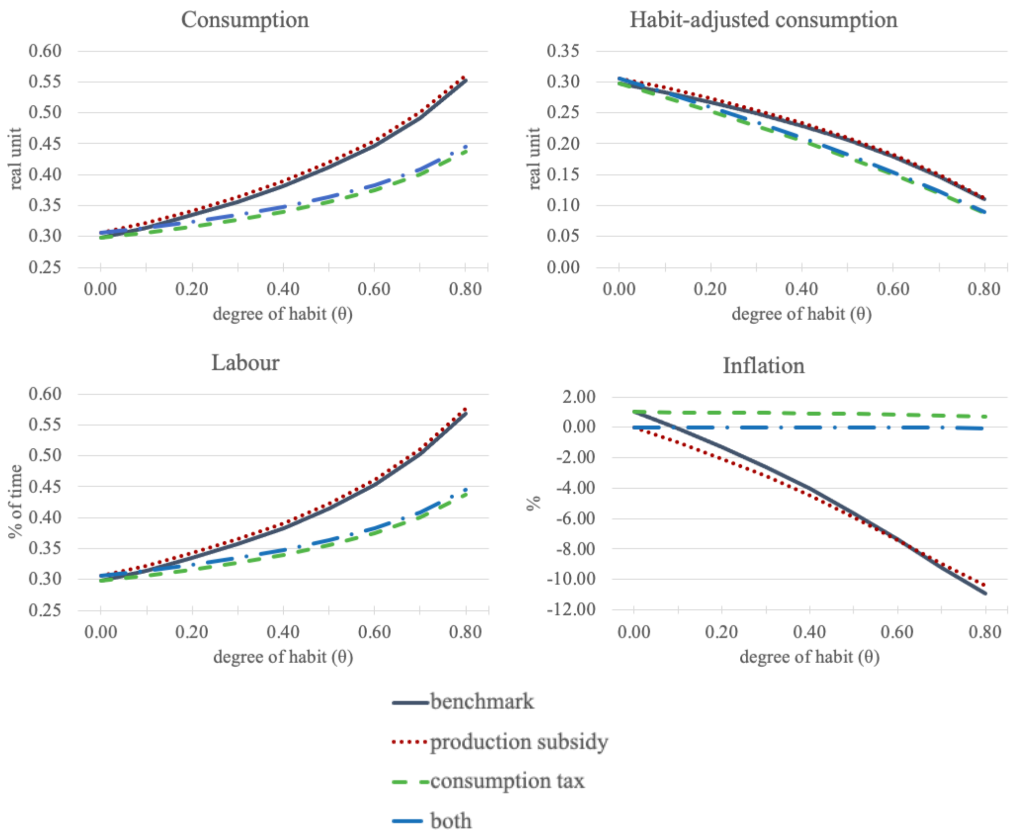
As amply discussed, external consumption habits are linked to increased volatility. While the consumption tax can replicate the steady state of an efficient economy with internal consumption habits, it does not completely offset the effect of the externality when responding to shocks. In other words, the consumption tax can reduce the volatility of the economic system to an extent, but it cannot fully undo the increased volatility. The volatility of inflation, real interest rate, and nominal interest rate in particular is lower in column (4) of Table 2.12 compared to column (1), yet these values remain higher than in the case without habits (see Table 2.4, first column). These high volatilities mean that, despite the nominal interest rate being positive in the case with both production subsidy and consumption tax, the likelihood of breaching the ZLB is not zero. However, the nominal interest rate is now negative only 3.35% of the time, a significant improvement from the almost certainty of breaching the ZLB in the benchmark case.

Figure 2.5 shows how the deterministic steady state values of consumption, habit-adjusted consumption, inflation, and labour change across degrees of habit, for the four specifications: benchmark (as in Figure 2.1), with a consumption tax (following Section 2.6.2), with a production subsidy (following Section 2.6.1), and with both.

With both taxes in place inflation is zero (dash-dotted blue line): the steady state is efficient. The bias created by the monopolistic distortion does not depend on the degree of habit, and therefore when a consumption tax is introduced to the benchmark case and the effect of monopolistic distortion is isolated, inflation remains roughly constant across values of θ (dashed green line). The inflation bias induced from the monopolistic distortion is positive. The inflation bias created by the consumption externality, instead, is directly linked to the degree of habit. The production subsidy isolates the effect of the externality, and the inflation is non-positive all throughout the range of θ (dotted red line). The bias of external consumption habits is negative. It is clearly the consumption habits that determine the negative sign of inflation.

Consumption is always increasing in the degree of habit, and habit-adjusted consumption

Figure 2.5: Steady State Values by Degrees of Habit



The figure shows the deterministic steady states of consumption, habit-adjusted consumption, labour, and inflation for varying degrees of external consumption habit for four distinct scenarios: benchmark, with production subsidy, with consumption tax, and with both.
Note: inflation is annualised, while consumption and labour are quarterly.

always decreasing. The latter does, however, decrease more when the effect of the habits is absorbed by the consumption tax. The consumption tax makes households internalise their habits: they will not overconsume, but they will consume more as the degree of habit gets stronger. More and more of the increase in consumption will result from sustaining the habit, while habit-adjusted consumption decreases. Habit-adjusted consumption decreases by more when the effect of the habits is absorbed because consumption itself increases by less. When the effect of the habits is not absorbed consumption increases by more, which in turn forces households to work more in order to sustain the habit (dotted red and solid grey lines).

These results indeed reinforce Result 1: external consumption habits and monopolistic power are competing distortions, and their inflation biases go in separate directions. When $\theta = 0.60$ in the discretionary scenario consumption habits are stronger than monopolistic power, and their effect ultimately dominates.

2.7 Dealing with the Externality

One of the key takeaways of the previous Section is that the discretionary central bank can replicate an efficient steady state by introducing a production subsidy that offsets the monopolistic distortion, and a consumption tax that offsets the consumption externality. This double intervention eliminates the positive inflation bias created by the monopolistic distortion and the (opposing and often, in my specification, dominating) negative inflation bias created by the consumption externality. It must be remembered, however, that the consumption tax only completely offsets the externality at steady state. When the economy is not at steady state the externality is only partially offset.

Table 2.14: Stochastic Steady States with Degree of External Habit $\theta = 0.60$

	Discretion		**Commitment**
	Benchmark	***Prod. subsidy & Consumption tax***	***Benchmark***
Inflation	-7.386	-0.002	0.000
	(0.177)	(0.047)	(0.095)
Consumption	0.447	0.383	0.452
	(0.009)	(0.007)	(0.009)
Labour	0.453	0.383	0.452
	(0.003)	(0.003)	(0.003)
Output	0.453	0.383	0.452
	(0.009)	(0.007)	(0.009)
Real rate	3.974	3.978	3.971
	(2.240)	(2.178)	(2.214)
Nominal rate	-3.483	3.976	3.972
	(2.296)	(2.205)	(2.174)
Wage	0.896	0.406	0.909
	(0.022)	(0.010)	(0.023)
Welfare	-886.06	-824.40	-876.81
$\|\text{Euler error}\|_\infty$	5.40E-5	5.51E-5	5.63E-5

The table presents stochastic steady state values and standard deviations for all variables with external consumption habits, for the discretionary regime benchmark or with production subsidy and consumption tax, compared to the commitment regime in the benchmark case.
Note: Inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

How does, then, an economic system of discretionary regime with production subsidy and consumption externality fare against a committed central bank? The comparison in Table 2.14 seems to suggest that, while the introduction of production subsidy and consumption tax can improve on the situation faced by a discretionary central bank, the commitment case is still to be preferred.

In a commitment regime output, consumption, and labour can be inefficiently high without repercussions on inflation: the committing central bank's ability to deliver zero inflation is not affected by the presence of external consumption habits. Wage is also higher under commitment — in fact, it is unchanged from the wage level of the case with no habits.

External habits affect the real interest rate, so the bigger the externality, the more volatile the real interest rate will be, and this volatility and instability propagate throughout the economy. Risk aversion creates and drives the link between externality and volatility. It follows that when the central bank is able to create a more stable environment by committing to a infinitely-lived policy, it can overcome the externality, avoid the negative inflation bias, and achieve zero inflation in steady state.

Commitment monetary policy simultaneously undoes the negative inflation bias created by external habits and the classic positive inflation bias created by time inconsistency by credibly committing to a zero-inflation policy, sustained by a positive nominal interest rate. This does not, however, curb the overconsumption externality. Discretionary monetary policy is also unable to curb the externality, and furthermore cannot avoid the large downward pressure on prices.

Table 2.15: Likelihood of Breaching the ZLB with Degree of External Habit $\theta = 0.60$

Discretion		Commitment
Benchmark	*Prod. subsidy & Consumption tax*	Benchmark
93.27%	3.35%	3.11%

The table gives the likelihood of breaching the ZLB calculated as the percentage of time in the 1,000,000-period simulation where the nominal interest rate is set below zero.

Finally, in the commitment case the likelihood of breaching the ZLB is marginally lower than in the discretionary case with production subsidy and consumption tax, as shown in Table 2.15. Commitment, I conclude, is to be preferred to discretion when dealing with external consumption habits. overconsumption externality.

2.8 Conclusion

I introduce external consumption habits to an otherwise standard New Keynesian Dynamic Stochastic General Equilibrium model with a discretionary central bank. The habits create an overconsumption externality: households fail to internalise how their current consumption choices create a habit stock to be sustained in the future, and end up overworking in order to be able to afford the levels of consumption created by the habit. Output, consumption, and labour are inefficiently high. I show that the introduction of external consumption habits generates a sizeable negative inflation bias, larger changes in the nominal interest rate, and more volatility in the economy.

The aim of the central bank is to contain the externality. In an attempt to curb the overconsumption, it will be tempted to surprise households with falling prices to induce them to postpone consumption. Households expect this surprise from the discretionary central bank, and take falling prices into account when making their consumption-leisure choices. This makes negative inflation inevitable, with no benefits for output. For my benchmark parameterisation, the negative inflation bias created by external consumption habits is so large that it overpowers the common positive inflation bias resulting from market power.

Driven by consumption-smoothing motives, stronger habits imply larger drops in the real interest rate following a positive technology shock. The discretionary central bank is then forced to create a bigger change in nominal interest rate to accommodate the drop in real interest rate. The volatility then propagates to the rest of the economy: inflation drops, the increase in consumption and output is contained and smoother, and labour decreases more on impact and readjusts faster. The economy is more volatile.

Stronger habits imply both a lower nominal interest rate in equilibrium and a larger drop in the same following a positive technology shock. In practice, this would often breach the Zero Lower Bound. Further work could focus on fully integrating the Zero Lower Bound into the model, and assessing any behavioural changes that follow.

The results in this Chapter suggest that internal consumption habits might be a more fruitful venue to pursue in empirical work. I have shown how external consumption habits create a large negative inflation bias, a fact that the literature has so far overlooked due to its focus on linearised models.

3. Central Banks with a Present Bias

3.1 Introduction

This Chapter investigates a model of a central bank with a present bias: if a discretionary central bank cares relatively more about the present and relatively less about the future, how does this affect monetary policy making? What are the consequences for the economy as a whole? In my setting the central bank is dealing with the effects of the over-consumption externality caused by external consumption habits, and the strength of the present bias of the central bank impacts the trade-off how it perceives the trade-off between current costs and future benefits. I show that in the discretionary case this alters the behaviour of the central bank.

Following Laibson (1997), I model the present bias as a quasi-hyperbolic discounting function. Whilst the present bias is an established topic in the behavioural economics literature (Wilkinson & Klaes, 2017), and despite experimental evidence of its relevance (Ainslie, 1992), quasi-hyperbolic discounting is seldom included in macroeconomic models. Furthermore, the macroeconomic literature has so far considered cases where it is the households who have quasi-hyperbolic discounting. The scenario where the central bank has a present bias whilst the private sector does not is missing in the literature, and this Chapter addresses this gap. This is even more important in light of what the present bias could represent: either a phenomenon endogenous to the central bank, perhaps linked to the composition of its monetary policy committee, or pressure on the central bank exerted externally that makes it act myopically.

As in the previous Chapter, my analysis is focused on qualitative effects and the importance of various channels, and not on empirical magnitudes. I expand the model of the Chapter 2 by adding quasi-hyperbolic discounting for the central bank in a context of discretionary monetary policy and where households have superficial external consumption habits. These habits, I showed, give rise to an overconsumption externality, and under discretion are associated with strong downward pressure on prices as well as increased volatility of all variables, and in particular nominal interest rate and inflation. I find that while the strength of the present bias is only relevant in the first two periods for the committing central bank, it is relevant in every period for the discretionary one. This makes the discretionary scenario more complex, and for this reason I choose to focus this Chapter on the case of a discretionary central bank with a present bias.

I discuss how allowing the discretionary central bank to be affected by the present bias when setting its monetary policy rule exposes the trade-off created by external consumption habits: curbing the overconsumption externality is done at the expense of creating disinflation today. With Rotemberg pricing, inflation has associated quadratic costs, and therefore creating rapidly falling prices comes at a great cost.

Containing the overconsumption externality means incurring costs today to the benefit of future welfare, and a central bank with no present bias is willing to do this because it values the future. As the present bias of the central bank grows, however, the central bank values the future less and less, and values the present relatively more, making it less willing to bear the high cost today. A central bank with a present bias prefers to create smaller inflation costs for itself, even though this creates a greater habit stock to be sustained in the future. Indeed I find that the present bias is linked to pressure on inflation that brings it closer to zero, motivated by the desire to minimise current inflation costs.

I find that a change in the strength of the present bias generates variations in all economic variables. When the present bias of the central bank becomes stronger, the central bank cuts the nominal interest rate, leading to inflation and an increase in output. When the present bias becomes weaker, the situation is mirrored: the central bank raises the nominal interest rate, which leads to deflation and a fall in output. A changing strength of the present bias, then, has a direct impact on the economy. On the other hand, I also find that the strength of the present bias has no qualitative and a very limited quantitative impact on how the central bank reacts to technology and markup shocks.

Similarly to Chapter 2, the model in this Chapter is also fully non-linear. As I mentioned in the previous Chapter, this is more appropriate when considering models where inflation is not zero in steady state, and where risk aversion might play an important role – which log-linearisation would simply erase.

Section 3.2 first summarises the relevant literature on monetary policy and consumption habits, and then discuss the foundation for the present bias in the behavioural literature as well as some of its applications to the macroeconomic literature. Section 3.3 presents the model: the individual choices of representative households and firms, which are then aggregated, and the problem faced by the central bank. I discuss the problem for committing and discretionary central banks separately:

in Subsection 3.3.5 I present the results for the committing central bank, and in the remainder of the Chapter I focus on the case of the discretionary central bank presented in Subsection 3.3.6. The results are presented in Section 3.4: first I study the simpler case of a deterministic strength of the present bias in Subsection 3.4.1, and then presents comparative statics and comparative dynamics in the case of a stochastic strength of the present bias in Subsection 3.4.2. Section 3.5 explores the source of the present bias, discussing different options and relating them to the literature. Finally, Section 3.6 concludes.

3.2 Literature Review

The first part of the literature review summarises the most relevant literature on monetary policy, with a focus on models that include consumption habits. The second part discusses the literature on the present bias.

3.2.1 Monetary Policy with Consumption Habits

It has become common for monetary policy models to include consumption habits. Consumption habits introduce a link between past and current consumption, and their inclusion in New Keynesian Dynamic Stochastic Equilibrium (DSGE) models influences their steady state as well as their short-run dynamics. Their microfoundations go back to Duesenberry (1949), building on psychological studies (Ouellette & Wood, 1998). Applications of consumption habits date back to the 1970s (see e.g. Ryder and Heal, 1973), gaining prominence in the 2000s.

Habit formation introduces endogenous persistence, which creates hump-shaped dynamics (Fuhrer, 2000). Consumption habits also add a backward-looking term in the Phillips curve, which is essential in generating sluggish adjustment to shocks (Ravn, Schmitt-Grohé, Uribe, & Uuskula, 2010).

Habits can be either internal (Fuhrer, 2000, Amato and Laubach, 2004, Christiano, Eichenbaum, and Evans, 2005, and Leith and Malley, 2005) or external (Smets and Wouters, 2007), depending on whether the household's consumption is contingent on his own past consumption or aggregate past consumption. Another distinction that can be drawn is between superficial and deep habits. Superficial habits are formed at the level of the overall consumption basket, whilst deep habits are at the level of individual goods (Ravn, Schmitt-Grohé, and Uribe, 2006, Ravn, Schmitt-Grohé, Uribe, and Uuskula, 2010, and Leith, Moldovan, and Rossi, 2015).

In line with Chapter 2, I choose to focus on superficial external consumption habits. At the aggregate level, there exists an externality associated with external habits, which introduces an additional challenge for monetary policy. Consumers cannot fully internalise the effect that their current consumption choices have on creating a habit stock for the future, and they end up overconsuming. This has important implications for optimal monetary policy: the usual desire to stabilise inflation is traded off against the new overconsumption externality (Leith, Moldovan, & Rossi, 2012).

A monetary policy aimed at stabilising inflation would not be able to curb the overconsumption that results from superficial external consumption habits. In the case of a central bank that conducts monetary policy under commitment, Leith, Moldovan, and Rossi (2012) show that external consumption habits force the central bank to respond less aggressively to shocks. The monetary authority instead creates higher inflation to counterbalance the effects of the externality and curb the overconsumption induced by the habits. In the case of a discretionary central bank, I showed in Chapter 2 that the external consumption habits give rise to a sizeable negative inflation bias, larger changes in the nominal interest rate, and greater volatility in the economy.

3.2.2 Present Bias

A hyperbolic discount function, by assigning higher discount rates over shorter horizons and lower discount rates over longer horizons, "sets up a conflict between today's preferences, and the preferences that will be held in the future" (Laibson, 1997; p. 445). Hyperbolic discount functions therefore can induce dynamically inconsistent preferences.

A common way of modelling this in a discrete-time setting is through a quasi-hyperbolic, or quasi-geometric, discount function. Quasi-hyperbolic discounting relies on two parameters: β, which as usual captures exponential time discounting, and δ, which captures the present bias. Where the former applies to all future dates and is used to obtain the present value of future reward, the latter draws the line between present and future.

At each date t, the agent values the stream of future instantaneous utility as

$$U_t = u_t + \delta \sum_{\tau=1}^{\infty} \beta^{t+\tau} u_{t+\tau}$$

where the time discount factor β and the strength of the present bias δ take values in the interval $[0,1]$. Specifically, $\delta = 1$ is a case of no present bias, and lower values of δ are associated to a stronger present bias.

Decreasing values of δ make the present relatively more important for decision-making. With a strength of the present bias δ smaller than 1, the agent undervalues future rewards (and overvalues future costs) to a degree δ. Take, for example, 3 periods, so that we have current utilities u_1, u_2, and u_3. From the perspective of the first period, overall utility is $U_1 = u_1 + \delta\beta u_2 + \delta\beta^2 u_3$. However, when in the second period utility is $U_2 = u_2 + \delta\beta u_3$. It is straightforward to see how this bias towards the present and against the future can give rise to preference reversals.

Quasi-hyperbolic discounting, with its present bias, can be used to model myopic behaviour. The parameter δ can be interpreted as the inverse of the degree of myopia, or blindness to the future. In this sense, a quasi-hyperbolically discounting agent underestimates future changes, and therefore takes sub-optimal decisions (Phelps and Pollak, 1968, and Akerlof, 1991).

Whilst hyperbolic and quasi-hyperbolic discounting have become important features of behavioural economic (Wilkinson & Klaes, 2017), their application to the macroeconomic context is still relatively limited. Macroeconomic models that include quasi-hyperbolic discounting have mostly focussed on the Neoclassical growth model, highlighting how the present bias introduces the possibility of multiple equilibria arising because of strategic interaction between the household and its future self (Krusell and Smith, 2003, Maliar and Maliar, 2005, 2006a and 2006b). Krusell, Kuruscu, and Smith (2002) show that when households have quasi-hyperbolic discounting the solution to the planner's problem delivers lower welfare compared to competitive equilibrium.

Graham and Snower (2013) add quasi-hyperbolic discounting to a sticky-wage New Keynesian model, and find that quasi-hyperbolic discounting brings households to prefer positive inflation to zero inflation. This is because positive inflation erodes the real wage over time, leading households to work relatively less today and relatively more in the future, which they discount quasi-hyperbolically and therefore care relatively less about.

Dennis and Kirsanov (2020) study how quasi quasi-hyperbolic discounting affects how the central bank conducts monetary policy by adding it to a New Keynesian business cycle model. They find that when households discount the future quasi-hyperbolically, it is desirable for the discretionary central bank to do the same. In fact, when the central bank discounts the future by more than households do the average inflation is lowered and becomes closer to the Ramsey optimal rate of zero, thus raising household welfare.

3.3 The Model

The model is a New Keynesian Dynamic Stochastic General Equilibrium model in discrete time with superficial external habits in consumption, thus building on the model from Chapter 2. The model in this Chapter has two main differences from the one in Chapter 2. First, the elasticity of substitution between intermediate goods is now stochastic, which opens the model to the possibility of markup shocks that affect the profit-optimisation problem of the intermediate-good producers. There are therefore three distinct sources of volatility in the model: technology innovations, changes in the strength of the present bias, and cost mark-up shocks.

Secondly, and most importantly, the central bank now has quasi-hyperbolic discounting, which depending on the strength of the present bias can affect its optimal interest rate decision. I present and describe the central bank's problem in Sections 3.3.6 and 3.3.5.

It should be noted that it is only the central bank that has quasi-hyperbolic discounting, and the discounting behaviour of the private sector is unchanged. Sections 3.3.1 through 3.3.4 outline the model. As before, households consume and supply labour to intermediate-good producing firms; the goods these firms produce are then assembled into final goods by retail firms, employing no labour. As intermediate goods are used in the production of final goods, only final goods are consumed. The final-good market is perfectly competitive, whilst the intermediate-good one is monopolistically competitive. Households can transfer wealth across periods (i.e. borrow/save) through a risk-free, one-period nominal bond that is traded among households. The bond is in zero net supply. The return on the bond is given by the nominal interest rate, which is set by the central bank. Finally, as before, intermediate-good firms face a Rotemberg (1982) rigidity in setting prices.

3.3.1 Households

The household's habit-adjusted consumption is given by $c_t - \theta \cdot C_{t-1}$, where c_t is current individual consumption, C_{t-1} is last period's aggregate consumption, and $\theta \in [0,1)$ is the degree of habit. Similar functional forms for external habits can be found, for example, in Ravn, Schmitt-Grohé, Uribe, and Uuskula (2010) and Leith, Moldovan, and Rossi (2012). Households are not conscious of the impact that their consumption choices have on aggregate consumption. They do not internalise their contribution to the level of aggregate consumption, and the consequences that contribution has in terms of a habit to be sustained. External consumption habits give rise to an externality whereby households overconsume, as discussed in Section 3.2.

Households choose consumption, labour, and the quantity of bonds: $\{c_t, h_t, b_t\}_{t=0}^{\infty}$. They seek to maximise the expected discounted sum of utilities

$$E_0 \sum_{t=0}^{\infty} \beta^t \cdot \left[\frac{(c_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-h_t)^{1-\psi} - 1}{1-\psi} \right], \tag{3.1}$$

subject to the flow budget constraint

$$c_t + \frac{b_t}{P_t} = w_t \cdot h_t + \frac{b_{t-1}}{P_t} \cdot (1 + R_{t-1}) + D_t. \tag{3.2}$$

P_t is the price of the final good at time t, w_t is the real wage, R_{t-1} is the interest rate earned on bonds bought at time t-1, and D_t is the dividends earned from households' ownership of the firms. $\beta \in (0,1)$ is the time discount factor, σ and ψ are the time substitutability of habit-adjusted consumption and leisure respectively, $\sigma, \psi > 0$, and χ is the weight on utility from leisure, $\chi > 0$.

Households get their income from labour, bonds, and dividends, and spend it on consumption and new bonds. The Lagrangian is

$$\begin{aligned}\mathscr{L}_t = E_0 \sum_{t=0}^{\infty} \beta^t \cdot \Bigg[& \frac{(c_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-h_t)^{1-\psi} - 1}{1-\psi} \\ & - \mu_t \cdot \left[c_t + \frac{b_t}{P_t} - w_t \cdot h_t - \frac{b_{t-1}}{P_t} \cdot (1 + R_{t-1}) - D_t \right] \Bigg],\end{aligned} \tag{3.3}$$

with first order conditions

$$\frac{\partial \mathscr{L}_t}{\partial c_t}: \quad (c_t - \theta \cdot C_{t-1})^{-\sigma} - \mu_t = 0, \tag{3.4}$$

$$\frac{\partial \mathscr{L}_t}{\partial h_t}: \quad -\chi \cdot (1-h_t)^{-\psi} + \mu_t \cdot w_t = 0, \tag{3.5}$$

$$\frac{\partial \mathscr{L}_t}{\partial b_t}: \quad -\mu_t \cdot \frac{1}{P_t} + \beta \cdot E_t \left[\mu_{t+1} \cdot \frac{1+R_t}{P_{t+1}} \right] = 0. \tag{3.6}$$

Substituting the Lagrange multiplier μ_t out, combining equations (3.4) and (3.5), rearranging, and defining inflation as $\pi_t \equiv \frac{P_t}{P_{t-1}} - 1$ we get

$$w_t = \chi \cdot \frac{(1-h_t)^{-\psi}}{(c_t - \theta \cdot C_{t-1})^{-\sigma}}, \tag{3.7}$$

and

$$(c_t - \theta \cdot C_{t-1})^{-\sigma} = \beta \cdot E_t \left[\frac{1+R_t}{1+\pi_{t+1}} \cdot (c_{t+1} - \theta \cdot C_t)^{-\sigma} \right]. \tag{3.8}$$

By equation (3.7) the representative household chooses the optimal amount of labour to supply to equate the marginal benefit of labour to the marginal cost. If the household works one unit more then they earn real wage w_t, the marginal benefit. The disutility from working more detracts from overall utility; by working (and earning) more the household is however able to afford more consumption, which adds to overall utility. The ratio between marginal disutility from labour and marginal utility from extra consumption, weighted by χ the relative weight of leisure, is the marginal cost of labour in terms of final goods.

Equation (3.8) compares the expected marginal costs and marginal benefits of the inter-temporal dynamic consumption choice problem, and is referred to as the consumption Euler equation. The left-hand side is the marginal benefit of current consumption, while the right-hand side is the discounted marginal benefit of future consumption in real terms. In equilibrium these two equations must be respected because the household will be choosing optimal labour and consumption. This means that they will choose a level of labour where marginal costs of labour are equal its marginal benefits; and a level of consumption that is inter-temporally optimal, so they have no desire to consume more (less) now in exchange for consuming less (more) later. Note that the consumption externality is present in both conditions: the representative household is aware that the consumption habit needs to be sustained. What households fail to internalise is how their own consumption choice affects aggregate consumption and hence the consumption habit.

3.3.2 Final-Good Producers

Final good producers operate in a perfectly competitive market. The final good firm chooses intermediate inputs Y_{jt} to maximise profits (distributed to households as dividends)

$$P_t \cdot Y_t - \int_0^1 P_{jt} \cdot Y_{jt} dj, \tag{3.9}$$

given the production technology

$$Y_t = \left(\int_0^1 Y_{jt}^{\frac{\varepsilon_t - 1}{\varepsilon_t}} dj \right)^{\frac{\varepsilon_t}{\varepsilon_t - 1}}, \tag{3.10}$$

where $\varepsilon_t > 1$ is the elasticity of substitution between any two intermediate inputs, Y_t denotes final output, and $j \in [0,1]$ refers to the indexing of each particular intermediate good, with the assumption that each good is only produced by a single firm. Final good producers do not employ any labour: their production process can be thought of as a reassembling of intermediate goods into final goods.

Substituting the production equation into the maximisation problem we get

$$\max_{Y_{jt}} \left[P_t \cdot \left(\int_0^1 Y_{jt}^{\frac{\varepsilon_t - 1}{\varepsilon_t}} dj \right)^{\frac{\varepsilon_t}{\varepsilon_t - 1}} - \int_0^1 P_{jt} \cdot Y_{jt} dj \right]. \tag{3.11}$$

Taking the derivative of equation (3.11) with respect to Y_{jt} gives the equation for the amount of intermediate goods final-good producers demand in order to maximise their profits,

$$P_t \left(\int_0^1 Y_{jt}^{\frac{\varepsilon_t - 1}{\varepsilon_t}} dj \right)^{\frac{1}{\varepsilon_t - 1}} \cdot Y_{jt}^{-\frac{1}{\varepsilon_t}} - P_{jt} = 0,$$

$$\Leftrightarrow P_t \cdot Y_t^{\frac{1}{\varepsilon_t}} \cdot Y_{jt}^{-\frac{1}{\varepsilon_t}} - P_{jt} = 0,$$

$$\Leftrightarrow \left(\frac{Y_{jt}}{Y_t} \right)^{-\frac{1}{\varepsilon_t}} - \frac{P_{jt}}{P_t} = 0,$$

which gives the demand equation for inputs

$$Y_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\varepsilon_t} \cdot Y_t, \quad \forall j. \tag{3.12}$$

Intermediate goods are demanded based on their price relative to the one of the final good. Substitute the demand equation (3.12) into the production function to get

$$Y_t = \left[\int_0^1 \left(\left(\frac{P_{jt}}{P_t} \right)^{-\varepsilon_t} \cdot Y_t \right)^{\frac{\varepsilon_t - 1}{\varepsilon_t}} dj \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}},$$

$$= \left[\int_0^1 \left(\frac{P_{jt}}{P_t} \right)^{1-\varepsilon_t} \cdot Y_t^{\frac{\varepsilon_t - 1}{\varepsilon_t}} dj \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}},$$

$$= Y_t \cdot \left[\int_0^1 \left(\frac{P_{jt}}{P_t} \right)^{1-\varepsilon_t} dj \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}},$$

which implies

$$\left[\int_0^1 \left(\frac{P_{jt}}{P_t} \right)^{1-\varepsilon_t} dj \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}} = 1. \tag{3.13}$$

It follows that profits from the final firm are zero, and that

$$P_t = \left[\int_0^1 P_{jt}^{1-\varepsilon_t} dj \right]^{\frac{1}{1-\varepsilon_t}}, \tag{3.14}$$

so that the prices of the intermediate good are aggregated into the price of the final good according to the elasticity of substitution between intermediate goods. Note that the consumption habit does not directly affect the supply of final goods, only the demand. This is because the final producer's problem is static.

3.3.3 Intermediate-Good Producers

To solve the intermediate-good producer's problem and characterise their behaviour, we first find the amount of labour that minimises production costs. This gives a demand for labour and an equation for real marginal costs. We then set up the problem of inter-temporal profit (i.e. value of the firm) maximisation.

The j'th intermediate-good producer chooses h_{jt} to minimise real costs

$$w_t \cdot h_{jt}, \tag{3.15}$$

subject to the production function

$$Y_{jt} = A_t \cdot h_{jt}. \tag{3.16}$$

Labour is the only factor of production employed by intermediate-good producers. A_t is a time-varying exogenous technology factor, and technology follows the AR(1) process $\ln A_{t+1} = \rho_A \cdot \ln A_t + \eta^A_{t+1}$, with $\eta^A_t \sim i.i.d.N(0,\sigma^2_A)$. The Lagrangian is

$$\mathscr{L}_{jt} = w_t \cdot h_{jt} + \omega_{jt} \cdot [Y_{jt} - A_t \cdot h_{jt}], \tag{3.17}$$

with first order conditions

$$\frac{\partial \mathscr{L}_{jt}}{\partial h_{jt}} : \quad w_t - \omega_{jt} \cdot A_t = 0, \tag{3.18}$$

$$\frac{\partial \mathscr{L}_{jt}}{\partial \omega_{jt}} : \quad Y_{jt} - A_t \cdot h_{jt} = 0, \tag{3.19}$$

which give the demand for labour

$$h_{jt} = \frac{Y_{jt}}{A_t}, \tag{3.20}$$

and real marginal costs

$$\omega_{jt} = \frac{w_t}{A_t}. \tag{3.21}$$

Intermediate-good producers have market power and face quadratic costs when changing prices (Rotemberg, 1982), with parameter $\phi > 0$ measuring price adjustment costs. Since intermediate-good producers are symmetrical in their costs and production, the prices they set optimally will also be symmetrical in equilibrium. Specifically, they choose P_{jt} in order to maximise

$$V_j = E_0 \sum_{t=0}^{\infty} \beta^t \cdot \frac{\mu_t}{\mu_0} \cdot \left[\left(\frac{P_{jt}}{P_t} - \omega_t \right) \cdot Y_{jt} - \frac{\phi}{2} \cdot \left(\frac{P_{jt}}{P_{jt-1}} - 1 \right)^2 \cdot Y_{jt} \right], \tag{3.22}$$

subject to the demand for inputs as given by equation (3.12). Substituting the constraint (3.12) into the maximisation problem, letting $p_t \equiv \frac{P_{jt}}{P_t}$, and using the definition $1+\pi_t \equiv \frac{P_t}{P_{t-1}}$ we obtain

$$V_j = E_0 \sum_{t=0}^{\infty} \beta^t \cdot \frac{\mu_t}{\mu_0} \cdot \left[(p_t - \omega_t) \cdot {p_t}^{-\varepsilon_t} \cdot Y_t - \frac{\phi}{2} \cdot \left(\frac{p_t \cdot (1+\pi_t)}{p_{t-1}} - 1 \right)^2 \cdot {p_t}^{-\varepsilon_t} \cdot Y_t \right]. \tag{3.23}$$

All firms choose the same optimal relative price, as they face the same real marginal costs and the same price adjustment costs, so in equilibrium it is true that $P_{jt} = P_t$ as we are choosing to look at a symmetric equilibrium. Taking the derivative with respect to p_t and simplifying we get the New Keynesian Phillips Curve (NKPC),

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon_t}{2} \cdot {\pi_t}^2 = \frac{1-\varepsilon_t}{\phi} + \frac{\varepsilon_t}{\phi} \cdot \omega_t + \beta \cdot E_t \left[\frac{c_{t+1} - \theta \cdot C_t}{c_t - \theta \cdot C_{t-1}} \cdot \frac{Y_{t+1}}{Y_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right], \tag{3.24}$$

which gives the relationship between inflation and real marginal costs. Inflation is positively related to real marginal costs and expectations of future inflation. It is also positively related to future expected marginal utility from consumption and output, but negatively related to their current realisations.

In this framework, the elasticity of substitution between goods ε_t captures the degree of competition among intermediate-good producing firms. A rise in this elasticity implies that goods in the economy are relatively closer substitutes for each other, indicating a higher level of competition between firms. This leads to a lower mark-up and to lower profits.

I introduce the possibility of a cost-push or markup shock which affects the elasticity of substitution between intermediate goods. This is modelled as

$$\ln \varepsilon_{t+1} = (1-\rho_\varepsilon) \cdot \ln \overline{\varepsilon} + \rho_\varepsilon \cdot \ln \varepsilon_t + \eta^\varepsilon_{t+1}, \tag{3.25}$$

with $\eta^\varepsilon_t \sim i.i.d.N(0, \sigma^2_\varepsilon)$.

A positive markup shock, i.e. a negative shock to ε_{t+1}, gives the firm more market power, which leads to an increase in the output price and a reduction in the quantity supplied. When markups are persistent, the reduction in future output leads to a persistent drop in the amount of labour the firm demands.

3.3.4 Aggregation

Aggregating across households gives the equation for labour-leisure choice (or labour supply)

$$w_t = \chi \cdot \frac{(1-H_t)^{-\psi}}{(C_t - \theta \cdot C_{t-1})^{-\sigma}}, \tag{3.26}$$

and the Euler equation for consumption

$$(C_t - \theta \cdot C_{t-1})^{-\sigma} = \beta \cdot E_t \left[\frac{1+R_t}{1+\pi_{t+1}} \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma} \right]. \tag{3.27}$$

Given that intermediate-good firms are have the same cost-structure and set the same prices, in equilibrium real marginal costs are homogeneous across such firms

$$\omega_t = \frac{w_t}{A_t}, \tag{3.28}$$

along with the already mentioned NKPC

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon_t}{2} \cdot \pi_t^2 = \frac{1-\varepsilon_t}{\phi} + \frac{\varepsilon_t}{\phi} \cdot \omega_t + \beta \cdot E_t \left[\left(\frac{C_{t+1} - \theta \cdot C_t}{C_t - \theta \cdot C_{t-1}} \right)^{-\sigma} \cdot \frac{Y_{t+1}}{Y_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1}) \right]. \tag{3.29}$$

The NKPC shows that consumption habit affects marginal costs through its effect on labour supply and the real wage.

Furthermore, we have the aggregate production function

$$Y_t = A_t \cdot H_t, \tag{3.30}$$

and combining the household budget constraint (3.2) with the definition of profits (3.9) we obtain the aggregate resource constraint

$$C_t = \left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot Y_t. \tag{3.31}$$

Because of the costs associated with inflation some of the goods that could otherwise be consumed are instead wasted by the price-adjustment process. As mentioned before, technology follows the AR(1) process

$$\ln A_{t+1} = \rho_A \cdot \ln A_t + \eta_{t+1}^A, \tag{3.32}$$

with $\eta_t^A \sim i.i.d.N(0, \sigma_A^2)$. The elasticity of substitution between intermediate goods also follows an AR(1) process, given by

$$\ln \varepsilon_{t+1} = (1-\rho_\varepsilon) \cdot \ln \overline{\varepsilon} + \rho_\varepsilon \cdot \ln \varepsilon_t + \eta_{t+1}^\varepsilon, \tag{3.33}$$

with $\eta_t^\varepsilon \sim i.i.d.N(0, \sigma_\varepsilon^2)$.

3.3.5 Committing Central Bank

The central bank that sets monetary policy with commitment will select the policy path that maximises the infinite discounted stream of utility, announce its policy, and commit to it. As the interest rate can be determined residually based on optimal consumption, labour and inflation paths, the central bank effectively chooses $\{C_t, H_t, \pi_t\}_{t=0}^{\infty}$ to maximise welfare

$$\frac{(C_0 - \theta \cdot C_{-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-H_0)^{1-\varphi} - 1}{1-\varphi} + E_0\left[\delta_0 \cdot \sum_{t=1}^{\infty} \beta^t \left[\frac{(C_t - \theta \cdot C_{t-1})^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1-H_t)^{1-\varphi} - 1}{1-\varphi}\right]\right] \tag{3.34}$$

, subject to

$$C_t = \left(1 - \frac{\phi}{2} \cdot \pi_t^2\right) \cdot A_t \cdot H_t, \tag{3.35}$$

$$\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon_t}{2} \cdot \pi_t^2 = \frac{1-\varepsilon_t}{\phi} + \frac{\varepsilon_t}{\phi} \cdot \chi \cdot \frac{(1-H_t)^{-\psi}}{(C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t} + \beta \cdot E_t\left[\frac{(C_{t+1} - \theta \cdot C_t)^{-\sigma} \cdot A_{t+1} \cdot H_{t+1}}{(C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot A_t \cdot H_t} \cdot \pi_{t+1} \cdot (1+\pi_{t+1})\right]. \tag{3.36}$$

The welfare maximised by the central bank under commitment is now split into two terms: a first term relating to current welfare, and a second term for future welfare that is weighted by the strength of the present bias δ_t. The constraints are unchanged, as the behaviour of the private sector is not directly affected by δ_t.

The strength of the present bias δ_t takes values between 0 and 1, with $\delta_t = 1$ being the case of no present bias and with lower values of δ_t associated to stronger present bias. I define the case with $\delta_t = 1 \forall t$ as the central bank with no present bias.

I model the present bias parameter δ_t to follow the AR(1) process

$$\ln \delta_{t+1} = (1-\rho_\delta) \cdot \ln \overline{\delta} + \rho_\delta \cdot \ln \delta_t + \eta_{t+1}^{\delta}, \tag{3.37}$$

with the constant strength of the present bias $\overline{\delta} \in [0,1]$, the persistence of present bias changes $\rho_\delta \in [0,1]$, and the present bias shock $\eta_t^{\delta} \sim i.i.d. N(0, \sigma_\xi^2)$.

The Lagrangian is

$$
\begin{aligned}
\mathscr{L}_0 = {} & \frac{(C_0-\theta\cdot C_{-1})^{1-\sigma}-1}{1-\sigma}+\chi\cdot\frac{(1-H_0)^{1-\varphi}-1}{1-\varphi} \\
& +\gamma_0\cdot\left[\left(1-\frac{\phi}{2}\cdot\pi_0^2\right)\cdot A_0\cdot H_0-C_0\right] \\
& -\lambda_0\cdot\left[\left(\pi_0\cdot(1+\pi_0)+\frac{1-\varepsilon_0}{2}\cdot\pi_0^2-\frac{1-\varepsilon_0}{\phi}\right)\cdot(C_0-\theta\cdot C_{-1})^{-\sigma}\cdot A_0\cdot H_0\right. \\
& \left.-\frac{\varepsilon_0}{\phi}\cdot\chi\cdot(1-H_0)^{-\varphi}\cdot H_0-\beta\cdot E_0\left[(C_1-\theta\cdot C_0)^{-\sigma}\cdot A_1\cdot H_1\cdot\pi_1\cdot(1+\pi_1)\right]\right] \\
& +\delta_0\cdot E_0\left[\sum_{t=1}^{\infty}\beta^t\cdot\left[\frac{(C_t-\theta\cdot C_{t-1})^{1-\sigma}-1}{1-\sigma}+\chi\cdot\frac{(1-H_t)^{1-\varphi}-1}{1-\varphi}\right.\right. \\
& +\gamma_t\cdot\left[\left(1-\frac{\phi}{2}\cdot\pi_t^2\right)\cdot A_t\cdot H_t-C_t\right] \\
& -\lambda_t\cdot\left[\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot H_t\right. \\
& \left.\left.\left.-\frac{\varepsilon_t}{\phi}\cdot\chi\cdot(1-H_t)^{-\varphi}\cdot H_t-\beta\cdot(C_{t+1}-\theta\cdot C_t)^{-\sigma}\cdot A_{t+1}\cdot H_{t+1}\cdot\pi_{t+1}\cdot(1+\pi_{t+1})\right]\right]\right].
\end{aligned}
\tag{3.38}
$$

The first order conditions at time $t=0$ are

$$
\begin{aligned}
\frac{\partial\mathscr{L}_0}{\partial C_0}: \ & (C_0-\theta\cdot C_{-1})^{-\sigma}-\gamma_0 \\
& +\sigma\cdot\left(\pi_0\cdot(1+\pi_0)+\frac{1-\varepsilon_0}{2}\cdot\pi_0^2-\frac{1-\varepsilon_0}{\phi}\right)\cdot(C_0-\theta\cdot C_{-1})^{-\sigma-1}\cdot A_0\cdot H_0\cdot\lambda_0 \\
& +\sigma\cdot\theta\cdot\beta\cdot E_0\left[(C_1-\theta\cdot C_0)^{-\sigma-1}\cdot A_1\cdot H_1\cdot\pi_1\cdot(1+\pi_1)\right]\cdot\lambda_0 \\
& -\delta_0\cdot\theta\cdot\beta\cdot E_0\left[(C_1-\theta\cdot C_0)^{-\sigma}\right] \\
& -\delta_0\cdot\sigma\cdot\theta\cdot\beta\cdot E_0\left[\left(\pi_1\cdot(1+\pi_1)+\frac{1-\varepsilon_1}{2}\cdot\pi_1^2-\frac{1-\varepsilon_1}{\phi}\right)\right. \\
& \left.\cdot(C_1-\theta\cdot C_0)^{-\sigma-1}\cdot A_1\cdot H_1\cdot\lambda_1\right]=0.
\end{aligned}
\tag{3.39}
$$

$$
\begin{aligned}
\frac{\partial\mathscr{L}_0}{\partial H_0}: \ & -\chi\cdot(1-H_0)^{-\varphi}+\gamma_0\cdot\left(1-\frac{\phi}{2}\pi_0^2\right)\cdot A_0 \\
& -\left(\pi_0\cdot(1+\pi_0)+\frac{1-\varepsilon_0}{2}\cdot\pi_0^2-\frac{1-\varepsilon_0}{\phi}\right)\cdot(C_0-\theta C_{-1})^{-\sigma}\cdot A_0\cdot\lambda_0 \\
& +\frac{\varepsilon_0}{\phi}\cdot\chi\cdot\left[\varphi\cdot(1-H_0)^{-\varphi-1}\cdot H_0+(1-H_t)^{-\varphi}\right]\cdot\lambda_0=0.
\end{aligned}
\tag{3.40}
$$

$$
\begin{aligned}
\frac{\partial\mathscr{L}_0}{\partial\pi_0}: \ & -\gamma_0\cdot\phi\cdot\pi_0 \\
& -\left[1+2\cdot\pi_0+(1-\varepsilon_0)\cdot\pi_0\right]\cdot(C_0-\theta\cdot C_{-1})^{-\sigma}\cdot\lambda_0=0.
\end{aligned}
\tag{3.41}
$$

The first order conditions at time $t = 1$ are

$$\begin{aligned}
\frac{\partial \mathscr{L}_0}{\partial C_1}:\ & -\frac{\sigma}{\delta_0}\cdot E_0\big[(C_1-\theta\cdot C_0)^{-\sigma-1}\cdot A_1\cdot H_1\cdot \pi_1\cdot(1+\pi_1)\big]\cdot\lambda_0 \\
& + E_0\Big[(C_1-\theta\cdot C_0)^{-\sigma}-\gamma_1 \\
& + \sigma\cdot\left(\pi_1\cdot(1+\pi_1)+\frac{1-\varepsilon_1}{2}\cdot\pi_1^2-\frac{1-\varepsilon_1}{\phi}\right)\cdot(C_1-\theta\cdot C_0)^{-\sigma-1}\cdot A_1\cdot H_1\cdot\lambda_1 \\
& + \sigma\cdot\theta\cdot\beta\cdot(C_2-\theta\cdot C_1)^{-\sigma-1}\cdot A_2\cdot H_2\cdot\pi_2\cdot(1+\pi_2)\cdot\lambda_1\Big] \\
& + \beta\cdot E_0\Big[-\theta\cdot(C_2-\theta\cdot C_1)^{-\sigma} \\
& + \sigma\cdot\theta\cdot\beta\cdot(C_2-\theta\cdot C_1)^{-\sigma-1}\cdot A_2\cdot H_2\cdot\pi_2\cdot(1+\pi_2)\cdot\lambda_2\Big]=0.
\end{aligned} \tag{3.42}$$

$$\begin{aligned}
\frac{\partial \mathscr{L}_0}{\partial H_1}:\ & \frac{1}{\delta_t}\cdot E_0\big[(C_1-\theta\cdot C_0)^{-\sigma}\cdot A_1\cdot\pi_1\cdot(1+\pi_1)\big]\cdot\lambda_0 \\
& - E_0\Big[\chi\cdot(1-H_1)^{-\varphi}+\gamma_1\cdot\Big(1-\frac{\phi}{2}\pi_1^2\Big)\cdot A_1 \\
& - \Big(\pi_1\cdot(1+\pi_1)+\frac{1-\varepsilon_1}{2}\cdot\pi_1^2-\frac{1-\varepsilon_1}{\phi}\Big)\cdot(C_1-\theta C_0)^{-\sigma}\cdot A_1\cdot\lambda_1 \\
& + \frac{\varepsilon_1}{\phi}\cdot\chi\cdot\big[\varphi\cdot(1-H_1)^{-\varphi-1}\cdot H_1+(1-H_1)^{-\varphi}\big]\cdot\lambda_1\Big]=0.
\end{aligned} \tag{3.43}$$

$$\begin{aligned}
\frac{\partial \mathscr{L}_0}{\partial \pi_1}:\ & \frac{1}{\delta_1}\cdot(C_1-\theta\cdot C_0)^{-\sigma}\cdot(1+2\cdot\pi_1)\cdot\lambda_0-\gamma_1\cdot\phi\cdot\pi_1 \\
& - \big[1+2\cdot\pi_1+(1-\varepsilon_1)\cdot\pi_1\big]\cdot(C_1-\theta\cdot C_0)^{-\sigma}\cdot\lambda_1=0.
\end{aligned} \tag{3.44}$$

Finally, the first order conditions at time $t = 2, ..., \infty$ are

$$\begin{aligned}
\frac{\partial \mathscr{L}_0}{\partial C_t}:\ & E_0\Big[(C_t-\theta\cdot C_{t-1})^{-\sigma}-\gamma_t \\
& - \sigma\cdot(C_t-\theta C_{t-1})^{-\sigma-1}\cdot A_t\cdot H_t\cdot\pi_t\cdot(1+\pi_t)\cdot\lambda_{t-1} \\
& + \sigma\cdot\Big(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\Big)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma-1}\cdot A_t\cdot H_t\cdot\lambda_t \\
& - \sigma\cdot\theta\cdot\beta\cdot(C_{t+1}-\theta\cdot C_t)^{-\sigma-1}\cdot A_{t+1}\cdot H_{t+1}\cdot\pi_{t+1}\cdot(1+\pi_{t+1})\cdot\lambda_t\Big]=0.
\end{aligned} \tag{3.45}$$

$$\begin{aligned}
\frac{\partial \mathscr{L}_0}{\partial H_t}:\ & E_0\Big[(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot\pi_t\cdot(1+\pi_t)\cdot\lambda_{t-1}-\chi\cdot(1-H_t)^{-\varphi}+\gamma_t\cdot\Big(1-\frac{\phi}{2}\pi_t^2\Big)\cdot A_t \\
& - \Big(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\Big)\cdot(C_t-\theta C_{t-1})^{-\sigma}\cdot A_t\cdot\lambda_t \\
& + \frac{\varepsilon_t}{\phi}\cdot\chi\cdot\big[\varphi\cdot(1-H_t)^{-\varphi-1}\cdot H_t+(1-H_t)^{-\varphi}\big]\cdot\lambda_t\Big]=0.
\end{aligned} \tag{3.46}$$

$$\begin{aligned}
\frac{\partial \mathscr{L}_t}{\partial \pi_t}:\ & E_0\Big[(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot(1+2\cdot\pi_t)\cdot\lambda_{t-1}-\gamma_t\cdot\phi\cdot\pi_t \\
& - \big[1+2\cdot\pi_t+(1-\varepsilon_t)\cdot\pi_t\big]\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot\lambda_t\Big]=0.
\end{aligned} \tag{3.47}$$

The first order conditions give costs and benefits of a marginal increase in consumption, labour and inflation, respectively. In equilibrium, marginal costs should equal marginal benefits. Extra consumption brings marginal utility and relaxes the resource constraint, but it makes the New-Keynesian Phillips Curve (NKPC), i.e. equation (3.36), a stricter constraint. Extra labour gives marginal disutility, tightens the resource constraint but relaxes the NKPC. Extra inflation makes the resource constraint more binding, and the NKPC less binding.

Current optimal policy is linked to past policy through the multiplier λ_{t-1}, which essentially binds the central bank to keep its promises. The fact that $\lambda_{-1} = 0$ means that the first order conditions differ from period 0 to period 1-onwards; this implies that the central bank will commit to a optimal policy in period 0 and then, having its constraints changed in the following period, will be tempted to "cheat" on its promises. The Lagrange multiplier reflects indeed the time inconsistency of commitment.

Furthermore, as the first order conditions outlined above highlight, the presence of the strength of present bias δ_t adds a further source of time inconsistency. The first order conditions at time $t = 0$ also differ from the first order conditions at time $t = 1$ through the parameter δ_0. Specifically, comparing the first order conditions in consumption (3.39) and (3.42) we can see that when the central bank has a present bias (i.e. $\delta_0 < 1$), it gives a smaller weight to the future at time $t = 0$ and a larger weight to the past at time $t = 1$. The present bias drives the central bank to overvalue the past and undervalue the future only in the first two periods: from the period $t = 2$ onward, the parameter δ_0 no longer appears in the first order conditions.

A central bank with a present bias conducting monetary policy under commitment has two interacting sources of time inconsistency: the common one relating to expectations, and a novel one driven by the present bias. As a result, the first order conditions of this central bank are different not only in period $t = 0$, but also in period $t = 1$. From period $t = 2$ onward, however, the first order conditions are the same as those of a central bank with no present bias conducting policy under commitment.

Result 3. 1 *The strength of the present bias of a committing central bank is only relevant in the first two periods.*

As discussed in Chapter 2, the central bank conducting monetary policy under commitment needs to be aware of the repercussions its current choices have on future policy-making, through aggregate consumption. A current marginal increase in consumption comes at the extra cost of creating a higher habit stock to be sustained in the future, a fact that policy makers have to take into account when formulating monetary policy.

This is still the case when the central bank quasi-hyperbolically discounts the future. However, a central bank with a stronger present bias and lower value for δ_t gives a lower weight to the cost of creating a consumption habit stock to be sustained in the future, as equation (3.39) shows. When setting the optimal interest rate the central bank also with a present bias gives more weight to the resource constraint set by past allocation of resources. This is because a central bank values the present increasingly more, and past and future increasingly less, as its present bias becomes stronger.

A central bank conducting monetary policy under commitment, then, does not experience the present bias in a fundamentally different way compared to a discretionary central bank. However, unlike a discretionary central bank, a committing one sets the policy rule only once, in the very first period, and then applies this rule every period. The committing central bank makes its policy choice only once, and because of this reason its strength of the present bias is relevant only in the first two periods.

In the case of a discretionary central bank, on the other hand, the strength of the present bias is relevant in every period. This makes the discretionary scenario more complex and worth exploring in more depth, and for this reason I focus the rest of this Chapter on the case of a discretionary central bank with a present bias.

3.3.6 Discretionary Central Bank

The discretionary central bank does not have the ability to credibly commit to optimal policy, and therefore cannot today set policy for future periods. When deciding on current monetary policy the discretionary central bank knows it will have to make a similar decision in every subsequent period, and takes that into account.

The central bank maximises current welfare (i.e. the habit-adjusted utility) subject to the behaviour of the private sector. The central bank has a present bias, captured by the time-varying parameter δ_t. δ_t follows the process outlined in equation (3.37).

The following equation is the Bellman equation which summarises the discretionary central bank's optimal policy problem:

$$V(C_{t-1},A_t,\delta_t,\varepsilon_t) = \max_{\{C_t,H_t,\pi_t\}} E_t\Bigg[\frac{(C_t-\theta\cdot C_{t-1})^{1-\sigma}-1}{1-\sigma}+\chi\cdot\frac{(1-H_t)^{1-\psi}-1}{1-\psi}$$
$$+\delta_t\cdot\beta\cdot W(C_t,A_{t+1},\delta_{t+1},\varepsilon_{t+1})+\gamma_t\cdot\left[\left(1-\frac{\phi}{2}\cdot\pi_t^2\right)\cdot A_t\cdot H_t-C_t\right]$$
$$-\lambda_t\cdot\left[\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot H_t\right.$$
$$\left.-\frac{\varepsilon_t}{\phi}\cdot\chi\cdot(1-H_t)^{-\psi}\cdot H_t-\beta\cdot G(C_t,A_{t+1},\delta_{t+1},\varepsilon_{t+1})\right]\Bigg], \tag{3.48}$$

and

$$W(C_{t-1},A_t,\delta_t,\varepsilon_t) = E_t\Bigg[\frac{(C_t-\theta\cdot C_{t-1})^{1-\sigma}-1}{1-\sigma}+\chi\cdot\frac{(1-H_t)^{1-\psi}-1}{1-\psi}$$
$$+\beta\cdot W(C_t,A_{t+1},\delta_{t+1},\varepsilon_{t+1})+\gamma_t\cdot\left[\left(1-\frac{\phi}{2}\cdot\pi_t^2\right)\cdot A_t\cdot H_t-C_t\right]$$
$$-\lambda_t\cdot\left[\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot H_t\right.$$
$$\left.-\frac{\varepsilon_t}{\phi}\cdot\chi\cdot(1-H_t)^{-\psi}\cdot H_t-\beta\cdot G(C_t,A_{t+1},\delta_{t+1},\varepsilon_{t+1})\right]\Bigg]. \tag{3.49}$$

The future values of habit-adjusted consumption, labour and inflation have been grouped in a single term,

$$G(C_{t-1},A_t,\delta_t,\varepsilon_t) \equiv (C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot H_t\cdot\pi_t\cdot(1+\pi_t). \tag{3.50}$$

Comparing the problem of the discretionary central bank with a present bias to that of the discretionary central bank without a present bias (described previously in Section 2.3.5, see page 22), we can see that the quasi-hyperbolic discounting affects the value associated with future policy-making. With a lower value of δ_t the present bias of the central bank grows stronger, and the central bank takes policy decisions giving more importance to the present period and less importance to having to set policy again in future periods — and it does this consistently, every period. The central bank is therefore in a position where it can make repeatedly myopic policy choices.

The first order conditions are

$$\frac{\partial V(C_{t-1},A_t,\delta_t,\varepsilon_t)}{\partial C_t}: \quad (C_t-\theta\cdot C_{t-1})^{-\sigma}+\delta_t\cdot\beta\cdot E_tW_1(C_t,A_{t+1},\delta_{t+1},\varepsilon_{t+1})-\gamma_t$$
$$+\sigma\cdot\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma-1}\cdot A_t\cdot H_t\cdot\lambda_t$$
$$+\beta\cdot E_tG_1(C_t,A_{t+1},\delta_{t+1},\varepsilon_{t+1})\cdot\lambda_t=0. \tag{3.51}$$

$$\frac{\partial V(C_{t-1},A_t,\delta_t,\varepsilon_t)}{\partial H_t}: \quad -\chi\cdot(1-H_t)^{-\psi}+\gamma_t\cdot\left(1-\frac{\phi}{2}\cdot\pi_t^2\right)\cdot A_t$$
$$-\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot\lambda_t$$
$$+\frac{\varepsilon_t}{\phi}\cdot\chi\cdot\left[\psi\cdot(1-H_t)^{-\psi-1}\cdot H_t+(1-H_t)^{-\psi}\right]\cdot\lambda_t=0. \tag{3.52}$$
$$\frac{\partial V(C_{t-1},A_t,\delta_t,\varepsilon_t)}{\partial \pi_t}: \quad -\phi\cdot\gamma_t\cdot\pi_t-\left(1+2\cdot\pi_t+(1-\varepsilon_t)\cdot\pi_t\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot\lambda_t=0. \tag{3.53}$$

Appendix B.1 shows how equation (3.51) was derived using the Benveniste and Scheinkman (1979) condition.

From equation (3.51), a marginal increase in consumption gives the benefits of positive marginal utility and of the resource constraint being relaxed on the margin, but at the same time it has the costs of decreasing marginal value for the following period (because of the higher habit stock that must be sustained), placing current policy stricter, and giving even stricter constraints on future policy.

From equation (3.52), a marginal increase in labour brings costs in terms of marginal disutility (because of reduced leisure) and by tightening the resource constraint. At the same time, it has benefits in that it relaxes the relationship between output and inflation on the margin.

Last, from equation (3.53), a marginal increase in inflation tightens the resource constraint but relaxes the NKPC.

Equation (3.51) is the only first order condition that is affected by the quasi-hyperbolic discounting, where a lower strength of the present bias δ_t gives a lower marginal cost of higher current consumption creating a higher habit stock to be sustained in the future. Because the bank is myopic and it values the future less, it is less concerned about the sustainability of overconsumption.

3.3.7 Model Parameterisation

Table 3.1 reports the value given to each parameter. A time discount factor of 0.99 is in line with an annual real interest rate of 4%. Similar values for the inverse of inter-temporal elasticity of substitution for consumption, σ, and the substitutability of labour, ψ, can be found in Leith, Moldovan, and Rossi (2012) and Ravn, Schmitt-Grohé, Uribe, and Uuskula (2010). The weight on utility from leisure χ is calibrated to imply labour around 0.4 in the benchmark model, i.e. roughly 9 hours of work per day, or close to 50 per week. The baseline value for the degree of consumption habit, θ, is set to 0.60 following the literature (e.g. Leith, Moldovan, and Rossi, 2012), and in line with the previous Chapter. The technology parameters ρ_A and σ_A are in line with the RBC literature (e.g. King and Rebelo, 1999).

Table 3.1: Baseline Parameters

Description	Parameter	Value
Subjective discount factor	β	0.99
Inverse of inter-temporal elasticity of substitution	σ	2.00
Leisure demand elasticity	ψ	4.00
Weight on leisure in utility	χ	2.50
Rotemberg price adjustment cost	ϕ	80.00
Degree of consumption habit	θ	0.60
Persistence of technological innovations	ρ_A	0.95
Standard deviation of technological innovations	σ_A	0.008
Constant elasticity of subst. between intermediate goods	$\overline{\varepsilon}$	11.0
Persistence of elasticity changes	ρ_ε	0.85
Standard deviation of changes in elasticity	σ_ε	0.05
Constant strength of present bias	$\overline{\delta}$	0.90
Persistence of present bias changes	ρ_δ	0.70
Standard deviation of changes in present bias	σ_δ	0.025

The table gives parameter values used in the numerical solution and simulation.

Setting the constant elasticity of substitution between intermediate goods $\overline{\varepsilon_t} = 11$ implies a steady state mark-up of 10%, as in Leith, Moldovan, and Rossi (2012). I follow Dennis and Kirsanova (2021) in the value assigned to the persistence of elasticity changes $\rho_\varepsilon = 0.85$, and reduce the volatility to $\sigma_\varepsilon = 0.05$, which implies a range between 8.27 and 14.62 for 99.7% of the distribution of ε_t.[1]

Finally, the parameter $\overline{\delta}$ is calibrated to obtain a normal distribution for the present bias parameter δ_t that is centred around the value of 0.9. I calibrate the persistence of present bias changes and the standard deviation of changes so that the value of δ_t unlikely to exceed a value of 1.00: with $\rho_\delta = 0.70$ and $\sigma_\delta = 0.025$, 99.7% of the distribution of δ_t lies between 0.8103 and 0.9997.

3.4 Results

In this section I first study the impact of a present bias on the equilibrium by comparing the steady states with varying strength of present bias. I do this by temporarily setting δ_t to be a deterministic

[1] Because ε_t is constructed to be normally distributed, 99.7% of data generated by the process described in equation (3.33) lies within 3 standard deviations of the mean.

variable, and choosing values for this parameter. This allows me to compare scenarios with different strength of present bias, from a central bank with no present bias to a relatively myopic one.

I then revert back to a stochastic δ_t for a static and dynamic analysis of the effect of the present bias. I compare the stochastic steady state of a central bank with no present to that of the central bank with a strength of the present bias that follows equation (3.37). I also analyse how responsive the nominal interest rate, i.e. the policy tool of the central bank, is to changes in the strength of the present bias, as well as to consumption, technology, and the demand elasticity.

I investigate how the central bank and the private sector react to an unexpected change in strength of the present bias, by plotting and discussing the Generalised Impulse Response Functions of the main variables to a positive present bias shock. Furthermore, I explore to what extent the present bias modifies how the economy reacts to a technology shock and a markup shock.

The model is solved numerically using value function iteration. The numerical solution is then used to simulate the economy for one million periods. A detailed description of the algorithm can be found in Appendix A.2.

3.4.1 Deterministic δ

In this Subsection, I study how the stochastic steady state is affected by changes in the strength of the present bias δ_t as a deterministic variable, i.e.

$$\delta_t = \delta \; \forall t, \tag{3.54}$$

where I assign different values to it. I do this to be able to build an understanding of the effect of the present bias in a simpler setting before turning to a stochastic analysis in Subsection 3.4.2.

Table 3.2 reports the stochastic steady states, calculated by averaging out the values over the simulation period. Specifically, the columns of Table 3.2 show what happens to the stochastic steady state as the present bias the central bank becomes stronger.

As the present bias of the central bank becomes stronger (i.e. δ becomes smaller), the central bank gives a lower discounted value to the future. The results in Table 3.2 show that in the context analysed this translates into the central bank with a present bias being less concerned with curbing the habit stock, and being relatively more concerned with the current burden of inflation (or disinflation) costs. It is worth remembering that in this scenario inflation costs are quadratic (see equation (3.31)), and therefore the sign of inflation has no bearing on the size of these costs.

Being less concerned with curbing the overconsumption stemming from the external consump-

Table 3.2: Stochastic Steady States by Strength of Present Bias δ

Strength of present bias (δ)	**1.00**	**0.90**	**0.80**	**0.70**
Inflation	-7.419	-6.162	-5.018	-4.000
	(0.701)	(0.587)	(0.474)	(0.367)
Consumption	0.447	0.449	0.450	0.451
	(0.009)	(0.009)	(0.009)	(0.009)
Labour	0.453	0.453	0.453	0.452
	(0.003)	(0.003)	(0.003)	(0.003)
Output	0.453	0.453	0.453	0.453
	(0.009)	(0.009)	(0.009)	(0.009)
Real rate	3.978	3.975	3.969	3.965
	(2.517)	(2.589)	(2.655)	(2.708)
Nominal rate	-3.516	-2.248	-1.098	-0.074
	(2.391)	(2.504)	(2.598)	(2.670)
Wage	0.895	0.899	0.902	0.904
	(0.026)	(0.025)	(0.025)	(0.025)
$\|\|$Euler error$\|\|_\infty$	5.71E-5	5.68E-5	5.61E-5	5.60E-5

The table presents deterministic steady state values and standard deviations for all variables for the discretionary regime, for varying degrees of external consumption habits.
Note: inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units.

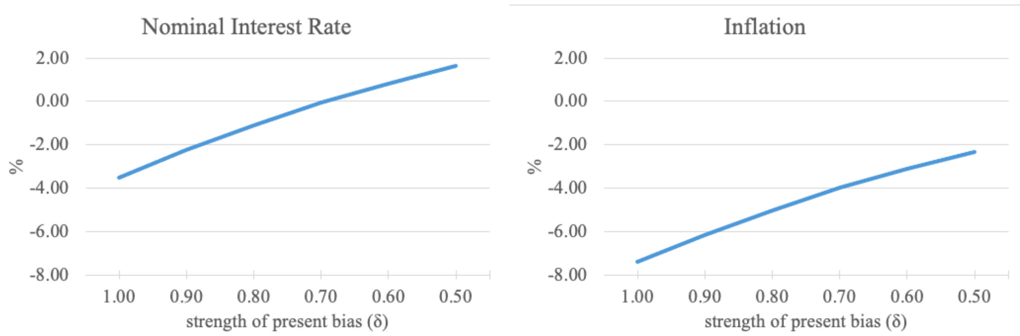
tion habits, and motivated by its distaste for inflation costs, the central bank sets a higher nominal interest rate, which results in inflation closer to zero – in this case, less disinflation, as inflation is negative because of external consumption habits. With Rotemberg prices, an inflation rate closer to zero leads to fewer resources being wasted during the production process. This means that production is more efficient, in turn leading to higher real wages.

Table 3.2 shows that higher wages impact the households' consumption-leisure choice by incentivising them to work the same amount or marginally less, and use the slightly higher wages to be able to afford slightly higher levels of consumption. The extra amount that households consume is what is no longer wasted in the production process, thus not pushing output (and labour) upwards through higher demand.

Overall, the effect of the present bias on consumption, labour, output, and wages is rather small. Even with a strength of the present bias of $\delta = 0.50$ (not shown in the table) and the central bank with a present bias valuing the future half as much as a central bank with no present bias does, consumption increases by around 1%. This is because, whilst the central bank has a present bias and gives a lower discounted value to the future, the private sector does not.

The strength of the present bias δ has a bigger impact on inflation and nominal interest rate. Table 3.2 shows that, going from $\delta = 1.00$ to $\delta = 0.70$, inflation and the nominal interest rate increase by about 3.4 percentage points each. These changes are visualised in Figure 3.1, which shows the deterministic steady states of nominal interest rate and inflation for strength of present bias varying from $\delta = 1.00$ to $\delta = 0.50$.

Figure 3.1: Steady State Values by Strength of Present Bias δ



The figure shows the deterministic steady states of annualised inflation and annualised nominal interest rate for varying strength of present bias.

Figure 3.1 indeed shows that a central bank with a stronger present bias sets a higher nominal interest rate because it has a diminished motivation to curb the habit stock and gives relatively more importance to the current cost of inflation. Setting a higher nominal interest rate achieves a lower level of disinflation: with an inflation level closer to zero, the costs associated to inflation are diminished.

Result 3. 2 *The central bank's strength of the present bias affects the trade-off between inflation costs and the overconsumption externality. The present bias is linked to pressure on inflation that brings it closer to zero, to reduce the costs associated with inflation.*

It should be noted that the present bias pushing nominal interest rates up and creating a positive inflation bias is specific to the context of external consumption habits, where a discretionary central bank with no present bias creates negative nominal interest rates and inflation. The distortion created by the present bias acts to push up nominal interest rates because this would create an output boost in the current period, lower disinflation, and raise current welfare.

3.4.2 Stochastic δ

Comparative Statics

Table 3.3 compares the steady states of a central bank with no present bias i.e. $\delta_t = 1\ \forall t$, a central bank with a present bias with a deterministic $\delta_t = 0.90\ \forall t$, and a central bank with a present bias with a random δ_t that follows the AR(1) process described in equation (3.37) centred around $\overline{\delta} = 0.90$. The Table reports average outcomes, and volatilies in brackets. All cases include volatility in the technology level and the elasticity of substitution between intermediate goods, and therefore the comparison between columns allows to investigate how the volatility for each variable evolves with the introduction of first deterministic and then stochastic present bias.

Table 3.3: Stochastic Steady States by Present Bias

	Central bank with no present bias	**Central bank with a present bias**	
	$\delta_t = 1\ \forall t$	$\delta_t = 0.90\ \forall t$	Random δ_t
Inflation	-7.419	-6.162	-6.173
	(0.701)	(0.587)	(0.700)
Consumption	0.447	0.449	0.449
	(0.009)	(0.009)	(0.009)
Labour	0.453	0.453	0.453
	(0.003)	(0.003)	(0.003)
Output	0.453	0.453	0.453
	(0.009)	(0.009)	(0.009)
Real rate	3.978	3.975	3.969
	(2.517)	(2.589)	(2.691)
Nominal rate	-3.516	-2.248	-2.267
	(2.391)	(2.504)	(2.549)
Wage	0.895	0.899	0.899
	(0.026)	(0.025)	(0.026)
$\|\|\text{Euler error}\|\|_\infty$	5.71E-5	5.68E-5	7.99E-6

The table presents deterministic steady state values and standard deviations for all variables for the discretionary regime, for varying degrees of external consumption habits.
Note: inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units.

In line with the results and discussion in Subsection 3.4.1, compared to a central bank with no present bias, one with a random present bias produces higher average outcomes for nominal interest rate and inflation, marginally higher average outcomes for wage and consumption, and about the same average outcomes for labour and output. This is because, as mentioned above, the strength of the present bias affects the behaviour of the central bank but has a very limited impact on the allocation choices of the private sector. Specifically, the central bank's strength of the present bias affects the trade-off between inflation costs and the overconsumption externality.

A random present bias, however, has a somewhat smaller effect compared to a deterministic present bias: inflation and and the nominal interest rate are marginally lower in the fourth column of Table 3.3 compared to the third. This is because the distribution of the random δ_t is log-normal, implying that in the simulation there will be more instances of δ_t above the average (and closer to $\delta = 1$) than below the average. Despite this, the overall effect is still that of a central bank with a present bias creating higher nominal interest rates and higher inflation.

Table 3.3 also shows that the present bias does not make labour, output, consumption, wages, and inflation more volatile. This is because the private sector, unlike the central bank, does not have a present bias: they do not react to the central bank's changing strength of present bias by adjusting their allocation choices. Because production and consumption are not more volatile, neither is inflation.

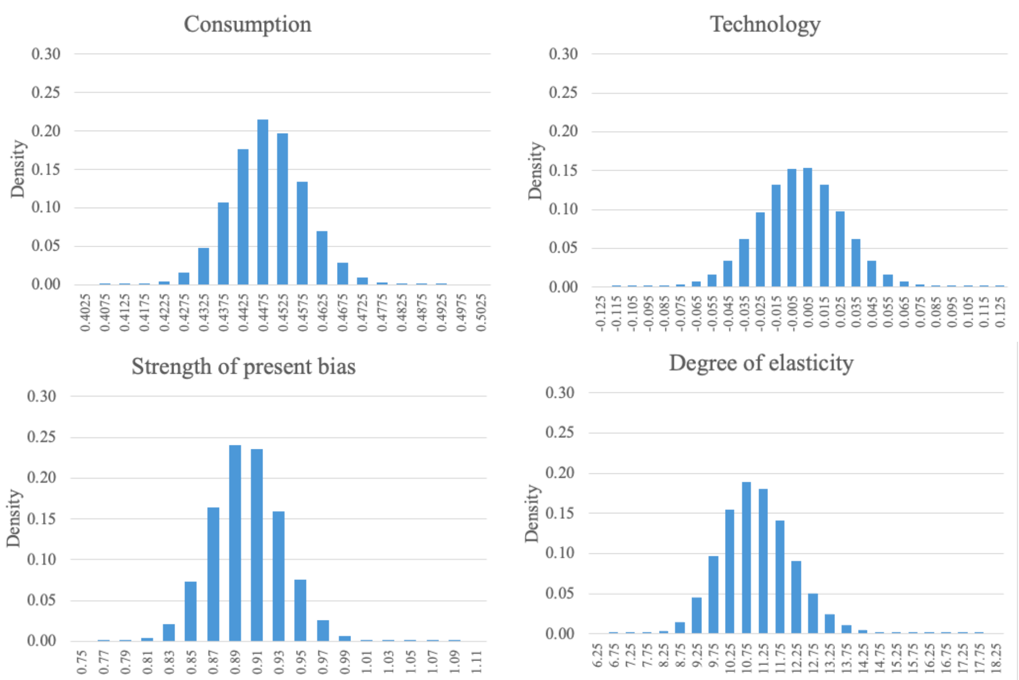
The nominal interest rate, on the one hand, becomes more volatile with a central bank with a deterministic present bias, and its volatility increases further with a central bank with a random present bias. A present bias, and even more so a random present bias, causes the central bank to move the nominal interest rate more. On the other hand, inflation is less volatile with a deterministic present bias compared to a case with no present bias, but the present bias being random adds back to the volatility of inflation.

Result 3. 3 *A central bank with a present bias creates a more volatile nominal interest rate, but this volatility does not propagate to the rest of the economy.*

In Chapter 2 I found that the external consumption habits did have the effect to exacerbate the stabilisation bias, and the findings in this Chapter seem to suggest that the external consumption habits produce stronger effects than the strength of the present bias. This suggests that the volatility created by external consumption habits drowns out the extra volatility that a changing strength of the present bias might bring, and thus the strength of the present bias of the central bank does not necessarily aggravate the stabilisation bias any further.

Figure 3.2 presents the distributions of consumption C_t, technology $\ln A_t$, strength of the present bias δ_t, and degree of elasticity of substitution between intermediate goods ε_t, obtained from simulating the model for 1,000,000 periods. Technology is constructed to be normally distributed around its mean of $\ln A_t = 0$, whilst the strength of the present bias and the degree of elasticity are log-normal distributions around their respective means of $\delta_t = 0.90$, and $\varepsilon_t = 11.0$. Variance is given by σ_A, σ_δ, and σ_ε (see Table 3.1 for values). The distribution for consumption has mean $C_t = 0.45$ and variance $\sigma_C = 8.39e^{-5}$, in line with the results presented in Table 3.3.

Figure 3.2: Distributions

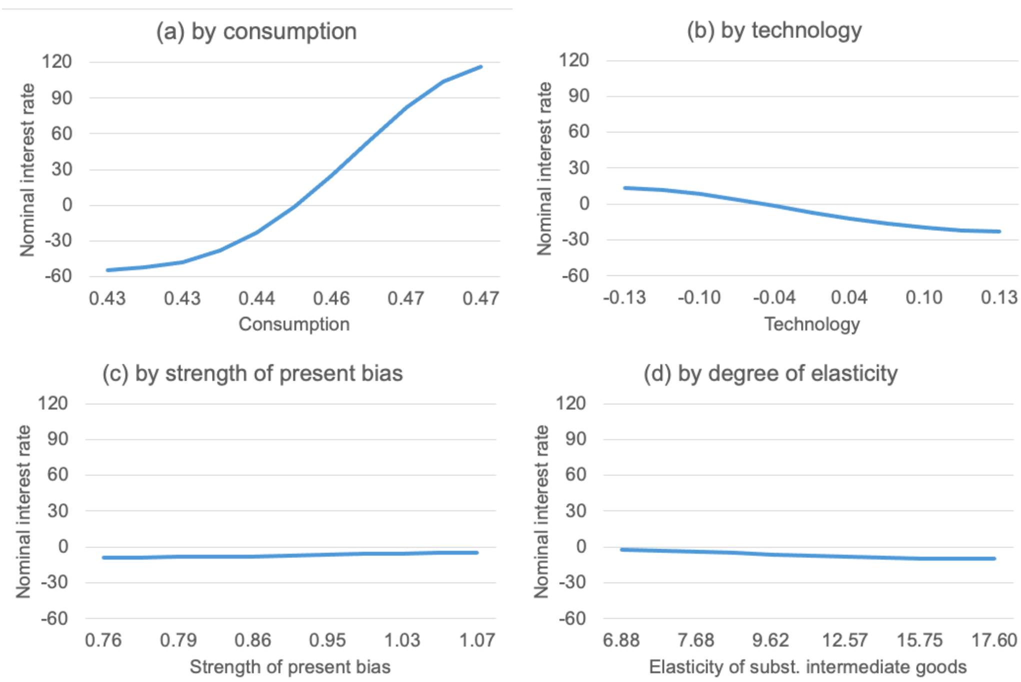


The figure shows the distributions of consumption, technology, strength of the present bias, and degree of elasticity of substitution between intermediate goods, obtained from the simulation.

Figure 3.3 investigates how sensitive the nominal interest rate is to changes in consumption, technology, strength of the present bias, and degree of elasticity of substitution between intermediate goods. This is done by selecting a range for each of the four variables, based on the distributions shown in Figure 3.2, and calculating the value of the nominal interest rate on a number of nodes spacing the chosen range. I do this separately for each of the four variables, allowing only one of these to vary whilst fixing the other three to their steady state values. I chose this partial equilibrium approach to be able to visualise the outcome of my analysis: had I chosen to plot the general equilibrium effect of consumption, technology, strength of the present bias, and degree of elasticity on the policy rule, the outcome would have been a figure in five dimensions.

The results of my analysis are plotted in Figure 3.3. The panels present the marginal effect each variable has on the nominal interest rate, holding the other state variables constant. In analysing this panel of four graphs, it is important to remember that in the model consumption levels depend on the values taken by the other three variables. Because changes in technology, strength of the present bias, or degree of elasticity are associated with changes in the consumption level, the large variations shown in Figure 3.3.a are often mitigated.

Figure 3.3: Policy Rule: Nominal Interest Rate (Annualised)



The four-panel figure shows the graph of the annualised nominal interest rate on the grid of consumption, technology, strength of the present bias, and degree of elasticity. Each graph is obtained by calculating the value of nominal interest rate at each node of the grid for one variable whilst keeping the other ones fixed at their respective mean levels.

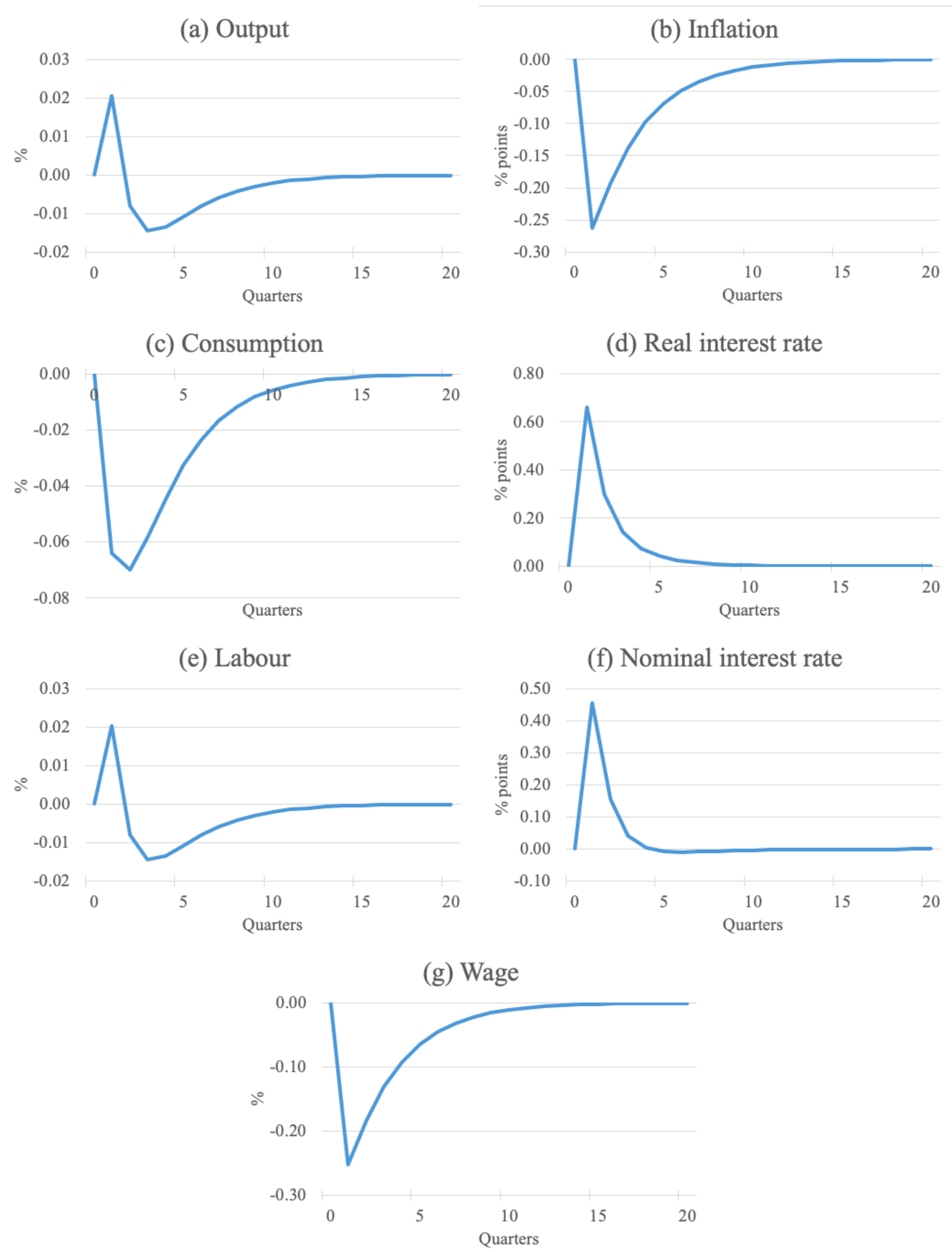
Figure 3.3 shows that variations in consumption have the largest partial-equilibrium impact on the nominal interest rate, with the latter increasing from about -50 at the lowest levels of consumption to over 100 at the highest levels of consumption. Variations in technology, strength of the present bias, and degree of elasticity have much smaller impact on the nominal interest rate. Like consumption, the strength of the present bias is also positively related to the nominal interest rate, with the nominal interest rate increasing in the strength of the present bias. However, as mentioned, this partial-equilibrium increase is much smaller than in the case of consumption: the nominal interest rate goes from -8.7 at the stronger present bias to -4.4 at the weaker present bias. On the other hand, technology and the elasticity of substitution between intermediate goods are inversely related to the nominal interest rate.

Figure 3.3 suggests two things. First, the partial equilibrium effect of external consumption habits on the interest rate is stronger than the effect of a present bias. Second, the partial equilibrium effect of a present bias is to put downward pressure on the nominal interest rate.

Comparative Dynamics: Direct Impact of the Present Bias

Having discussed the impact that the present bias has on the model's stochastic steady state, I turn to the dynamic analysis and explore how a central bank with a present bias reacts to a change in the strength of the present bias δ_t. Figure 3.4 shows the response to a positive present bias shock in the New Keynesian model with external habits and a discretionary central bank. The size of the shock is one standard deviation, bringing the strength of the present bias from the average value $\delta_0 = 0.9$ to $\delta_1 = 0.925$ in the following period. A positive present bias shock, it should be noted, weakens the present bias.

Figure 3.4: Generalised Impulse Response Functions to a Positive Present Bias Shock



The figure shows the generalised impulse response functions to a positive present bias shock of output, consumption, labour, inflation, real and nominal interest rates, and wage.
Note: % deviation from relative no-shock path.

When the present bias of the central bank becomes unexpectedly weaker, the central bank raises the interest rate (panel f) to bring down inflation and to curb the overconsumption externality.

A weaker present bias translates into valuing the future relatively more and therefore valuing the present relatively less, and this leads to the overconsumption externality becoming relatively more important and the cost of inflation becoming relatively less important for the central bank. A central bank with a weaker present bias raises the nominal interest rate to better contain the overconsumption externality, as it is more willing to bear the associated costs coming from greater disinflation.

With higher nominal interest rates, bonds become relatively more attractive and therefore the households now prefer to postpone consumption (panel c) and save more in bonds instead. A higher interest rate also incentivises households to supply more labour (panel e), with the aim of saving more by using their wages to buy bonds.

As the labour supply increases, output also increases (panel a): this is because in this model unemployment is not possible, and therefore increased labour supply translates into higher output. However, the oversupply of labour leads to lower real wages (panel g). Furthermore, the increase in production leads to falling prices (panel b), which is indeed the aim of the central bank.

After the first period the present bias shock beings to fade away, and the central bank's present bias gradually returns to its mean strength $\overline{\delta} = 0.9$. As a result the central bank gradually lowers the nominal interest rate (panel f), leading to inflation increasing (panel b). However, because the bonds have earned households higher-than-average returns, the households use these returns to sustain gradually increasing consumption (panel c). This leads to households reducing the amount of labour they supply (panel e).

After the first initial increase, then, labour falls – and so does output (panel a). In fact, the higher returns from the bonds allow households to decrease their supply of labour to levels below their average labour supply. This pushes real wages up, as seen in Figure 3.4.g.

Whilst Figure 3.4 describes the effect of a positive present bias shock, negative present bias shocks are possible. These are closely approximated by the reverse[2] of Figure 3.4: a stronger present bias makes the central bank cut the nominal interest rate, leading to higher inflation, higher consumption, and labour and output falling at first to then experience a mild increase that lasts a few periods.

Result 3. 4 *A negative shock to the strength of the present bias leads to the central bank re-weighting the trade-off between output and inflation. The central bank tightens monetary policy, causing inflation to fall and output to rise.*

[2]In a non-linear system, the effect of a negative shock is not identical to the reverse of the effect of a positive shock. However, because the non-linearities of this model are symmetric around zero, the two are similar enough to be approximately reversed.

With persistence parameter $\rho_\delta = 0.70$, the present bias shock fades away from the system relatively quickly: all variables return to their pre-shock levels in 20 periods or less, with nominal and real interest rates converging the fastest. In particular, inflation converges slower than the nominal interest rate because of the propagation effects that increasing the interest rates has on this economy, as outlined above.

Comparative Dynamics: Indirect Impact of the Present Bias

Figures 3.5 and 3.6 compare the reaction of a central bank without and with a present bias (as previously defined, see page 78) to a positive technology shock and to a positive markup shock. Both shocks are one standard deviations from average values, and the two central banks being compared are those of Table 3.3.

Figure 3.5 shows that the strength of the present bias has an extremely limited bearing in how the central bank reacts to a positive technology shock. The two cases are qualitatively identical: the central bank reacts by lowering the nominal interest rate (panel f), to curb the overconsumption externality that would result from the increased productivity. This leads to a temporary fall in prices (panel b), and a temporary increase in output (panel a) and consumption (panel c).

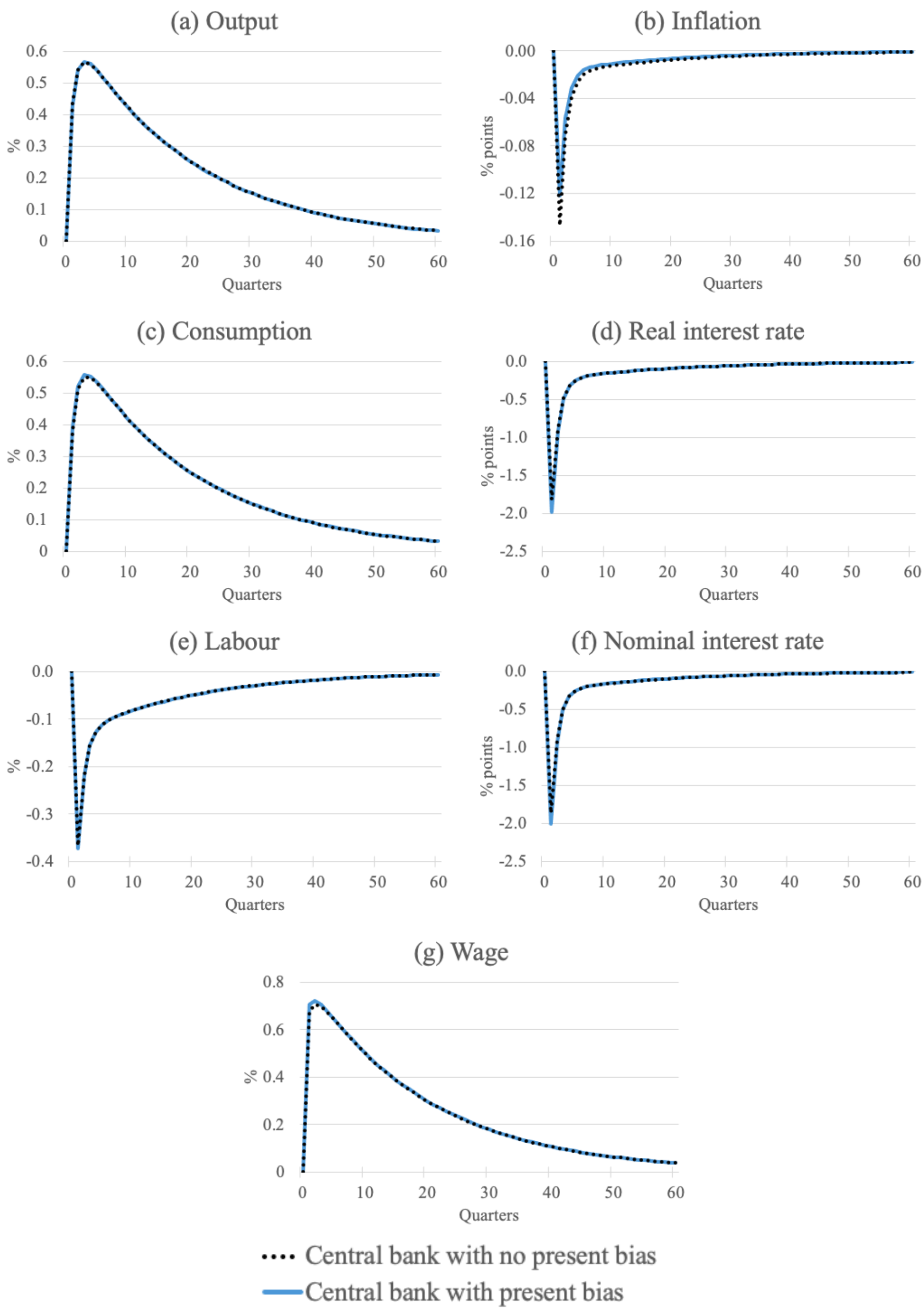
Quantitatively, we can notice a small difference between the central bank without and with a present bias from Figure 3.5, in that the central bank with no present bias can create a slightly smaller change in the nominal interest rate to achieve a slightly bigger change in inflation. Changes of the central bank with a present bias have somewhat "less bite" because in this case the private sector is acclimatised to a more volatile nominal interest rate. Ultimately, however, the difference is minimal.

Figure 3.6 shows that the strength of the present bias has some quantitative effect on how the central bank reacts to a positive markup shock, though does not qualitatively change the central bank's reaction.

In the case of a discretionary central bank dealing with external consumption habits, a positive markup shock puts downward pressure on production, which would lead to lower labour demand, lower wages, and lower consumption. The central bank reacts by cutting the nominal interest rate (panel f), which incentivises households to consume more, increasing consumption (panel a) and creating inflation (panel b).

The central bank with a present bias has a smaller reaction to the positive markup shock, with the aim of containing the costs resulting from inflation. It cuts the nominal interest rate by less, which gives a smaller incentive to households to save instead of consuming and therefore it leads

Figure 3.5: Generalised Impulse Response Functions to a Positive Technology Shock

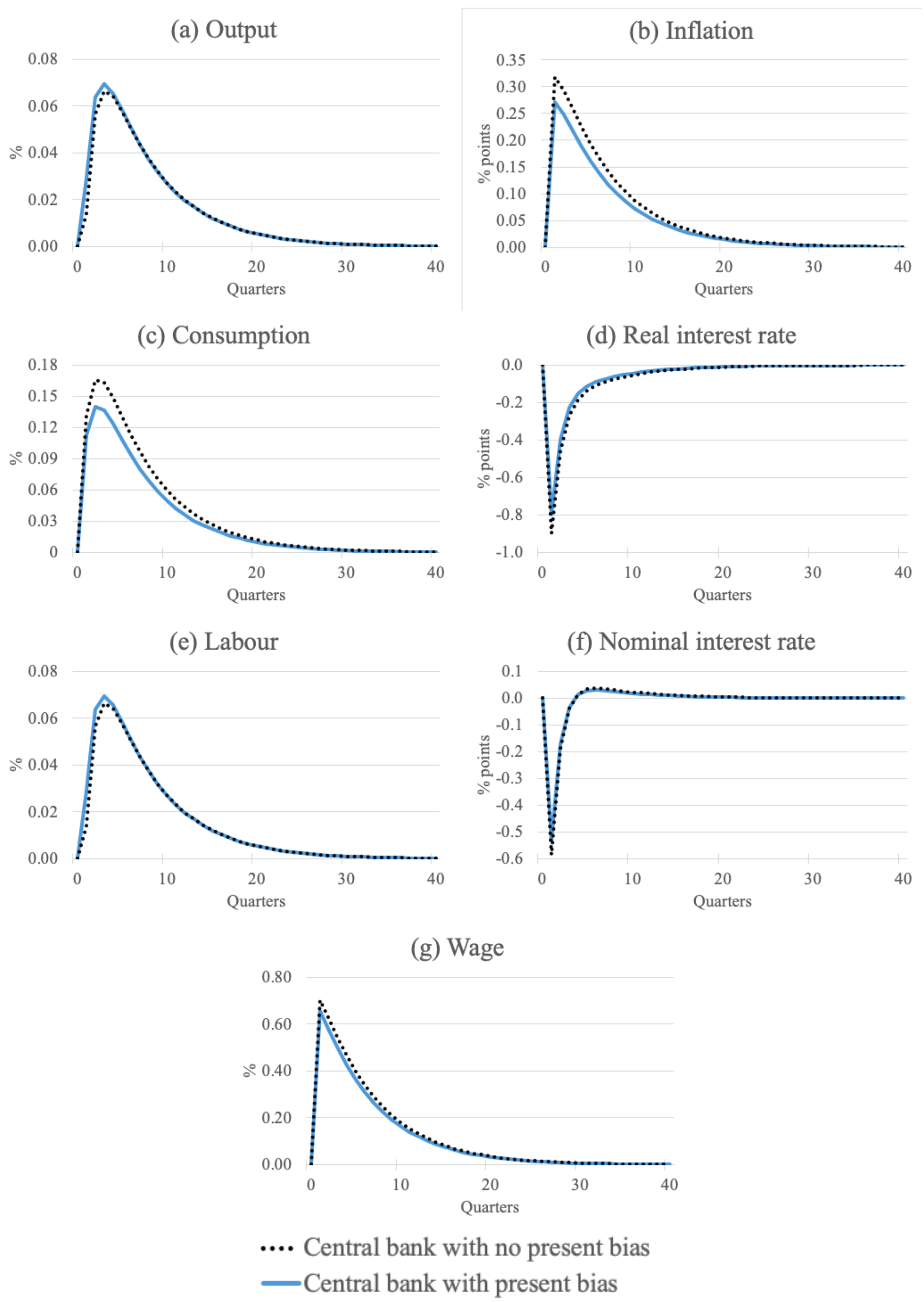


The figure shows the generalised impulse response functions to a positive technology shock of output, consumption, labour, inflation, real and nominal interest rates, and wage, comparing the case of a central bank with no present bias to the case of a central bank with a present bias.
Note: % deviation from relative no-shock path.

to a smaller increase in consumption. Because consumption increases by less, so does inflation. Because consumption and inflation peak at lower levels, they also converge faster than in the case with a central bank with no present bias.

The differences for wage, labour, and output are marginal. Furthermore, the strength of the present bias has limited to no effect on how long it takes the economy to revert back to the

Figure 3.6: Generalised Impulse Response Functions to a Positive Markup Shock



The figure shows the generalised impulse response functions to a positive elasticity shock of output, consumption, labour, inflation, real and nominal interest rates, and wage, comparing the case of a central bank with no present bias to the case of a central bank with a present bias.
Note: % deviation from relative no-shock path.

equilibrium.

Result 3. 5 *The indirect impact of the present bias is mostly negligible, and the strength of the present bias does not qualitatively change how the central bank responds to shocks.*

3.5 The Source of the Present Bias

The previous section explored the economic consequences to a central bank having a varying strength of the present bias, highlighting how allowing the central bank to have a present bias, alters the trade-off between present costs and future benefits. In the case analysed here, a more central bank with a present bias will be less prone to bear the cost of inflation in the present in order to earn the future benefits of containing the externality in consumption. This affects the equilibrium nominal interest rate and inflation, though it appears to have limited impact on other variables and on how the central bank responds to technology or markup shocks.

I also found that when the present bias of the discretionary central bank suddenly becomes stronger the central bank cuts the nominal interest rate, leading to an inflationary episode. The opposite occurs when the present bias of the central bank suddenly becomes weaker.

Having discussed the outcomes of a present bias, I now turn to a brief discussion of its possible causes. A first option is that the changes in present bias are endogenous to the discretionary central bank, perhaps guided by the personal strength of the present bias of the members of the bank's board of directors. The strength of the present bias could also be linked to the macroeconomic context the central bank faces, for example the present bias of the central bank could become stronger when inflation passes a given threshold. Future research could re-formulate the process for strength of the present bias δ_t (equation (3.37)) linking it to the costs of inflation.

For central banks, long horizons are often the cornerstone of their communication strategy and their forward guidance policies (see e.g. Evans, 2021, De Vijlder, 2021, and Brzeski, 2022). Central banks do, however, occasionally show sign of acting giving more weight to immediate outcomes. Central banks aggressively cutting interest rates in 2022 in order to reverse the global inflationary surge could be seen in the optic of central banks acting to contain the current costs of inflation. Whilst the Fed's experience with the 1970s OPEC crisis is a well-known example showing that rapidly growing inflation is better dealt with sooner rather than later (Goodfriend, 1993), a present bias could also be a contributing factor. Central bankers around the world might also be hiking their nominal interest rate motivated by a present bias, with the expectation that the Federal Reserve will be, as it is, tough on inflation (Cole, 2022).

Another example could be found in how central banks reacted to the COVID-19 crisis in 2020, when many of them adopted policies based on current conditions rather than forecasts. De Grauwe and Ji (2020) suggest that "[w]hen uncertainty is extreme, prudent central banks should be guided by what they observe" rather than by forecasts that are too unreliable because of the high uncertainty.

In crisis periods like the one faced during the COVID-19 crisis, then, current-looking monetary policy, or monetary policy with a strong present bias, might perform better. Future research could extend the model presented here to include uncertainty shocks, and link the value of δ_t to the degree of uncertainty.

Another option is that the strength of the present bias δ_t is exogenous to central banks, and more specifically comes from the behaviour of the government. In this scenario, δ_t could model political pressure on central banks. As I discuss in the next Chapter, despite independence central banks can still be subject to the swaying of politicians: from 2010 to 2018 Binder (2021) counts over 200 quarterly instances of a government pressuring close to 40 central banks to deviate from their optimal behaviour by cutting or raising the nominal interest rate, and other types of pressure like replacing the governor or changing legislation. Chapter 4 investigates the patterns and characteristics of political pressure in detail, as well as its link with inflation.

I conjecture that the core of political pressure could be a fundamental disagreement between the government and the central bank, stemming from the fact that these two institutions could be operating on different horizons. Central banks, even discretionary ones, are decision makers who operate on a long time horizon. Their policy decisions are guided by long-term goals. Governments and politicians, on the other hand, tend to operate on a shorter time horizon. Disagreement between government and central bank, then, could come about because the former has more short-term objectives that clash with the latter's longer-term objectives. The government trying to rush along the central bank, pressuring them to get aligned to their shorter-term objectives, could be seen as the central bank suddenly being forced to have a present bias. Further research could explore this conjecture empirically and then embed the findings into a theoretical framework.

The initial findings in this Chapter suggest that the present bias discount factor δ_t could be used to model political pressure. In particular, temporary episodes of pressure could be modelled through the strength of the present bias parameter δ_t, as defined in equation (3.37). Constant pressure, on the other hand, the results in Section 3.4.1 and more specifically Table 3.2 would be more relevant. In order to continue exploring whether the present bias discount factor δ_t could be used to model political pressure, future research could consider adding a fiscal side to the model, and in particular debt. The addition of debt would allow to investigate what impact political pressure has on debt accumulation.

3.6 Conclusion

This Chapter investigates how a changing strength of the present bias for the discretionary central bank affects how it conducts policy. In order to study this I introduce quasi-hyperbolic discounting for the central bank in the context of a New Keynesian DSGE model with discretionary monetary policy making and the households having superficial external consumption habits. These habits, I showed in Chapter 2, create an overconsumption externality and lead to rapidly falling prices. In this Chapter I discuss how a central bank with a present bias is less willing to bear the high inflation costs that are associated with curbing the overconsumption externality and, caring less about the size of the habit stock to be sustained in the future, chooses to create a level of disinflation that is closer to zero.

First I investigate the effect that a progressively lower deterministic strength of the present bias has on monetary policy making and on the whole economy. I find that a present bias is associated with, in this context, stronger upward pressure on prices. This is, in fact, pressure towards a zero inflation level: a central bank with a present bias aims to reduce the quadratic costs associated with inflation or disinflation. Whilst nominal interest rate and inflation increase as the present bias of the central bank grows stronger, the other economic variables incur very limited changes. This is because the behaviour of the private sector is unchanged, as they do not discount the future quasi-hyperbolically.

I then study the case of a central bank with a present bias with a stochastic strength of the present bias. This central bank with a present bias, in line with the results outlined just above, sets a higher nominal interest rate compared to a central bank with no present bias, leading to a level of disinflation closer to zero. The central bank with a present bias also creates a more volatile nominal interest rate.

Every time its strength of the present bias changes, the central bank adjusts the nominal interest rate to either decrease or increase inflation, according to how willing to bear the current inflation costs it has become. A changing strength of the present bias, then, creates booms and bursts that would not have occurred otherwise. However, the strength of the present bias has no qualitative and a very limited quantitative impact on how the central bank reacts to technology and markup shocks.

To summarise, the present bias makes the central bank desire an inflation level closer to zero in the current period – even when this is done at the expense of the future, because the central bank with a present bias values it less. Whilst the present bias has a very limited impact on how the central bank reacts to other shocks, a shock to the strength of the present bias itself creates economic fluctuations. These findings make it plausible to be able to use the strength of the present bias to model pressure coming from the government, pushing the central bank to change its optimal policy behaviour. In this scenario, an episode of political pressure could be expressed as a present bias shock. This is an area of interest for further research, which I indicate could benefit from including debt into the model.

4. Political Pressure

4.1 Introduction

The theme of this Chapter can be traced back to a article I read in the Financial Times in the early spring of 2017. The article was "Central bank independence is losing its lustre", by Münchau (2017). That article laid bare two critical ideas. First, "central bank independence is not the natural order of things" (Münchau, 2017), but rather a product of political economy and ultimately politics. Here I must recognise the enormous contribution that the late Alberto Alesina had to this discussion. Second, "the foundations of central bank independence are not as strong as they were" (Münchau, 2017). Central banks are pressured to deviate from their optimal behaviour. They are pressured by the media, by public opinion, by politicians. It was the latter that particularly interested me, and I set to investigate political pressure.

In this Chapter I use a combination of datasets and various empirical methods to analyse political pressure: using eleven years of quarterly data on governments exerting pressure on central banks I am able to investigate the patterns of political pressure, how some characteristics of the central bank and the country could be linked to political pressure to ease monetary policy (i.e. lower the interest rate), and finally how pressure to ease policy, and succumbing to it, relate to inflation.

My results corroborate other themes discussed in the literature on central bank independence and the previous empirical evidence on political pressure: pressure to ease policy is by far the most common type of pressure, and most central banks are pressured rarely, though there are cases of systematic pressure. Somewhat surprisingly, the degree of *de jure* Central Bank Independence (CBI) does not seem to have a strong and linear relation with political pressure to ease policy, and I argue this results deserves to be investigated more, possibly with longer or new indexes for CBI.

As for country characteristics, my findings confirm that political pressure to ease policy is less likely in countries with lower levels of perceived corruption, with higher political checks and balances, and is more likely to come from left-nationalist and other governments – as previously discussed in the literature, and in particular in Binder (2021).

In a deeper analysis of the link between the politics of the government and pressure to ease policy, I am able to split political parties into four distinct clusters, based on their likelihood of pressure to ease policy. These are: the no-pressure cluster, made of nationalist right-wing and centrist; the low-pressure cluster, made of not nationalist right-wing, centrist, and left-wing Parties; the medium-pressure cluster, made of not nationalist other Parties; and the high-pressure cluster, made of nationalist left-wing and other Parties. The grouping is made based on their politics, and the difference in likelihood of pressure is statistically significant across the four groups. Furthermore, the likelihood of pressure is also related to country income categorisation, but this relationship is not linear.

I also find, novel to existing empirical work, that the likelihood of pressure is related to unsustainable levels of public debt, to corruption, and to the policy trilemma. Firstly, the central banks in the top 5% countries for levels of public debt-to-GDP are more likely to be pressured, possibly because governments find the debt-to-GDP level unsustainable. Moreover, central banks in countries with below-median debt-to-GDP levels are more likely to succumb to the pressure to ease policy, and I argue this is because they have lower marginal costs from succumbing.

Secondly, I find that in countries with low levels of perceived corruption, central banks are more likely to be pressured to ease, suggesting that observing the government pressure the central bank contributes to the perception of corruption. However, the level of perceived corruption does not appear to be linked to the likelihood of succumbing to pressure to ease policy.

Thirdly, the central bank's policy positioning on monetary sovereignty, exchange rate stability, and financial openness, or policy trilemma, is related to the likelihood of political pressure. I further investigate the link between the policy trilemma, and the likelihood of pressure through probit regressions. These show that the link between the policy trilemma and the likelihood of pressure to ease policy is strong and non-linear. Moreover, it is robust to the degree of perceived corruption: although it is true that countries with more corrupt institutions are more likely to have their central bank pressured by the government to decrease the interest rate, the corruption is not the underlying reason for the country's positioning on the policy trilemma to be related to political pressure.

Another novel finding presented in this Chapter is that political pressure to ease policy and the political cycle do not appear to be linked: Parties are not more likely to exert pressure to ease policy in the lead-up to an election.

Finally, I find that central banks that have historically been more tolerant of high inflation are more likely to be pressured, and that succumbing to pressure to ease policy is linked to higher inflation in the following quarter.

The Chapter is structured as follows. Section 4.2 discusses the literature: the Political Business Cycle literature, which led to central banks being made independent from governments, and how political pressure persists despite that. Section 4.3 describes the data, from the sources I combine to how I derive the variables I use in the analysis. Section 4.4 explains the analysis and presents the results: the patterns of political pressure in Section 4.4.1, political pressure to ease policy by country characteristics in Section 4.4.2, political pressure to ease policy by central bank characteristics in Section 4.4.3, and the relation between pressure to ease policy and inflation in Section 4.4.4. Section 4.5 discusses the results. Finally, Section 4.6 concludes.

4.2 How Central Banks Became Independent

Historically, governments used to be in charge of both fiscal and monetary policy. In the late 1980s - early 1990s, the political economy literature found that partisan bias was creating economic fluctuations (and high inflation): right-wing and left-wing Parties have incompatible goals, and their alternating gives rise to the Political Business Cycle. In order to eliminate the fluctuations associated with the political business cycle, monetary policy was taken away from the government and assigned to independent central banks. This was not, however, the end of politics interfering with monetary policy: governments have been politically pressuring central banks. However, as discussed later (see Figure 4.1) political pressure has been widespread since independence, suggesting that either independence is not complete, or that it does not shield central banks from politics, or both.

I discuss the Political Business Cycle (henceforth: PBC) and the debates that lead to central bank independence in Section 4.2.1, and political pressure in Section 4.2.3.

4.2.1 The Political Business Cycle

The PBC, viewed as the fluctuation in economic activity resulting from the actions of political agents, has been studied since the 1970s. Nordhaus (1975) was the first to suggest that the PBC is due to opportunistic pre-electoral manipulation: in his model incumbent politicians steer the economy before election in order to get re-elected. Their behaviour gives rise to fluctuations. Hibbs (1977) proposes the PBC is instead due to partisan bias. Political parties differ in their ideology, as a product of the constituency they target. Right-wing Parties traditionally target high-income individuals, whilst left-wing Parties target low-income individuals. The first group tends to be more concerned with inflation, the second with unemployment. It follows that right-wing Parties prefer a combination of low inflation and relatively higher unemployment, while left-wing Parties prefer the opposite. The alternating of Parties with opposing objectives then creates fluctuations in the economy.

With the 1980s came Lucas' rational expectations revolution. Researchers have shown that the PBC is compatible with rational expectations, as long as there is uncertainty about the electoral outcome (Rogoff, 1990). If the outcome of elections is not certain, then both opportunistic manipulation and partisan bias give rise to fluctuation even if agents are rational (Alesina, 1987, and 1988).

While there is mixed empirical support for the idea of opportunistic pre-electoral manipulation creating the PBC, partisan bias as the source of fluctuations has found more backing. As the Phillips curve indicates, there can be a short-run trade-off between the goals of full employment and price stability, and switching between political parties with different preferences can drive a business cycle. Hibbs (1977) observes how in the U.S. and in the U.K. unemployment decreases during Democratic/Labour governments, but increases during Republican/Conservative governments. Furthermore, Alesina and Gatti (1995) note how Republicans/Conservatives winning the election is followed by a deflationary shock, while Democrats/Labour winning the election is followed by an inflation surprise. The inflation surprise is linked to a fall in unemployment, which makes good on the left-wing government's promise to its constituency and increases their chances of staying in power.

Alesina and Gatti (1995) conclude that allowing the government to use fiscal and monetary policy to their discretion has short-run effects on output and employment. This discretion also has a long-run impact on inflation: governments being in charge of both fiscal and monetary policy can generate an inflationary bias. Interestingly, the empirical evidence shows that allowing discretionary fiscal and monetary powers to the government bears no effect on growth.

There is a potential solution to the inflationary bias issue: making the central bank independent of government. Inflation is negatively related to the degree of Central Bank Independence (CBI), Alesina and Gatti (1995) argue, so an independent central bank committed to a long-term objective will achieve lower inflation with no repercussions for real growth or employment in the long run. CBI is essentially a *free lunch*!

Alesina and Summers (1993) argue that "an independent central bank [...] may behave more predictably, promoting economic stability". CBI can protect the economy from political business cycles. CBI can achieve the goal of constraining short-term discretionary actions of politicians, while preserving the basic principles of a democratic government.

4.2.2 Cooperation Between Governments and Central Banks

Separating monetary policy from fiscal policy, however, does not mean that Central Bank and government can exist as separate and never-crossing institutions: in truth their policy spaces often do overlap, because in some circumstances inflation and output can be two sides of the same coin, which leaves the door open for both cooperation as well as clashes. Clashing instances are the topic of this Chapter, but before diving into cases of disagreement it is helpful to give a brief overview of cases of cooperation, and what they can mean for the economy.

The discussion about the effects of cooperation was revived by the Great Financial Crisis, where for example the Federal Reserve cooperated closely with the U.S. Treasury. Meltzer (2009) criticised this close cooperation, arguing it risked sacrificing much of the independence the Federal Reserve had gained over previous decades by yielding to political pressure. Blinder (2012), on the other hand, argued that the desirability of close cooperation is contingent on the circumstances, distinguishing from normal times to during and after a serious financial crisis. In normal times central banks should be conducting monetary policy in a manner that is transparently independent of governments. Financial crises, however, make cooperation more natural for a number of reasons: first, the central bank is relatively less concerned with the long run and relatively more concerned with the short run economic performance, thus putting them on the same time horizon as the government. Second, it is not just the central bank's time horizons that change during a crisis, but also its principal objective: the central bank is now concerned with the survival of the financial system, aligning their goals with those of the government. Third, cooperation can serve to calm nervous financial markets. Fourth, financial crises can make the separation between monetary and fiscal policy extremely blurry — for example in the case of lending or asset purchasing of considerable size, which may even involve possible losses, "start looking like backdoor spending, or at least putting taxpayer money at risk — that is, like *fiscal* policy" (Blinder, 2012; p. 5). Finally, the government can lend accountability and legitimacy to the central bank: the government gives the actions of the central bank political legitimacy, and the central bank's accounting solvency might need to be backed by the government.

In the aftermath of a financial crisis, the economy can remain weak and in need of stimulus. Often in these circumstances monetary and fiscal policy powers are constrained — by the Zero Lower Bound on nominal interest rates, and by large budget deficits and accumulated debt. In the post-crisis period, monetary and fiscal policy should remain expansionary, while the central bank should slowly disengages from the government and gradually re-establish its independence.

During the global financial crisis starting in 2008, close coordination with the Treasury did not endanger the credibility of the Fed, Blinder argues, because anti-inflation credibility is only one aspect of credibility: promising and then delivering to "do whatever it takes" to handle a financial crisis successfully builds credibility for the future, even if that credibility is not explicitly about fighting inflation. Transparency and extensive communication are key to ensuring this success, to make sure that the public, markets, and politicians can understand any unusual or unprecedented policy measures.

4.2.3 Political Pressure

Alesina and Gatti (1995) reprise Grilli, Masciandaro, and Tabellini (1991) in distinguishing between two aspects of CBI: political and economic independence. Political independence, or goal-independence, is the ability of the central bank to set its policy objective without any interference from the government. Economic independence, or instrument-independence, is the ability of the central bank to use instruments of monetary policy without restrictions. While most central banks now have legal economic independence, political independence is in most cases only partial. Important things to consider in looking at the political independence of a central bank are whether the appointment of governor and/or board is controlled by the government, whether the participation in policy decisions of government officials is mandatory or government approval is required, or whether the role of the central bank is explicitly stated in the constitution (Grilli, Masciandaro, and Tabellini, 1991).

The discussion in Grilli, Masciandaro, and Tabellini (1991) already implies that institutional setting plays a key role in central bank independence and political pressure. The way a central bank is designed and the laws that regulate it determine its quality, and how easy it is for the government to politically pressure the central bank. Many central banks get their mandate directly from the government, for example the Fed; the mandate of the European Central Bank (henceforth: ECB), instead, comes from a Treaty negotiated between nations. While the Federal Reserve has legal mandate over prices as well as employment, the ECB's primary objective is price stability. We have seen the consequence of the ECB's strict framework in Germany questioning the legality of Quantitative Easing. Furthermore, in some contexts the government ratifies the decisions of the central bank (for example the Bank of Italy in pre-euro times), or elects some or all the members of the board of directors of the central bank (for example the Fed's Governors elected by Congress). The degree of transparency is not uniform across central banks either: both the Bank of England and the Federal Reserve publish their minutes within days from the meeting (Bank of England, n.d. and Federal Open Market Committee, n.d. respectively), but the US Federal Reserve also publishes its greenbook containing detailed information about decision-making after five years (Federal Reserve Bank of Philadelphia, n.d.).

Fry (1998) notes that, for his sample of developing countries, it is not independence alone that protects a central bank from political pressure, but rather independence alongside competence. The two, in fact, are likely intertwined: Fry argues that "independence is gained in large part through competence and the ability to demonstrate it" (Fry, 1998; p. 525). Competence is demonstrated by setting achievable goals and following through on promises, and continuous competence builds credibility towards successful independence.

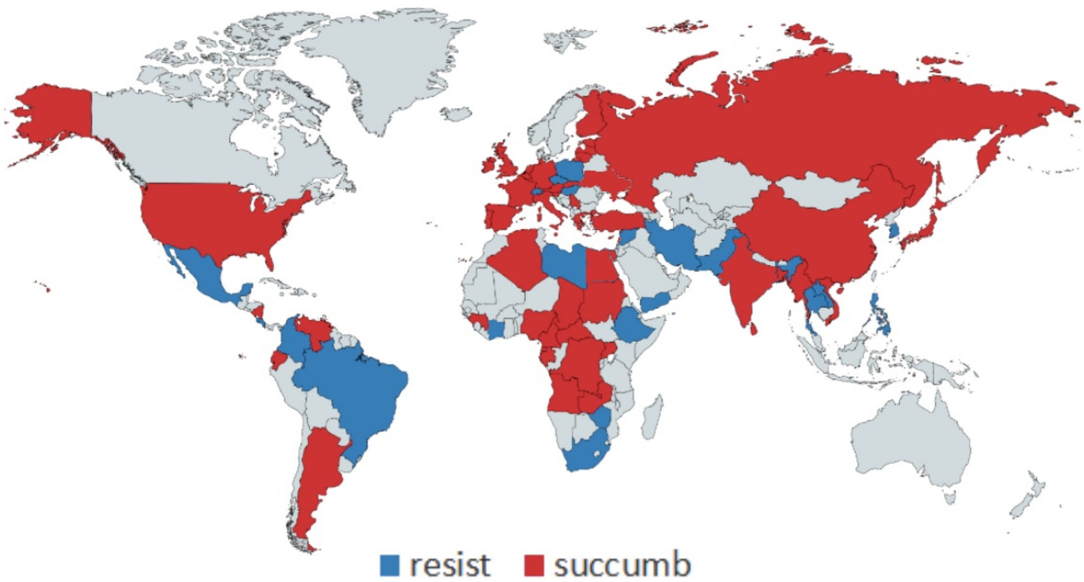
Nowadays most central banks have economic independence, both in the more classical institutional sense as well as in terms of credibility. Political independence, however, varies and is in general only partial. A weaker degree of political independence cannot isolate central banks from governments, leaving the door open to political pressure. When their objectives clash, the government might try to sway the central bank to act in accordance with political preferences.

This was apparently the case for the USA in the early 1970s: according to Abrams (2006) President Richard Nixon pressured Federal Reserve Chairman Arthur Burns to lower interest rates during 1970–1972 in an effort to lower unemployment and get re-elected. The excessive easing of monetary policy of 1971-1972 did reduce unemployment from the 6.2% in 1969 (the year Nixon took office) to 3.3% in 1972 and 3.4% in 1973. It also, however, exacerbated the inflationary boom created by the first oil price shock: the Consumer Price Index increased by 9.37% in 1973 and 11.8% in 1974.

Figure 4.1 uses Binder (2021) dataset on political pressure to map the Central Banks that have been pressured during 2010-2020, and how many of them succumbed to pressure. Empirical evidence provides some patterns when it comes to politically pressured central banks. Governments seem to have a preference for monetary policy to be loosened in the run-up to elections. This is certainly true for the U.S. (Havrilesky, 1988 and Froyen, Havrilesky, and Waud, 1997), but Binder (2021) shows that it holds true for central banks at different levels of independence and from a very diverse set of countries. Binder (2021) also finds that political pressure is more likely to come from governments with left-wing/nationalist politics, with fewer political checks and balances, or with weaker electoral competition. Pressure coming from a left-wing government is in line with a preference for ease in monetary policy, as that would match the traditional party's political bias. Many nationalist (and populist) governments also rest their power on the promise of a "return to more prosperous times", i.e. an expansion, so it does fit their narrative to create an output boost.

Political pressure on central banks generally correlates with higher and more persistent inflation,

Figure 4.1: Political Pressure, 2010-2020



The figure presents a map of political pressure, where the countries in red are those where the central bank succumbed at least once between 2010 and 2020; and the countries in blue are those where the central bank was pressured but never succumbed in the period.
Note: Based on Binder (2021)'s coding of Economist Intelligence Unit (EIU) and Business Monitor International (BMI) reports.

independently of the degree of legal central bank independence (Binder, 2021). Moreover, Binder (2021) finds that even if the central bank resists the government's political pressure, continuous pressure may lead to an erosion of trust.

This simple pattern implies two important results. First, it is interesting to notice that central bank independence was linked by Alesina and Gatti (1995) to lower inflation, and now political pressure correlates with higher inflation: political pressure undoes the benefits of central bank independence.

Second, political pressure and higher inflation are related independently of the quality of institutions: while the degree and practicalities of central bank independence certainly affect how easy political pressure might be, its link to higher inflation seems to be an independent macroeconomic feature. A clear message that emerges from this literature survey is that if governments and central banks have different preferences regarding short-term output boosts, conflict might ensue. If allowed, the government will pressure the central bank to act their way. If the central bank acts in favour of the government, for short-term reward rather than long-term stability, inflation is created. The credibility of the central bank is at stake.

Political pressure on central banks is indeed an ongoing issue: the Federal Reserve was under visible political pressure coming from the Trump administration and, more often than not, President Trump himself (Condon, 2018a). The central banks of India, Turkey, Russia, Nigeria, South

Africa, and Thailand have all been pressured in recent times (Condon, 2018b). At Davos 2018 the President of Argentina Macri was questioned on whether he has been pressuring the central bank to lower interest rates (Mander, 2018). The Governor of the Reserve Bank of India resigned in December 2018 after being pressured from the BJP (Bharatiya Janata Party) government (Nag, 2018). The Italian populist-rightwing coalition government recently criticised the Bank of Italy for its involvement in the banking crisis. The League politicians wanted to legally acknowledge that the reserves of the Bank of Italy belong to the Italian state, and the Bank's job is merely to manage them. The move was extensively seen as a threat to the Bank's independence (Johnson, 2019). Most recently, Liz Truss questioned the independence of the Bank of England in setting interest rates while running for the Conservative Party leadership (Bruce, 2022).

Economics commentators have been vocal in ringing bells about the global trend of political pressure and the risks to central bank independence: "Political Pressure Growing on Central Banks" by El-Erian (2016); "The End of the Era of Central Bank Independence" by Münchau (2016); "Central Bank Independence is Losing Its Lustre" by Münchau (2017); "Central Bank Independence is as Dead as Vaudeville" by Dizard (2019); "Central Bank Independence Under Increasing Threat, Fitch Says" by Ward (2019).

4.3 The Data

The databases used are shown in Table 4.1: I combine six datasets to compare information across fourteen variables. Some data needed to be manipulated to obtain the variable of interest for the analysis, as I will now describe. I list the variables used in the analysis, reporting the period each variable covers, in Table 4.2. The monthly and yearly data from Table 4.1 is transformed into quarterly by either aggregating by quarter or by using further information contained in the datasets to disaggregate it by quarter, and therefore all variables in Table 4.2 are quarterly. I choose to analyse data on a quarter level to better exploit the dataset on political pressure developed by Binder (2021), which indeed records pressure at the quarterly frequency. Aggregating the pressure data to the yearly frequency instead would have lost information and nuance.

I aggregate Global Economic Monitor data on CPI prices from monthly to quarterly by calculating the average over the quarter. I then calculate quarterly inflation as the percentage changes in the quarterly CPI from the previous quarter.

The income category is obtained applying the World Bank's classification on World Bank World Development Indicators GNI per capita data, which divides countries into four categories:

Table 4.1: Datasets

Dataset	Data	Years	Frequency
World Bank Global Economic Monitor (GEM)[1]	CPI Price, nominal, not seas. adj.	1992M07-2022M06	monthly
World Bank Database of Political Institutions (DPI)[2]	Political System Party Orientation & Nationalism Checks and Balances	1975-2017	yearly
World Bank World Development Indicators (WDI)[3]	Income Category Debt (% GDP)	1960-2021	yearly
Garriga (2016)[4]	*De jure* CBI Index (weighted)	1970-2012	yearly
Aizenman, Chinn, and Ito (2008)[5]	Monetary Independence Index Exchange Rate Stability Index Financial Openness Index	1960-2020	yearly
Transparency International[6]	Corruption Perceptions Index (CoPI)	2019	–
Binder (2021)[7]	Pressure type (none, resist, or succumb) Any pressure mentioned (dummy) Pressure to ease (dummy) Pressure to tighten (dummy)	2010Q1-2020Q4	quarterly

The table gives an overview of all datasets used in the chapter, with the variables used, period, and frequency.
[1]Data available at https://datacatalog.worldbank.org/dataset/global-economic-monitor
[2]Data available at https://datacatalog.worldbank.org/dataset/wps2283-database-political-institutions
[3]Data available at https://datacatalog.worldbank.org/dataset/world-development-indicators
[4]Data available at https://sites.google.com/site/carogarriga/cbi-data-1
[5]Data available at http://web.pdx.edu/ ito/trilemma_indexes.htm
[6]Data available at https://www.transparency.org/en/cpi/2019
[7]The database 2010Q1-2019Q1 is available at https://osf.io/kjcfh/. The updated version to 2020Q4 was shared by the author.

high income, upper-middle income, lower-middle income, and low income. The data on GNI per capita is yearly, and hence is the classification into income categories I derive from it. However, as countries show extremely limited variation of income classification from year to year, it is not unreasonable to assume that there is no variation between quarters and use the yearly income level classification for each quarter of the year. The classification is updated annually by the World Bank.[1]

Similarly, the data available on government debt as a percentage of GDP is on an annual basis. In this analysis I assume that debt-to-GDP changes linearly during the year, which translates into constant increments each quarter. While debt as a share of GDP may often not change linearly, assuming it does is a better approximation than assuming the debt-to-GDP level is constant during the year. This would translate into the debt-to-GDP level jumping to the new level on January 1st of each year, which is a bigger distortion than assuming debt-to-GDP changes linearly. Another option

[1]More information can be found on the World Bank website.

would have been to only use the debt-to-GDP for the fourth quarter of the year, as the debt-to-GDP figures are calculated and given as of December 31st. This approach, however, would lose three quarters of the data: while it would be more accurate, it would make the analysis unreliable because of the small sample size.

Data from the Database of Political Institutions on political factors is also annual: this is not an issue for checks and balances or political system, as these do not vary in the decade considered so it is again reasonable to take yearly data as constant across quarters, but would be an obstacle for party orientation and nationalism, because these change over the year when a new government is elected. However, the dataset contains information on when elections were held.[2] This information allows me to transform the data on politics of the government from yearly into quarterly, assuming the new government is in power from the quarter after the election takes place.[3]

Following Binder (2021) I also calculate the 2010-2012 average of the *de jure* CBI Index developed by Garriga (2016), and use it for the whole period considered. The CBI Index is built upon information identifying statutory reforms affecting CBI, their direction, and the attributes necessary to build the Cukierman, Webb, and Neyapti (1992) index.

The indexes of monetary independence, exchange rate stability, and financial openness were developed by Aizenman, Chinn, and Ito (2008). As for the income categories, because of the very low variation in the indexes from year to year, I assumed that there was no unrecorded variation between quarters and that all changes in indexes happen in the first quarter. This assumption allows me to disaggregate the data into quarters.

The Corruption Perceptions Index developed by Transparency International ranks 180 countries and territories by their perceived levels of public sector corruption. The Corruption Perceptions Index is a composite index: it combines 13 surveys and assessments of corruption, collected by 12 independent institutions specialising in governance and business climate analysis. The most recent index, released in 2019, is used for the entire period.

Finally, the dataset developed by Binder (2021) codes political pressure from country reports from the Economist Intelligence Unit (EIU) and Business Monitor International (BMI). The variables of interests are the dummies for any pressure mentioned, pressure to ease policy, and pressure to tighten, as well as the variable coding whether pressured central banks resisted or succumbed. Binder collected all EIU and BMI reports from 2010 to 2018 that mention "central bank", "monetary policy", "reserve bank", or "national bank", and at least one of the following phrases: "political

[2] In the DPI dataset *executive elections* are relevant for presidential systems, while *legislative elections* for assembly-elected presidents and parliamentary systems.

[3] An exception is Belgium 2010-2011, and it was manually corrected.

pressure", "political interference", "government interference", "threat to independence", "independence threatened", "print money", "money printing", "monetize", or "monetise". She codes the central bank as *resisting* if reports "note that the central bank is resisting or attempting to resist actual, potential, or perceived government pressure, or that the effects of the pressure on the bank are not yet known" (Binder, 2021; p. 719). She codes the central bank as *succumbing* whenever "reports say that political pressure or government interference affects or will affect central bank policy, or imply that the government directly controls the central bank or money supply" (Binder, 2021; p. 719). She distinguishes between pressure to ease policy, pressure to tighten, pressure to print money (included in *pressure to ease policy*, but also coded by itself), pressure to replace the governor, and pressure to change legislation.

Table 4.2: Variables

Variable	Period Covered	Notes
Inflation	2010Q1-2020Q4	Quarter-to-quarter change
Political System	2010Q1-2017Q4	
Party Orientation	2010Q1-2017Q4	
Party Nationalism	2010Q1-2017Q4	
Checks and Balances	2010Q1-2017Q4	
Income Category	2010Q1-2020Q4	Constant across quarters for each year
Debt (% GDP)	2010Q1-2020Q4	Constant increments from Q1 to Q4 each year
De jure CBI Index	2010Q1-2020Q4	Constant to average of 2010-2012 CBI Index (weighted)
Monetary Independence Index	2010Q1-2020Q4	Constant across quarters for each year
Exchange Rate Stability Index	2010Q1-2020Q4	Constant across quarters for each year
Financial Openness Index	2010Q1-2020Q4	Constant across quarters for each year
Corruption Perceptions Index	2010Q1-2020Q4	Constant across the period
Pressure type	2010Q1-2020Q4	
Any pressure mentioned	2010Q1-2020Q4	
Pressure to ease	2010Q1-2020Q4	
Pressure to tighten	2010Q1-2020Q4	

The table gives an overview of all variables used in the chapter, the maximum period covered by these variables between 2010Q1 and 2020Q4, and notes where relevant.

Table 4.2 shows the list of variables used in the analysis. The analysis is conducted on quarterly data, 2010Q1-2020Q4 (2017Q4 for DPI data), on 118 central banks covering 153 countries, for a total of 6,732 observations. Appendix C.1 goes into detail on availability of data across datasets, country by country.

4.4 Analysis and Results

In Section 4.4.1 I explore the general patterns of political pressure. Most political pressure observed is pressure to ease policy, and repeated pressure is uncommon. I separately investigate whether pressure to ease policy is related to characteristics of the country (Section 4.4.2) or to characteristics of the central bank (Section 4.4.3), and then look at the relationship between pressure to ease policy and inflation (Section 4.4.4).

4.4.1 Patterns of Political Pressure

As per Table 4.3, pressure to ease policy is by far the most common type of pressure representing 81.0% of all recorded pressure (252 out of 311 cases). Pressure to tighten (i.e. raise interest rates) is far less common, at 5.5% of all recorded pressure (17 out of 311 cases). Pressure to change the legislation or constitution governing the central bank is almost always contemporaneous to pressure to either ease or tighten, and as their connection to inflation is less straight-forward I do not include them here. For the 311 cases of pressure recorded during the period 2010-2018, 57.9% of the time the central bank succumbed to the pressure, and 52.4% of the time to pressure to ease policy.

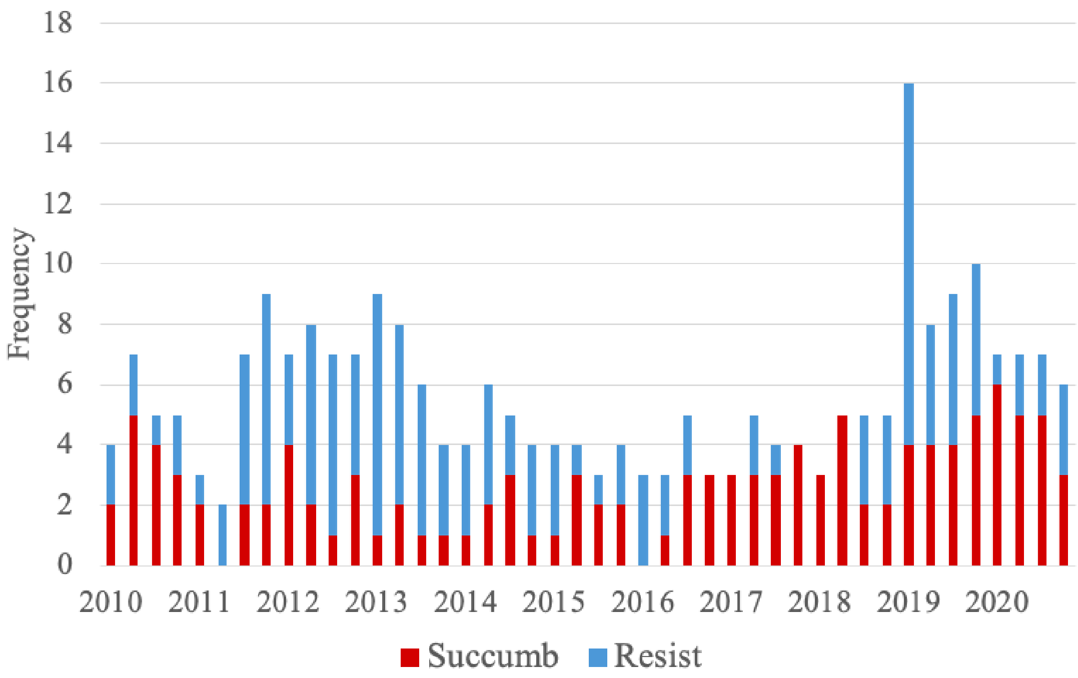
Because of the relevance of pressure to ease policy, and because pressure to tighten is rare and hence its sample size is too small to analyse, I focus my analysis on the former. pressure to ease policy and pressure to tighten have opposing effects on the economy, and it is therefore reasonable to assume they are motivated by different objectives. Conducting separate analyses for pressure to ease policy and pressure to tighten is more appropriate, as grouping them is likely to bias the results. This is particularly relevant when analysing the link with inflation.

Table 4.3: Cases of Political Pressure (Quarterly, 2010Q1-2020Q4)

	Resist	Succumb	Total
No Pressure	-	-	4,881
Pressure	180	131	311
to ease	132	120	252
to tighten	13	4	17

The table presents the number of cases of no pressure and pressure, by type (to ease and to tighten) and by outcome (resist or succumb).
Notes:
- Angola 2016Q2 and Vietnam 2014Q1 had contemporaneous pressure to ease policy and to tighten; they are therefore excluded from the rest of the analysis.
- Other types of pressure here not considered: pressure to replace the governor, and pressure to change legislation.

Figure 4.2: Pressure to Ease Policy Across Countries



The figure presents the quarterly frequency of cases of pressure to ease policy from 2010Q1 to 2020Q4. The stacked columns give the number of cases of central banks succumbing to pressure to ease policy in red, and the number of cases of central banks resisting to pressure to ease policy in blue.

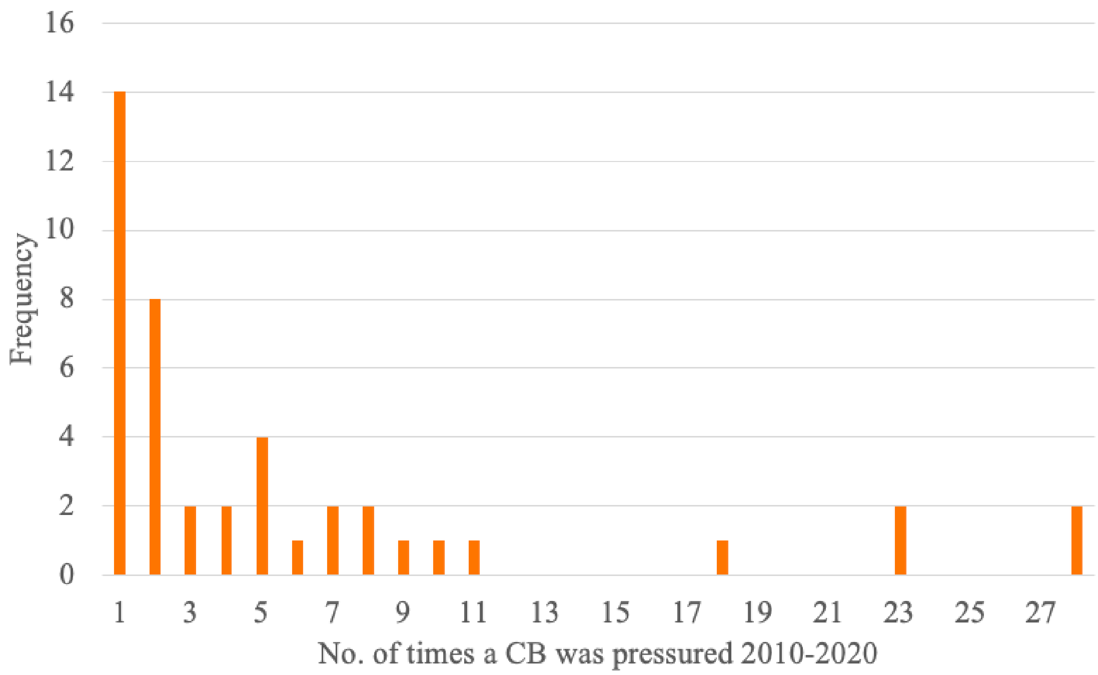
The data shows an average of 5.7 cases of pressure to ease policy and 2.7 cases of succumbing to the pressure per quarter over the whole period. Figure 4.2 seems to suggest a period of lower pressure to ease policy between 2014 and 2018, and a higher incidence of succumbing to pressure to ease policy in 2019 and 2020. However, establishing and investigating temporal patterns would require studying a longer time period.

It is uncommon for a central bank to be subject to repeated pressure (see Figure 4.3): it is most common for central banks to be pressured only once, and roughly 2 in 3 central banks were pressured on 5 or less occasions from 2010 to 2020. The countries with central banks most often pressured are: Turkey, pressured 28 times (succumbed 23 times); Angola, pressured 28 times (succumbed 11 times); Venezuela, pressured 23 times (succumbed all 23 times); Myanmar, pressured 23 times (succumbed 19 times); and finally Argentina, pressured 18 times (succumbed 8 times). See Appendix C.1 for the list of central banks that were pressured, how many times, and how many times they succumbed.

4.4.2 Country Characteristics

Table 4.4 investigates whether the income category, political checks and balances, political system, or party orientation and nationalism are related to the frequency of pressure. The first column

Figure 4.3: Counts of Pressure to Ease Policy (Quarterly, 2010Q1-2020Q4)



The figure presents the frequency of how many times a central bank was pressured to ease from 2010Q1 to 2020Q4, from being pressured once to being pressured 28 times. The figure only includes central banks that were pressured, excluding central banks that were pressured zero times in the period considered.

reports the number of observations for each category. *Pressure* reports the number of cases of pressure to ease policy, and *Succumb* the number of times the pressured central bank succumbed and eased monetary policy. *Share* gives the percentage of time that a central bank in the specified category was pressured or succumbed. They are measures for the likelihood of a central bank belonging to a certain category of being pressured or succumbing. Computed likelihoods might differ across subgroups, yet these differences might not be statistically significant. Tables C.3—C.9 in Appendix C.3 report the results of t-tests on pairwise differences.

Previous studies connected income level to legal CBI and to political pressure, as wealthier countries tend to be countries with stronger institutions. The World Bank classifies countries into four income categories based on their GNI per capita: high, upper-middle, lower-middle, and low income. Fewer observations are recorded for low-income countries compared to other income categories.

Central banks in high income countries are pressured significantly less than central banks in any other income group, and succumb less than all other central banks. Central banks in upper-middle income countries are pressured more than those in lower-middle income countries, yet succumb at similar rates. Central banks in upper-middle income countries are also pressured at similar rates as central banks in low income countries, yet succumb less often. Finally, central banks in

Table 4.4: Pressure to Ease Policy by Characteristics of Country (Quarterly, 2010Q1-2020Q4)

	Obs.	**Pressure**	**Share** (%)	**Succumb**	**Share** (%)
Income Category					
High	1,360	29	2.13	6	20.69
Upper-middle	1,700	87	5.12	37	42.53
Lower-middle	1,354	91	6.72	38	41.76
Low	464	18	3.88	12	66.67
Debt (% GDP)					
Extremely High (Top 5%)	48	8	16.67	2	25.00
High (Top 50%)	477	19	3.98	4	21.05
Low (Bottom 50%)	476	21	4.41	12	57.14
CPI					
High (Top 50%)	2,552	89	3.49	46	51.69
Low (Bottom 50%)	2,418	157	6.49	68	43.31
Checks & Balances					
High (5–9)	348	11	3.16	4	36.36
Low (0–4)	3,070	145	4.72	60	41.38
Political System					
Presidential	2,159	117	5.42	43	36.75
Assembly-el. President	255	6	2.35	4	66.67
Parliamentary	1,088	34	3.13	18	52.94
Party Orientation					
Right	612	14	2.29	2	14.29
Centre	246	6	2.44	1	16.67
Left	1,000	46	4.60	18	39.13
Other	1,527	91	5.96	44	48.35
NA (no executive)	89	0	-	-	-
Nationalism					
Not nationalist	2,954	103	3.48	53	51.46
Nationalist	477	54	11.32	12	22.22
NA (no executive)	59	0	-	-	-
Total	5,014	246	4.91	114	46.34

In this table I divide all the countries in the dataset based on their values in a number of country-related characteristics: for example based on the level of GNI per capita, I divide the countries into four income categories (high income, upper-middle income, lower-middle income, and low income). For each group I give the number of observations in the dataset that fall into this category, for example 1,360 observations in the datasets are from countries who, in the quarter considered, where high-income countries. Then I present the cases of pressure to ease policy, as the number of cases and as a share of all observations; and the cases of succumbing to the pressure, as the number of cases and as a share of all cases of pressure. I do this for income categories, debt as a share of GDP, the Corruption Perceptions Index, political checks and balances, political system, party orientation and nationalism.

Note: countries member of the BCEAO, the BEAC, the ECB and the ECCB are excluded. These central banks span multiple countries and the political pressure dataset does not specify which country's government is responsible for pressuring the central bank.

lower-middle income countries are pressured more than central banks in low income countries, but succumb less often. To summarise, then, most of the time the likelihood of pressure stays the same or increases as income decreases, with the exception of the likelihood of pressure in lower-middle and low income countries, where the relationship is reversed. While country income categorisation seems to be related to pressure, the data suggests that this relationship is not linear.

From 2010 to 2020, the median government debt across countries is 46.07% of GDP. I classify as "High Debt" the countries with a debt-to-GDP level above the median, and as "Low Debt" the countries with a debt-to-GDP level below the median. I also present the results for the top 5% of the debt-to-GDP distribution, i.e. debt levels above 134.15% of GDP, which I group in the "Extremely High-Debt" category. This high-debt group contains 48 observations from three distinct countries: Barbados, Jamaica, and Japan.

The likelihood of pressure on central banks does not differ significantly between countries with above-median and below-median levels of debt-to-GDP, and these central banks are pressured at the same rate. In countries in the top 5% of debt-to-GDP level distribution, however, the central banks are pressured significantly more often. It is possible that the governments of these countries find servicing high levels of debt-to-GDP to be expensive, and therefore pressure the central bank to lower the interest rate as this would make debt cheaper to service and therefore less unsustainable. Further research can expand this topic by differentiating debt between domestic and international, to investigate whether this differentiation is linked to the likelihood of pressure.

The data also shows that countries with above-median levels of debt-to-GDP are significantly less likely to see the central bank succumb to pressure. This might be because in countries with high levels of debt-to-GDP the marginal cost of succumbing to the pressure is higher for the central bank: if they did succumb to pressure, this would allow the government to borrow more cheaply and add on to the debt stock, making debt more expensive and the economy as a whole generally weaker. On the other hand, central banks in countries with low levels of debt-to-GDP have a lower marginal cost from succumbing to pressure, because the debt stock is lower.

The Corruption Perceptions Index is scored by the Transparency Group on a range from 0 to 100, where lower scores signify a higher perception of corruption. The median value for the countries considered is 38, and therefore I split the group into high Corruption Perceptions Index if their score is 38 or above, and low Corruption Perceptions Index if their score is below 38. Table 4.4 shows that in countries with low Corruption Perceptions Index central banks are more likely to be pressured compared to countries with high Corruption Perceptions Index, but are not more likely to succumb to pressure. As the Corruption Perceptions Index measures perceived corruption as opposed to effective corruption, we can deduce that observing the government pressure the central bank into lowering the interest rate contributes to creating a perception of public sector corruption, while observing the central bank succumb to this pressure appears to have no bearing on perceived corruption levels.

Political checks and balances are designed to push the government towards more accountability and transparency, and therefore stronger checks would be associated with less political pressure. Checks and balances are coded in the DPI dataset to take a range of integer values from 0 to 9; I therefore split them into two groups: high (5-9 points) and low (0-4 points). Most countries seem to have low checks and balances, as above 60% of observations belong to this category.

As expected, central banks in countries with low checks and balances are pressured significantly more. They do, however, succumb to pressure significantly less. One must remember that the variable "Checks & Balances" obtained from the DPI dataset refers only to the government, and not to the checks and balances of the central bank, so this grouping is likely not informative for succumbing trends.

Similarly to checks and balances, certain political systems might discourage (or encourage) pressure because of the structure of power. In presidential systems, executive and legislative powers are separated, while in parliamentary systems they are not, with possible consequences for the ease and likelihood of political pressure. The political system is divided into presidential, assembly-elected president and parliamentary. The most common system is presidential, the least common is an assembly-elected president.

The political system seems to be significantly related to pressure, albeit not to succumbing. Pressure is significantly more likely for presidential systems than with an assembly-elected president or for parliamentary systems. This is to be linked to the nature of presidential systems: their power duality, alongside the presidential autonomy, inhibits accountability (Linz, 1990 and 1994). As a consequence, a presidential system is often less able "to control its appointed officials", less stable, and ultimately more likely to slip into authoritarianism (Riggs, 1997; p. 257). The results seem to suggest that the structure of presidential systems indeed makes political pressure more likely.

Lastly, differentiating pressure by party orientation and nationalism might help uncover political motives behind the pressure: as noted in Section 4.2, left-wing governments have a preference for loose monetary policy, which could make them more likely to pressure the central bank to ease policy. The party orientation with respect to economic policy is as follows: right, if conservative, Christian democratic, or right-wing; left, if communist, socialist, social democratic, or left-wing; centre, if centrist or best described as centrist (not if competing factions average out to a centrist position); other, if do not fit into one of the above-mentioned categories (i.e., party's platform does not focus on economic issues, or there are competing wings), or no information. For the period 2010Q1-2017Q4 the DPI dataset shows 612 cases of right-wing governments, 1,000 cases of left-wing governments, 246 cases of centrist governments, 1,527 cases of other governments, and 89 cases of no government. Of these same governments, 477 cases were nationalist while 2,954 cases were not nationalist. DPI records a party to be nationalist if the "party is listed as nationalist in Europa, Banks, Political Handbook, or the Agora website [or] a primary component of the party's platform is the creation or defense of a national or ethnic identity" (Cruz, Keefer, and Scartascini, 2018; p. 7).

The politics of the party in government appear to play a very important role in the occurrence of pressure: political pressure is significantly more likely to come from left/other Parties rather than from right/centre Parties. Furthermore, nationalist Parties are over three times more likely to pressure than non-nationalist Parties. In Table 4.5 I combine this information and split the Parties into four clusters: (i) nationalist right-wing and centrist, (ii) not-nationalist right-wing, centrist, and left-wing Parties, (iii) not-nationalist other Parties, and (iv) nationalist left-wing and other Parties. The t-test shows that these four cluster are significantly distinct (see Table C.10 in Appendix C.3).

I find no pressure from the first cluster, low pressure from the second cluster, medium pressure from the third cluster, and high pressure from the fourth cluster. In the low-pressure cluster (i.e. cluster ii) 18 Parties are responsible for 36 cases of pressure over the period 2010-2017, with Parties pressuring on average 13.18% of the time they are in office. For the same period, the 15 Parties of the medium-pressure cluster (i.e. cluster iii) pressured significantly more often: 67 cases, or 26.24% of the time they are in office. In the high-pressure cluster (i.e. cluster iv) pressure is even more concentrated: 54 cases coming from only 5 Parties, which pressure 36.60% of the time they are in office.

75% of pressured central banks are subject to fewer than 5 cases of pressure, and 75% of politically pressuring Parties do so 5 or fewer times. The behaviour of most pressuring Parties is to pressure sporadically, either by choice or by lack of opportunity (i.e. not being in office long enough). Some Parties, however, are repeat offenders of pressure to ease policy, and have applied pressure on their central bank on repeated occasions. Table 4.6 reports figures for the top quartile of pressuring Parties: how often they pressured in absolute terms and as a share of time in office, along with their political orientation.

Table 4.6 confirms nationalist Parties, left-wing or other, to be one of the major guilty parties of political pressure. It also suggests the existence of another culprit: populist Parties, left- or

Table 4.5: Pressure to Ease Policy by Party Orientation and Nationalism (Quarterly, 2010Q1-2017Q4)

		Obs.	Pressure	Share (%)
(i)	Nationalist Right and Centre	68	0	0.00
(ii)	Not Nationalist Right, Centre, and Left	1,580	36	2.28
(iii)	Not Nationalist Other	1,326	67	5.05
(iv)	Nationalist Left and Other	409	54	13.20
Total		3,383	157	4.64

The table gives the four party clusters based on their party orientation and nationalist, the number of observations for each cluster, and the cases of pressure to ease policy as a number of cases and as a share of all observations in the cluster.

Table 4.6: Top Quartile of Pressure to Ease Policy

No. Pressure	As Share of Time in Office (%)	Party	Orientation	Country
26	83.87	MPLA	Left-wing nationalist	Angola
18	56.25	AKP	Other (populist)	Turkey
11	34.38	Ba'ath	Other (religious) nationalist	Syria
11	34.38	PSUV	Other (populist)	Venezuela, RB
9	45.00	USDP	Other (military) semi-nationalist[1]	Myanmar
7	87.50	-	Military regime	Myanmar
7	21.88	ZANU-PF	Other nationalist	Zimbabwe
6	30.00	GPC	Other nationalist	Yemen, Rep.
11.86	*49.16*	*Average for top quartile*		
4.13	*21.62*	*Average for all pressuring parties*		

The table gives the party name, orientation, and country for the top quartile of political pressure to ease policy, with the cases of pressure to ease policy as a number of cases and as a share of the party's time in office.

right-wing. The DPI dataset does not classify political parties on populism, so this conjecture cannot, at present, be further investigated. One must further note that these repeat offenders operate in countries that are perceived by their own citizens to be quite corrupt: in the 2019 Corruption Perceptions Index, out of 180 countries Turkey ranks 91st, Myanmar 130th, Angola 146th, Zimbabwe 158th, Venezuela 173rd, and Syria 178th (Transparency International, 2019). Political pressure might yet be another instance of corruption and poor governance going hand in hand, a process that sands the wheels of development (Aidt, 2009, and broadly Acemoglu, Johnson, and Robinson, 2005).

Myanmar's military regime, the Justice and Development Party (Adalet ve Kalkınma Partisi, AKP) of Turkey, and the United Socialist Party of Venezuela (Partido Socialista Unido de Venezuela, PSUV), all mentioned in Table 4.6, are three examples of other non-nationalist Parties that have pressured their central bank between 2010 and 2020. In particular, Turkey's AKP and Venezuela's PSUV are both often quoted to be populist Parties. Myanmar's Union Solidarity and Development Party (USDP) is the successor of the military regime. While it is not coded in the DPI dataset to be a nationalist party as of 2017, its nationalism has been rising in the past few years, see for example Nachemson (2020), and the country suffered a military coup in February 2021. More non-nationalist Parties with other political orientation that pressured their central banks are the Democratic Party of Japan (DPJ) and the Liberal Democratic Party (LDP) in Japan. All of these Parties have pressured their central bank five times or more between 2010 and 2020.

Table 4.6 presents all three other nationalist Parties that have pressured their central bank between 2010 and 2020. These are: Syrian-led Ba'ath Party, a religious nationalist party; the Zimbabwe African the populist National Union – Patriotic Front (ZANU–PF); and the General People's Congress (GPC) in Yemen.

The reasons for Parties applying repeated pressure on central banks seem to be often rooted in challenging macroeconomic circumstances. Some examples are Turkey's ongoing currency and debt crisis, Venezuela's hyperinflationary crisis, or Syria's war.

After analysing the data, one must finally ask: what makes left-wing and other nationalist and, perhaps, populist Parties more prone to politically pressure the central bank? I conjecture that the reason might in fact lie in political pressure fitting the political bias and the narratives of these Parties. As mentioned in Section 4.2, the political economy literature has long found left-wing Parties to have a smaller distaste for inflation, and a stronger preference for lower unemployment. Easing monetary policy would create an output boost, through higher public or private borrowing. In turn an output boost would reduce unemployment, in line with traditionally left-wing policy preferences. It is possible that these preferences are stronger in nationalist (and populist) Parties, or that these Parties are less concerned with the current *status quo* of governments not interfering in monetary policy.

Political narratives might be a concurrent factor. Looking at the narratives of nationalist and populist Parties, De Cleen and Stavrakakis (2017) argue that nationalists and populists construct their discourse differently: the former claim to represent the people as nation, the latter as underdog instead. Nationalistic narrative is centred around national belonging and a limited and sovereign community, and is validated by the strength of the nation. An important dimension of this strength is, of course, economic strength. Boosting the economy by means of political pressure on the central bank would fit the narrative of economic strength, by reducing unemployment. The core to populist narrative, on the other hand, is the idea of good people reclaiming power from corrupt elites. In this context the central bank could be framed as the corrupt elite, and the political pressure would be in itself be part of the act of reclaiming power.

Whether or not populism can be strongly linked to political pressure needs further investigation. The data and literature on nationalist left-wing Parties, on the other hand, seems to indicate that they are the most likely to pressure the central bank because achieving a monetary policy ease is in line with their policy bias and fits their political narrative.

Table 4.7: Pressure to Ease Policy Before and After Elections (2010Q1-2017Q4)

	Obs.	**Mean** (%)	**Std. Error**
Before Election	858	3.61	0.637
After Election	991	4.14	0.632
Combined	1,849	3.89	0.450
Difference		-0.52	0.898

The table gives the overall number of observations, the mean number of cases of pressure to ease policy and its standard error, up to 6 quarters before and up to 6 quarters after election. The table also gives the difference between the two means, and its standard error.
Note: significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Lastly, I investigate whether the pressure to ease policy is connected to the political cycle by counting the cases of pressure up to 6 quarters before an election, and for 6 quarters from when the new government is installed. Table 4.7 shows that there is no significant difference in the likelihood of pressure before or after an election. This evidence does not point to political pressure to ease policy and the political cycle being linked.

There are instances in the literature of central banks being more inclined to cut interest rates prior to elections: an example is the Federal Reserve in the already cited Burns-Nixon era as well as the Volcker-Reagan era, as argued by Funashima (2016). However, these seem to be isolated cases, with no evidence of this being consistent pattern across time and across geographies, as seen in Leertouwer and Maier (2001). They used a monthly panel model for 14 OECD countries to separately investigate the effect of fiscal and monetary policy in creating Political Business Cycles (PBCs), with data from the 1960s to 1997. Leertouwer and Maier (2001), indeed, found no evidence of cyclical behavior in the short-term interest rate, and were therefore able to exclude the hypothesis that central banks generally do not create PBCs. My result expands on this: central banks do not systematically ease interest rates before elections, nor are they pressured to.

4.4.3 Central Bank Characteristics

This Section turns to the characteristics of the central bank itself, to investigate whether its institutional features could make pressure to ease policy more or less likely, as well as more or less likely to succumb to. The characteristics of the central bank that I consider here were introduced in Section 4.3, and are: the *de jure* CBI Index developed by Garriga (2016), and the indexes of monetary independence, exchange rate stability, and financial openness developed by Aizenman, Chinn, and Ito (2008). Garriga (2016) builds the CBI Index following Cukierman, Webb, and Neyapti (1992)'s criteria, which measure and code four components of CBI: financial independence, policy independence, personnel independence, and central bank objectives. Cukierman, Webb, and Neyapti (1992) provides variables to be considered for each of the four components, as well as the weight they are assigned and the numerical coding. The CBI Index takes values between zero and one. As for the trilemma indexes developed by Aizenman, Chinn, and Ito (2008), they measure the Monetary Independence Index as the reciprocal of the annual correlation of the monthly interest rates between the home country and the USA (used as base country), using money market rates. For the exchange rate stability, they measure annual standard deviations of the monthly exchange rate between each country and the USA, and normalize the index to be between zero and one. Finally, the measurement of the Financial Openness follows Chinn and Ito (2006, 2008): based on the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER), it takes into account the presence of multiple exchange rates, restrictions on current account transactions, on capital account transactions, and the requirement of the surrender of export proceeds. These factors are weighted and the index normalised between zero and one.

Before proceeding with the analysis, it is worth noting that there is some overlap between the CBI Index and the policy trilemma indexes: one of the components of the CBI Index is policy independence, which is similar to monetary independence. The policy independence within the CBI Index and the Monetary Policy Index are however measured in different ways: the former is based on collating and scoring a number of policy features (for example who formulates monetary policy, or who has the final word in resolution of conflict). The latter, as discussed above, is calculated from monthly interest rates. The CBI Index, then, considers *de jure* independence in monetary policy, while the Monetary Policy Index considers *de facto* independence. We can expect the two to be often related, but at the same time it should be noted that *de facto* measures are more sensitive to macroeconomic effects other than solely policy decisions (Aizenman, Chinn, & Ito, 2008).

Table 4.8 presents the cases of pressure and succumbing to this pressure, and the likelihood for both (as defined for Table 4.4), by the degree of *de jure* CBI and the three policy indexes are related to the frequency of pressure. Tables C.11—C.14 in Appendix C.3 report the t-test tables of whether shares (likelihoods) are pairwise statistically-significantly different or not.

Table 4.8: Pressure to Ease Policy by Characteristics of Central Bank (Quarterly, 2010Q1-2020Q4)

	Obs.	Pressure	Share (%)	Succumb	Share (%)
CBI Index					
High (75-100%)	1,276	59	4.62	34	57.63
Upper-middle (50-75%)	1,232	47	3.81	27	57.45
Lower-middle (25-50%)	1,276	75	5.88	35	46.67
Low (0-25%)	1,231	41	3.33	11	26.83
Monetary Independence Index					
High (Top 50%)	2,011	96	4.77	57	59.38
Low (Bottom 50%)	2,011	98	4.87	46	46.94
Exchange Rate Stability Index					
High (Top 50%)	2,335	66	2.62	35	53.03
Low (Bottom 50%)	2,335	150	5.55	72	46.94
Financial Openness Index					
High (Top 50%)	2,168	34	1.59	7	20.59
Low (Bottom 50%)	2,170	183	7.44	90	46.63
Total	5,190	250	4.82	118	47.20

In this table I divide all the central banks in the dataset based on their values in a number of central-bank-related characteristics: for example based on the level of CBI index, I divide the countries into four categories (high CBI, upper-middle CBI, lower-middle CBI, and low CBI). For each group I give the number of observations in the dataset that fall into this category, for example 1,276 observations in the datasets are from central banks who, in the quarter considered, had a high level of CBI. Then I present the cases of pressure to ease policy, as the number of cases and as a share of all observations; and the cases of succumbing to the pressure, as the number of cases and as a share of all cases of pressure. I do this for CBI index, monetary independence index, exchange rate stability index, and financial openness index. Note: index values are often not uniform across member countries of currency unions. I use the average across member countries as index value for their central bank.

The literature suggests that political pressure is linked to the level of CBI, as central banks with a higher degree of independence would be shielded from political pressured, or pressure would be less successful. I divide *CBI Index* data from Garriga (2016) into quartiles: high (top 25%), upper-middle (75-50%), lower-middle (50-25%), and low (bottom 25%). Informed by the literature, I expect that either frequency of pressure or likelihood of succumbing, or both, will increase as the CBI Index decreases.

I do find evidence of a link between the *de jure* CBI Index and political pressure in the data, but not one in line with what the literature predicts. My analysis shows that central banks with lower-middle CBI is significantly more likely to be pressured compared to any other group: not only they are pressured more often than central banks with higher CBI, but are also pressured more than central banks with lower CBI. As for the likelihood of succumbing, central banks with low CBI are significantly less likely to succumb than any other group, and there are no significant differences between central banks with high, upper-middle, or lower-middle CBI. Central banks with low CBI being the least likely to succumb to pressure is, once again, in contrast to the literature.

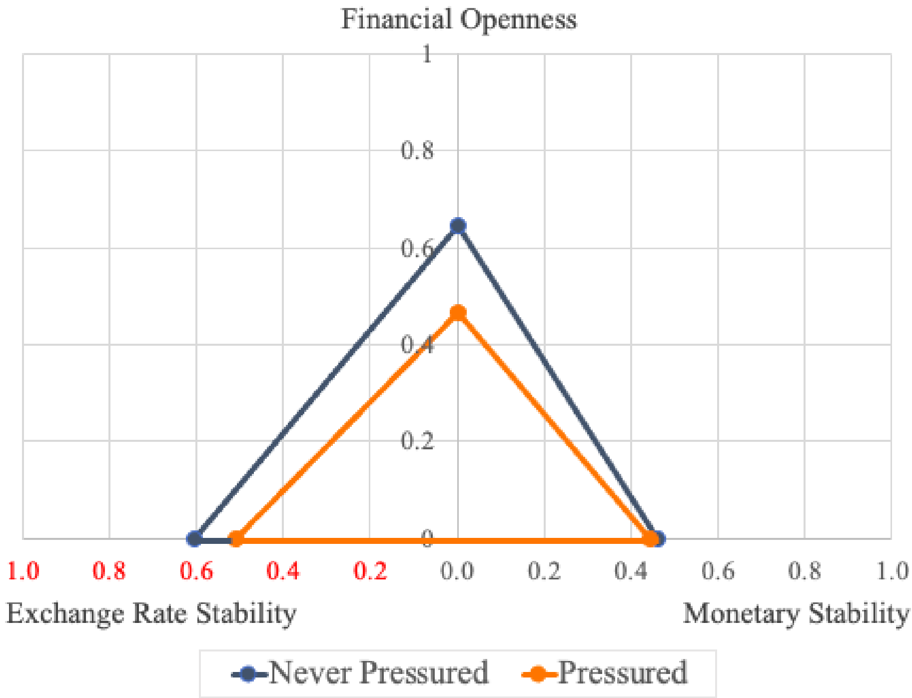
These result seems somewhat counter-intuitive, and should be further investigated. Overall, the fact that the link between CBI Index and the likelihood of pressure and of succumbing does not follow the predictions from the literature suggests that central bank independence might not be the panacea to politicians co-opting the tools and means of the monetary authority. It should however be kept in mind that the CBI Index used here is only available up to 2012: a more updated index is required to provide a more accurate analysis.

The degree of monetary independence is an obvious factor to investigate in relation to pressure to ease policy the interest rate. In order for the pressure to be successful, the central bank must have the ability to manipulate the interest rate, so it is possible that lower the degree of monetary independence are linked to lower chances of being pressured, as the pressure would hardly pay off. Looking at monetary independence alone, however, would miss the larger picture: monetary independence is related to exchange rate stability and financial openness. As per the infamous impossibility trilemma introduced by Mundell and Fleming in the 1960s (Boughton, 2003), an economy cannot simultaneously achieve free capital flow, fixed exchange rate, and sovereign monetary policy. A central bank can only pursue two out of the three mentioned policies. I therefore believe it appropriate to not only investigate if the degree of monetary independence is linked to political pressure, but also whether the degrees of exchange rate stability and financial openness are linked to it. It is possible that choosing a different combination of policies exposes the central bank to higher risk of being pressured.

I split each of the three indexes into high (above median) and low (below median). The results strongly suggest that the central bank's positioning on the policy trilemma and political pressure are connected. First, contrary to expectation, central banks with low monetary independence are not more or less likely to be pressured than central banks with high monetary independence, though they are less likely to succumb . Second, central banks with low exchange rate stability or low financial openness are more likely to be pressured than their peers with high exchange rate stability and high financial openness, respectively. Third, central banks with low financial openness are also more likely to succumb.

Figure 4.4 helps visualise these two points by plotting two policy triangles: one obtained from the average values of the three indexes of central banks who were pressured at least once in the period 2010-2020 (orange triangle), and one from the average values of central banks who were

Figure 4.4: The Policy Trilemma and Pressure to Ease Policy



The figure presents the policy triangle of central banks that were never pressured in the period between 2010 and 2020, compared to those who were pressured. The two triangles are constructed by connecting the average values of monetary stability, financial openness, and exchange rate stability for these two cohorts.

never pressured in the period 2010-2020 (blue triangle). The two groups do not have significantly different degrees of monetary independence, yet pressured central banks have significantly lower degrees of exchange rate stability and financial openness, resulting in a smaller policy triangle. See Tables C.15, C.16, and C.17 in Appendix C.3 for the t-test tables showing when the difference between these two groups is significant.

As discussed before, a policy-maker has to choose which size of the triangle to prioritise, as it is impossible to achieve complete financial openness, exchange rate stability, and monetary independence at once. It is therefore not enough to analyse how pressure to ease policy varies across single dimensions: one must look at how the three policies contemporaneously relate to pressure, in order to properly investigate how the policy-maker's choice is linked to political pressure. Furthermore, these three policies interact: in order to sustainably[4] gain on one index, the policy-maker often needs to accept retreating from one of the other two. There exists a three-way trade-off among the indexes.

I investigate how the indexes of Monetary Independence (*MI*), Exchange Rate Stability (*ERS*), and Financial Openness (*FO*) are related to the probability of political pressure to ease policy with

[4]A policy-maker can try to expand its triangle on all sides, yet this is not sustainable: reserves will be deployed, and the expansion will be short-lived.

a Random Effects (RE) probit regression. A probit regression models binary outcome variables as a linear combination of the predictors. Using RE allows me to account for individual effects as a source of random variability (note that fixed effects cannot be used with probit regressions). I present three specifications for my probit model: eq. (4.1) for the three policy indexes, but no interactions, eq. (4.2) for policy indexes and interactions, and eq. (4.3) for policy indexes, interactions, and CBI index (*CBI*).

$$PressuretoEase_{it} = \gamma + \beta_0 + \beta_1 \cdot MI_{it} + \beta_2 \cdot ERS_{it} + \beta_3 \cdot FO_{it} + \nu_{it} \tag{4.1}$$

$$\begin{aligned} PressuretoEase_{it} &= \gamma + \beta_0 + \beta_1 \cdot MI_{it} + \beta_2 \cdot ERS_{it} + \beta_3 \cdot FO_{it} + \beta_4 \cdot MI_{it} \times ERS_{it} \\ &+ \beta_5 \cdot MI_{it} \times FO_{it} + \beta_6 \cdot ERS_{it} \times FO_{it} + \beta_7 \cdot MI_{it} \times ERS_{it} \times FO_{it} + \nu_{it} \end{aligned} \tag{4.2}$$

$$\begin{aligned} PressuretoEase_{it} &= \gamma + \beta_0 + \beta_1 \cdot MI_{it} + \beta_2 \cdot ERS_{it} + \beta_3 \cdot FO_{it} + \beta_4 \cdot MI_{it} \times ERS_{it} + \\ & \beta_5 \cdot MI_{it} \times FO_{it} + \beta_6 \cdot ERS_{it} * FO_{it} + \beta_7 \cdot MI_{it} \times ERS_{it} \times FO_{it} + \beta_8 \cdot CBI_{it} + \nu_{it} \end{aligned} \tag{4.3}$$

The dependent variable is the dummy variable of pressure to ease policy, where $PressuretoEase_{it} = 0$ means there was no pressure to central bank i at time t, and $PressuretoEase_{it} = 1$ means pressure to i was observed during period t. γ is the random effect parameter, β_0 the constant, $\beta_1 - \beta_8$ the parameters being estimated, and ν_{it} the error term. The estimation results are shown in Table 4.9.

Including only the three policy indexes without any interaction terms leads to inconclusive results. As discussed before, in fact, it is not sustainable for a central bank to expand on all three indexes, that is increasing its monetary independence, exchange rate stability, and financial openness at the same time. Increases in one or, even more so, two indexes are often accompanied by a decrease in the third index. This makes the relationship between changes in the three indexes an important one to consider, thus motivating the inclusion of interaction terms.

Comparing the results in column (1) to column (2) of Table 4.9 we can see that adding the interaction terms made the relationship between monetary independence index, exchange rate stability index, and financial openness index with the probability of pressure significant on their own: now any of the three indexes increasing is related to a significant decline in the probability of the central bank being pressured. However, the two-way interaction terms are all positively related to probability of pressure, while an increase in the three-way interaction term is negative related to the probability of pressure. To summarise, then, the inter-play between the three policies makes the relation between changes in the indexes and changes in the probability of pressure non-linear.

Whether an increase in some of the indexes is related to higher or lower probability of pressure ultimately depends on the combination as size of changes. For example, the exchange rate stability

Table 4.9: RE Probit Regression Table: Pressure to Ease Policy, Policy Trilemma, and CBI

	(1)	(2)	(3)
Monetary Independence Index	-1.04***	-5.62***	-5.30***
	(0.397)	(1.430)	(1.669)
Exchange Rate Stability Index	-0.36	-3.91***	-4.46***
	(0.430)	(1.464)	(1.423)
Financial Openness Index	-0.56	-3.17***	-3.19***
	(0.430)	(1.132)	(1.133)
MI × ERS		8.89***	8.66***
		(2.690)	(2.768)
MI × FO		7.60***	7.00***
		(2.316)	(2.268)
ERS × FO		4.72***	5.27***
		(1.781)	(1.742)
MI × ERS × FO		-13.99***	-13.21***
		(4.015)	(4.016)
CBI Index			-0.24
			(0.833)
Constant	-1.74***	-0.01	0.27
	(0.455)	(0.768)	(0.836)
Obs.	3,662	3,662	3,583
Clusters	101	101	101

The table gives the estimated coefficient and standard errors for the three specifications of the RE probit regression described in equations (4.1) – (4.3).
Note: RE grouped by central bank; standard errors clustered at central bank level.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

index alone increasing by 0.01 points leads to an estimated reduction in the probability of pressure to ease policy by 4.29%. Exchange rate stability index and financial openness index both increasing by 0.01 each leads to an estimated reduction in the probability of pressure to ease policy by 7.03%. This result is in line with Figure 4.4, which showed that central banks that were never pressured had higher degrees of financial openness and exchange rate stability on average. When these two indexes change in opposite directions, however, the final effect is harder to predict. With the exchange rate stability increasing by 0.01 and financial openness decreasing by the same amount, the probability of pressure is estimated to decrease by 0.79%; however, in the opposite case the probability of pressure is estimated to increase by 0.69%. Assessing how changes in the policy trilemma positioning affect the probability of pressure needs to be done on a case-by-case basis.

Finally, column (3) reinforces the finding that the degree of *de jure* CBI is not related to political pressure: even when controlling for monetary independence, exchange rate stability, and financial openness, Garriga's CBI index has no statistically significant relationship with the probability of pressure to ease policy. This finding could be corroborated by using an alternative index for CBI, or an updated version of it.

The policy trilemma positioning significantly contributes to creating a context that can enable political pressure. First, for pressure to ease policy to happen the central bank must have some degree of monetary independence in order to be able to control the interest rate. The degree of monetary independence alone does not determine the likelihood of pressure,[5] yet lowering the degree of monetary independence can leads to estimated reduction in probability of pressure.

Second, capital controls are higher than average. Having capital controls means that changes in interest rate cannot spark more sizeable inflows or outflows of capital, which would dampen the desired impact on output.

Third, the exchange rate is more flexible than average. If the exchange rate was fixed, or generally less flexible, the local central bank lowering the interest rate would lead to money supply moving to the country with pegged currency and higher interest rate because of capital market arbitrage — without creating the desired output boost.

Another possible explanation is that countries with lower degrees of exchange rate stability and financial openness might tend to have more corrupt institutions, and as discussed in the previous Section the perception of corruption and the likelihood of pressure are linked. If this were the case, it would be corruption to drive the spurious relationship between the indexes and the probability of pressure. As Table 4.10 shows, all three indexes indeed have a significant pairwise correlation with the Corruption Perceptions Index: higher levels of monetary independence and of exchange rate stability are linked to lower levels of perceived corruption, while more financial openness is linked to a heightened perception of corruption.

Table 4.10: Pairwise Correlations between Policy Trilemma Indexes and Corruption Perceptions Index

	MI Index	ERS Index	FO Index
CoPI	-0.13***	-0.10***	0.47***

The table gives the pairwise correlations between Monetary Independence (MI) Index, Exchange Rate Stability (ERS) Index, and Financial Openness (FO) Index.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

[5] as discussed in relation to Figure 4.4, the degree of MI index did not significantly differ for the two groups.

Because, as discussed at length, the three indexes are interdependent, considering their interactions is essential in understanding the extent to which they might be effectively linked to the Corruption Perceptions Index. I therefore specify a regression which investigates the dependency between the Corruption Perceptions Index (referred to as CoPI in the equations and tables below) and all interactions of the indexes, as in

$$CoPI_{it} = \beta_0 + \beta_1 \cdot MI_{it} + \beta_2 \cdot ERS_{it} + \beta_3 \cdot FO_{it} + \beta_4 \cdot MI_{it} \times ERS_{it}$$
$$+\beta_5 \cdot MI_{it} \times FO_{it} + \beta_6 \cdot ERS_{it} \times FO_{it} + \beta_7 \cdot MI_{it} \times ERS_{it} \times FO_{it} + \nu_{it}. \quad (4.4)$$

Table 4.11: OLS Regression Table: Corruption and Policy Trilemma

	(4)
Monetary Independence Index	12.22
	(15.080)
Exchange Rate Stability Index	15.91
	(11.950)
Financial Openness Index	48.43***
	(14.721)
MI × ERS	-17.96
	(23.576)
MI × FO	-23.94
	(29.300)
ERS × FO	-30.72
	(20.761)
MI × ERS × FO	0.51
	(44.054)
Constant	22.70***
	(7.21)
Obs.	3,662
R-squared	0.25

The table gives the estimated coefficient and standard errors for the specifications of the OLS regression described in equation (4.4).
Note: standard errors clustered at central bank level.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 4.10 presents the regression estimates, which suggest a relationship between the Corruption Perceptions Index and the degree of financial openness — and no link with the other indexes. The literature has linked financial openness and corruption, arguing that capital controls reduce competition on financial markets, which increases rent seeking activities and can foster corruption (Majeed and MacDonald, 2011). In analysing Table 4.10, it should be remembered that the Corruption Perceptions Index measure used here gives higher scores to countries with lower levels of perceived public sector corruption. Therefore, my analysis suggests that open economies are perceived to be less corrupt. This is in line with established findings and general economic thinking: "Studies have shown that a very open economy is significantly associated with lower corruption. In other words, countries tend to be less corrupt when their trade is relatively free of government restrictions that corrupt officials can abuse" (Mauro, 1997; p. 4).

In light of this result, I add the Corruption Perceptions Index and the interaction between the Corruption Perceptions Index and the financial openness index to the probit regression specified in equation (4.2), and discussed in Table 4.9.

$$\begin{aligned} PressuretoEase_{it} = \gamma + \beta_0 + \beta_1 \cdot MI_{it} + \beta_2 \cdot ERS_{it} + \beta_3 \cdot FO_{it} + \beta_4 \cdot MI_{it} \times ERS_{it} + \\ \beta_5 \cdot MI_{it} \times FO_{it} + \beta_6 \cdot ERS_{it} \times FO_{it} + \beta_7 \cdot MI_{it} \times ERS_{it} \times FO_{it} + \\ \beta_9 \cdot CoPI_{it} + \beta_{10} \cdot CoPI_{it} \times FO_{it} + \nu_{it} \end{aligned} \tag{4.5}$$

Table 4.12 adds a new Column (5) to Columns (1) and (2) already presented in Table 4.9. All indexes and their interactions remain strongly significantly related to the probability of pressure to ease policy even after the Corruption Perceptions Index is introduced. The Corruption Perceptions Index is also significantly linked to the probability of pressure to ease policy: the higher the Corruption Perceptions Index score, and hence the lower the level of perceived public sector corruption, the lower the probability of pressure is. This result confirms the finding of the previous section, where I found that central banks were more likely to be pressure in countries with above-median corruption levels compared to countries with below-median corruption levels. However, the interaction term between the Corruption Perceptions Index and the financial openness index is not significant.

Overall, Table 4.12 confirms that, while it is true that countries with more corrupt institutions are more likely to have their central bank pressured by the government to decrease the interest rate, the corruption is not the underlying reason for the country's positioning on the policy trilemma to be related to political pressure. The link between monetary independence, exchange rate stability, and financial openness with pressure to ease policy exists regardless of corruption levels, and it

Table 4.12: RE Probit Regression Table: Pressure to Ease Policy, Policy Trilemma, and Corruption

	(1)	(2)	(5)
Monetary Independence Index	-1.04***	-5.62***	-3.91***
	(0.397)	(1.430)	(1.405)
Exchange Rate Stability Index	-0.36	-4.12***	-5.74***
	(0.430)	(1.464)	(1.482)
Financial Openness Index	-0.56	-3.17***	-4.31***
	(0.430)	(1.132)	(1.556)
MI × ERS		8.89***	9.22***
		(2.690)	(2.646)
MI × FO		7.60***	7.84***
		(2.316)	(2.250)
ERS × FO		4.72***	5.06***
		(1.781)	(1.800)
MI × ERS × FO		-13.99***	-14.76***
		(4.015)	(3.952)
CoPI			-0.04**
			(0.020)
CoPI × FO			0.03
			(0.024)
Constant	-1.74***	-0.01	1.86
	(0.455)	(0.768)	(1.211)
Obs.	3,662	3,662	3,662
Clusters	101	101	99

The table gives the estimated coefficient and standard errors for the three specifications of the RE probit regression described in equations (4.1), (4.2), and (4.5).
Note: RE grouped by central bank; standard errors clustered at central bank level.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

speaks of how policy choices can create contexts that enable political pressure.

4.4.4 Pressure to Ease Policy and Inflation

What is the relationship between pressure to ease policy and inflation? An ease in monetary policy is done to boost output, but it creates inflation, as previously discussed. I indeed find that inflation is higher when a central bank succumbs compared to when it is pressured but resists (Table 4.13). I also find that inflation is higher in central banks that are pressured, regardless of whether the central bank succumbs to the pressure or not (Table 4.14). This might be because the central bank was pressured and succumbed before, which would increase inflation and would create the expectation it might succumb again. Another, possibly overlapping, explanation is that central banks with higher tolerance for inflation are more likely to be pressured.

Table 4.13: Inflation by Outcome of Pressure to Ease Policy (2010Q1-2018Q4)

	Obs.	Mean	Std. Error
Resist	62	1.27	0.230
Succumb	50	2.40	0.470
Combined	112	1.78	0.250
Difference		-1.13**	0.523

The table gives the overall number of observations, the mean value of inflation and its standard error, by outcome of the pressure to ease policy. The table also gives the difference between the two means, and its standard error.
Note: significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 4.14: Inflation without and with Pressure to Ease Policy (2010Q1-2018Q4)

	Obs.	Mean	Std. Error
Not Pressured	3,925	1.01	0.031
Pressured	112	1.78	0.250
Combined	4,037	1.03	0.031
Difference		-0.77***	0.252

The table gives the overall number of observations, the mean mean value of inflation and its standard error, without and with pressure to ease policy. The table also gives the difference between the two means, and its standard error.
Note: significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

I further investigate whether pressure itself or succumbing to it can be linked to higher inflation, knowing that inflation has high persistence. To this aim I specify two panel regressions, taking into account that the Hausman test showed that Fixed Effects (henceforth: FE) is to be preferred to RE for investigating the link between current inflation and pressure to ease policy, yet RE is more appropriate for investigating the link between current inflation and succumbing:

$$Inflation_{it} = \alpha_i + \beta_0 + \beta_1 \cdot PressureToEase_{it} + \beta_2 \cdot Inflation_{i,t-1} + \nu_{it} \tag{4.6}$$

$$Inflation_{it} = \gamma + \beta_0 + \delta_1 \cdot Succumb_{it} + \delta_2 \cdot Inflation_{i,t-1} + \nu_{it} \tag{4.7}$$

In specification (4.6) I investigate whether the dependent variable $Inflation_{it}$ is explained by the FE factor α_i, the lagged value of inflation $Inflation_{i,t-1}$, and the dummy variable for the presence of pressure $PressureToEase_{it}$. In specification (4.7), instead, I look at the relation between the dependent variable $Inflation_{it}$ and the RE effect γ, the lagged value of inflation $Inflation_{i,t-1}$, and the dummy variable for the outcome of pressure $Succumb_{it}$. $Succumb_{it} = 0$ if the central bank of country i resists at time t, $Succumb_{it} = 1$ if it succumbs.

I also investigate the link between pressure to ease policy or succumbing to this pressure and inflation in the case where inflation might have a lag and rise in the following quarter, by specifying an alternative to regressions (4.6) and (4.7) with inflation moved forward one quarter. Now the Hausman test indicated FE to be preferred to RE in both cases. I therefore have

$$Inflation_{i,t+1} = \alpha_i + \beta_0 + \beta_1 \cdot PressureToEase_{it} + \beta_2 \cdot Inflation_{it} + \nu_{it} \tag{4.8}$$

$$Inflation_{i,t+1} = \alpha_i + \beta_0 + \beta_1 \cdot Succumb_{it} + \beta_2 \cdot Inflation_{it} + \nu_{it} \tag{4.9}$$

While regression (4.6) and (4.8) consider all observations, regressions (4.7) and (4.9) are restricted to cases where pressure is recorded. The estimation results are shown in Table 4.15.

Table 4.15: Inflation, Pressure to Ease Policy, and Succumbing (Panel Regressions with Clustered Std. Errors)

	(6)	(7)	(8)	(9)
	Current Inflation		Future Inflation	
Pressure to Ease	0.04		0.08	
	(0.124)		(0.148)	
Succumb		0.50		0.52**
		(0.334)		(0.250)
Lagged Inflation	0.30***	0.34***		
	(0.090)	(0.010)		
Current Inflation			0.28***	0.12
			(0.90)	(0.091)
Constant	0.73***	0.80***	0.73	1.22***
	(0.090)	(0.219)	(0.092)	(0.164)
Obs.	3,944	110	3,944	111
Clusters	93	34	93	30

The table gives the estimated coefficient and standard errors for the four specifications of the panel regression described in equations (4.6), (4.7), (4.8), and (4.9).
Note: standard errors clustered at central bank level.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

The results in Table 4.15 suggest that the current level of inflation may not affected by whether the central bank is pressured to ease or even succumbs to this pressure in the same quarter. Whether or not the central bank is pressured, at this stage the inflation level appears to be determined by its past level. However, succumbing to pressure to ease policy could be linked to higher inflation in the following quarter. Further research should include other variables that influence and are linked to inflation levels, starting from the output gap. At the time of writing, the data available for output gaps in particular was missing for many countries, providing a significant obstacle to the analysis. Successfully including output gaps for most if not all countries, however, would be key to evaluating what these initial results suggest: pressure to ease policy does not appear to lead to inflation, yet succumbing to pressure does appear to create inflation with a lag.

Previously, Tables 4.13 and 4.14 showed that inflation is higher in countries where the central banks is pressured, and even higher in countries where the central bank succumbs. The results in Table 4.15, however, reject the explanation that inflation is higher due to pressure: pressure to ease policy does not lead to higher current inflation, but rather the results seem to suggest that current inflation is higher because of persistence. Is it possible, then, that central banks in countries with higher levels of inflation are pressured more often because governments perceive them to have a higher tolerance for inflation?

To investigate this, I specify two RE probit regressions. The first explores whether the probability of pressure to ease policy is linked to past values of inflation, whilst the second whether the probability of succumbing is linked to the same. The regressions therefore follow

$$PressuretoEase_{it} = \gamma + \beta_0 + \beta_1 \cdot Inflation_{i,t-1} + \nu_{it} \tag{4.10}$$

$$Succumb_{it} = \gamma + \beta_0 + \beta_1 \cdot Inflation_{i,t-1} + \nu_{it} \tag{4.11}$$

Table 4.16 shows the estimates for the two RE profit regressions. The results suggest that higher past inflation levels are linked to increased probability of pressure to ease policy, thus corroborating the conjecture that central banks with higher tolerance for inflation tend to be pressured more often. Their higher tolerance of past inflation can be seen as a good omen for political parties intending to pressure, as it would signal a central bank less likely to resist the pressure on account of its dislike for inflation.

The probability of succumbing to pressure, on the other hand, does not appear to be linked to lagged levels of inflation. The central bank's decision to succumb to pressure to ease policy is independent of whether inflation is already high, suggesting that the central bank's strategy is not necessarily linked to the level of inflation.

Table 4.16: RE Probit Regression Table: Pressure to Ease Policy / Succumb and Inflation

	(10) Pressure to Ease	(11) Succumb
Lagged Inflation	0.07***	0.11
	(0.016)	(0.097)
Constant	-2.82***	-0.82**
	(0.200)	(0.370)
Obs.	3,947	110
Clusters	93	30

The table gives the estimated coefficient and standard errors for the two specifications of the RE probit regression described in equations (4.10) and (4.11).
Note: RE grouped by central bank; standard errors clustered at central bank level.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.5 Discussion

I have combined data from seven distinct sources to conduct a global analysis of the patterns of political pressure, investigating its link to a number of country and central banks, and to inflation. I focused on pressure to ease policy, which accounted for over four out of five instances of pressure happening from 2010 to 2020. Occasional pressure to ease policy was the most frequent, yet a handful of central banks were subject to repeated pressure. This suggests two patterns of pressure to ease policy: firstly, a sporadic one, where the political party in power could decide to pressure under certain circumstances and enabled by a combination of institutional features. Secondly, a pattern where pressure to ease policy is endemic: the political party in power will choose to pressure virtually every chance they get.

My findings confirm the hypothesis formed in the literature that the income level of the country is linked to the likelihood of pressure, yet I find that this relationship is not linear. Certainly, political pressure is not an issue of poorer countries, whose weak institutions could both open the door to pressure as well as prevent economic development: the link between a country's wealth and political pressure to ease policy is neither linear nor straightforward.

My analysis also confirms Binder (2021)'s finding that the likelihood of pressure is related to political checks and balances, to the political system, to party orientation, and to party nationalism. To these, I add that

Result 4. 1 *Parties can be split into four statistically different clusters, based on their likelihood of pressure to ease policy:*

i. No-pressure cluster: nationalist right-wing and centrist;

ii. *Low-pressure cluster: not nationalist right-wing, centrist, and left-wing Parties;*

iii. *Medium-pressure cluster: not nationalist other Parties; and*

iv. *High-pressure cluster: nationalist left-wing and other Parties.*

I furthermore investigate whether the level of public debt, calculated as a percentage of GDP, or the level of corruption in the public sector are linked to the likelihood of pressure or to how the central bank responds to it. For the former, I find that

Result 4. 2 *Central banks in the top 5% of countries by level of public debt-to-GDP are pressured to ease significantly more.*

I conjecture that these governments find servicing such high levels of debt-to-GDP to be too expensive, leading them to pressure the central bank to lower the interest rate to make the debt-to-GDP level less unsustainable. Moreover,

Result 4. 3 *Central banks in countries with above-median levels of public debt-to-GDP are less likely to succumb to pressure.*

I suggest that this is because central banks in countries with low levels of debt-to-GDP have a lower marginal cost from succumbing to pressure compared to central banks in countries with high levels of debt-to-GDP. Finally,

Result 4. 4 *In countries with low levels of perceived corruption, central banks are more likely to be pressured to ease, but they are not more likely to succumb to this pressure.*

I deduce that, while observing the government pressure the central bank contributes to the perception of corruption, observing the central bank succumb to this pressure does not.

I investigate whether pressure to ease policy is connected to the political cycle, and found no significant difference in the likelihood of pressure before or after an election. I conclude that

Result 4. 5 *Political pressure to ease policy and the political cycle do not appear to be linked.*

My analysis once again confirms Binder (2021)'s finding that the likelihood of pressure to ease policy does not diminish with the level of Central Bank Independence (CBI) increasing, as the literature posits; my findings suggest that the relationship between CBI and likelihood of pressure to ease policy is not linear. While these result should be further investigated, I argue that they seem to suggest that central bank independence is not the panacea to politicians co-opting the tools and means of the monetary authority.

Novel to the existing body of work, I investigate the link between the likelihood of pressure and the policy trilemma, i.e. the central bank's positioning on the policy triangle of monetary independence, exchange rate stability, and financial openness. My initial result is that the central bank's positioning on the policy trilemma and political pressure are connected, with pressure to ease policy being more likely with below-median exchange rate stability and financial openness. When I investigate the link between these three indexes combined and the probability of pressure, I find that

Result 4. 6 *The link between the policy trilemma and the likelihood of pressure to ease policy is strong, non-linear, and robust to the degree of perceived corruption.*

The inter-play between the three policy makes the direction of the relation between changes in the indexes and changes in the probability of pressure dependent on the specific context. The relation between policy trilemma and likelihood of pressure being robust to corruption levels allows me to conclude that corruption is not the sole driver of political pressure, running spuriously through weaker institutional choices on policy positioning. Instead, I conclude that the policy trilemma positioning significantly contributes to creating a context that can enable political pressure in its own right.

Lastly, I explore the link between pressure to ease policy and inflation, to find that pressure as well as succumbing to pressure are linked to higher inflation. Theory predicts that easing the interest rate creates inflation, and indeed I find that

Result 4. 7 *Succumbing to pressure to ease policy is linked to higher inflation in the following quarter.*

My results furthermore show that

Result 4. 8 *Higher past inflation levels are linked to increased probability of pressure to ease policy.*

I am therefore able to corroborate the conjecture that central banks with higher tolerance for inflation are more likely to be pressured.

4.6 Conclusion

In this Chapter I empirically explored what happens when the government and the central bank disagree and clash, specifically a scenario where governments pressure the central bank to ease or tighten monetary policy. I analysed data from combined datasets to conduct an empirical study of the types of pressure, the institutional characteristics that might be enabling it, and the link with inflation.

I have shown that despite central banks having been made independent from governments with the aim of promoting economic, and especially price, stability, this has not shielded them from being pressured by governments. Governments might pressure central banks to replace the governor, to change legislation, to print money, but most of all to manipulate the interest rate. The most common type of pressure is pressure to ease policy, and the data shows that central banks succumbed to such pressure roughly half of the time. Most central banks are pressured to ease rarely, yet there is a subgroup of central banks that is subject to systematic pressure to ease policy.

I find that the likelihood of political pressure appears related to the level of public sector corruption, to checks and balances on political institutions, and to the politics of the government, and to the policy choices of financial openness, exchange rate stability, and monetary independence (the Mundell-Fleming policy trilemma). The likelihood of pressure is also so significantly higher in countries with very high levels of public debt.

Finally, my empirical findings corroborate the link between succumbing to pressure to ease policy and higher inflation, as well as suggesting that central banks with a higher historic tolerance for inflation are more likely to be pressured to ease.

To conclude, making central banks legally independent has not stopped them from being pressured by political parties. The data seems to suggest that nationalist left-wing or other Parties, possibly including populist Parties, are more likely than their peers to pressure the central bank to ease monetary policy. Certain country and central bank features can create a context that makes pressure to ease monetary policy more likely: relatively flexible exchange rate and some capital controls, a presidential system, and low check and balances on politicians. These features could be enabling political pressure, by making it easier or less costly for those governments that want to pressure the central bank.

5. *Epilogue*

In my PhD thesis I studied the motivations, policy paths, and impacts of economic institutions in a number of different scenarios, employing a diverse range of methods and approaches. While Chapter 4 was empirical and employed econometrics methods, Chapters 2, and 3 dealt in theory.

In Chapter 2 (Overconsumption Externality) I studied the case of a central bank attempting to deal with a consumption externality created by external consumption habits. Left uncorrected, external consumption habits generate overconsumption, overproduction, and downward pressure on inflation as well as nominal interest rates. I showed that a discretionary central bank fails to contain the externality, resulting in a sizeable negative inflation bias, larger changes in the nominal interest rate, and a more volatile economy. Where a discretionary central bank fails to curb the externality, the government could introduce a consumption tax that fully corrects the effects of the externality in equilibrium while dampening volatility off equilibrium. I chose to use a DSGE model to study the effects of a consumption externality in a context of discretionary monetary policy because I regarded it to be the best fitting methodology "to explore the macro implications of distortions" (Blanchard, 2017), i.e. external consumption habits.

In Chapter 3 (Central Banks with a Present Bias) I studied how a changing strength of present bias for the discretionary central bank affects the way it conducts monetary policy by introducing quasi-hyperbolic discounting for the central bank in the context of a New Keynesian DSGE model with discretionary monetary policy making and the households having superficial external consumption habits. I find that a stronger present bias is associated with pressure towards a zero inflation level: a central bank with a present bias aims to reduce the costs associated with inflation or disinflation. A central bank experiencing random spouts of present bias also creates a more volatile nominal interest rate, and a changing strength of present bias creates booms and bursts that would not have occurred otherwise.

In Chapter 4 (Empirical Evidence on Political Pressure) I studied the empirical patterns of political pressure on central banks on a global level. In my empirical analysis I found that making central banks independent from governments has not shielded them from political pressure: central banks continue being subject to political pressure, mostly pressure to ease monetary policy (which makes private and public borrowing cheaper). Most central banks are pressured to ease rarely, yet there is a subgroup of central banks that is pressured systematically. Central banks succumb to pressure to ease roughly half of the time, which results in higher inflation. The likelihood of political pressure to ease is related to the policy choices related to the Mundell-Fleming trilemma, to the politics of the executive, with left-nationalist and other executives most likely to pressure, and to checks and balances; the likelihood of political pressure to ease is not related, somewhat surprisingly, to the degree of central bank independence.

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A. Algorithms

A.1 Overconsumption Externality: Numerical Solution and Simulation

In order to find C_t, H_t, and π_t that solve the central bank's maximisation problem the following steps are implemented:

I Compute Gauss-Chebyshev nodes for $A_t, \{a_i\}_{i=1}^{N_A}$, and $C_{t-1}, \{c_j\}_{j=1}^{N_C}$, compute Gauss-Hermite nodes and weights for $\eta_t, \{\eta_l\}_{l=1}^{N_\eta}$. Initialise the convergence tolerance, *tol*.

II Conjecture a value function $\tilde{V}(a_i, c_j)$, and $\tilde{G}(a_i, c_j)$ $\forall i, j$.

III For each node (a_i, c_j)

i Determine the set of nodes for $a', \{a'_l\}_{l=1}^{N_\varepsilon}$, according to $a'_l = \rho \cdot a_i + \eta_l$, $l = 1, ..., N_\varepsilon$

ii Taking π_{ij} as given, choose C_{ij} and H_{ij} to solve

$$V(a_i, c_j) = \max\left[\frac{(C_{ij} - \theta \cdot c_j)^{1-\sigma} - 1}{1-\sigma} + \chi \cdot \frac{(1 - H_{ij})^{1-\psi} - 1}{1-\psi} + \beta \cdot E_t \tilde{V}(a'_l, C_{ij})\right]$$

subject to

$$C_{ij} = \left(1 - \frac{\phi}{2} \cdot \pi_{ij}^2\right) \cdot a_i \cdot H_{ij},$$

$$\pi_{ij} \cdot (1 + \pi_{ij}) + \frac{1-\varepsilon}{2} \cdot \pi_{ij}^2 = \frac{1-\varepsilon}{\phi} + \frac{\varepsilon}{\phi} \cdot \chi \cdot \frac{(1 - H_{ij})^{-\psi}}{(C_{ij} - \theta \cdot c_j)^{-\sigma} \cdot a_i} + \beta \cdot \frac{E_t \tilde{G}(a'_l, C_{ij})}{(C_{ij} - \theta \cdot c_j)^{-\sigma} \cdot H_{ij}}.$$

This yields $C(a_i, c_j, \pi_{ij})$, $H(a_i, c_j, \pi_{ij})$, and $V(a_i, c_j, \pi_{ij})$.

iii Choose π_{ij} to maximise the Bellman equation

$$V(a_i, c_j, \pi_{ij}) = \max\Bigg[\frac{(C(a_i, c_j, \pi_{ij}) - \theta \cdot c_j)^{1-\sigma} - 1}{1-\sigma} + \chi \frac{(1 - H(a_i, c_j, \pi_{ij}))^{1-\psi} - 1}{1-\psi} + \beta \cdot E_t \tilde{V}(a'_l, C(a_i, c_j, \pi_{ij}))\Bigg].$$

This gives $\pi(a_i, c_j)$, $C(a_i, c_j)$, and $H(a_i, c_j)$, and $V(a_i, c_j)$ can be recovered.

IV If $||V - \tilde{V}|| < tol$, stop. Otherwise set $\tilde{V} = V$, compute $\tilde{G}$ as

$$\tilde{G}(a_j, C_{ij}) = (C_{ij} - \theta \cdot c_j)^{-\sigma} \cdot a_i \cdot H_{ij} \cdot \pi_{ij} \cdot (1 + \pi_{ij}),$$

and return to step III.

I choose $N_A = 11$, $N_C = 11$, and $N_\eta = 9$.

Once the model is numerically solved, the solution is used to simulate the economy for N=1,010,000 periods. The first 10,000 periods are later discarded, and the stochastic steady state is the average over the remaining 1,000,000 periods. The algorithm used to simulate the model is:

I Set the number of observations N, and choose an initial value for consumption, C_0.

II Simulate the AR(1) process for technology, according to $\ln A_t = \rho \cdot \ln A_{t-1} + \varepsilon_t$.

III Use the numerical solution previously obtained to get C_t, H_t, and π_t, for $t = 1, ..., N$.

IV Compute output and wage following

$$Y_t = \left(1 - \frac{\phi}{2} \cdot \pi_t^2\right)^{-1} \cdot C_t,$$

$$w_t = \chi \cdot \frac{(1 - H_t)^{-\psi}}{(C_t - \theta \cdot C_{t-1})^{-\sigma}},$$

for $t = 1, ..., N$.

V Compute nominal interest rate

$$R_t = E_t \left[\frac{1 + \pi_{t+1}}{\beta \cdot [(C_{t+1} - \theta \cdot C_t)^{-\sigma}]}\right] \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma} - 1,$$

and real interest rate

$$r_t = \frac{(C_t - \theta \cdot C_{t-1})^{-\sigma}}{\beta \cdot E_t [(C_{t+1} - \theta \cdot C_t)^{-\sigma}]} - 1,$$

for $t = 1, ..., N$, using Gauss-Hermite quadrature to evaluate expectations.

I compute Euler equation errors to get an approximation of the size of the uncertainty of my figures. The aggregated Euler equation for consumption states that, analytically,

$$(C_t - \theta \cdot C_{t-1})^{-\sigma} - \beta \cdot E_t \left[\frac{1 + R_t}{1 + \pi_{t+1}} \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma}\right] = 0. \tag{A.1}$$

When the model is solved and simulated following the algorithm described, however, the difference is not exactly zero. In fact, the difference depends on how nodes are chosen, and it can be used as an indication of how precise the code is. Specifically, I define the Euler error as the left-hand side of equation (A.1) computed with equally spaced nodes rather than Gauss-Chebyshev nodes for technology and consumption. Equally spaced nodes are bound to give less precise results. The results are reported in the last row of Tables 2.2, 2.4, 2.5, 2.7, 2.10, 2.12, and 2.14. The smaller the Euler error is, the more precise the algorithm is. All my Euler errors are in the order of E-5, giving me confidence in the accuracy of the numerical solutions I discuss.

Generalised Impulse Response Functions (GIRFs) are generated by comparing two paths: one with the shock object of analysis, and one without. Both paths are stochastic: the system is already subject to disturbances, as technology is perturbed by the familiar iid shocks. One of the two paths also has the additional shock super-imposed on the already perturbed system. This process is repeated for 10,000 different initial draws of perturbed pairs of paths (note that the pairs of paths are otherwise identical, until the additional shock is imposed on one), and the results averaged into a single pair of impulse response functions.

The Code

```
using GaussQuadrature, ChebyshevApprox, DataFrames, CSV, Distribu-
tions, LinearAlgebra

function cond.future.shock(shock.state)
  cond.future.tech.shock = rho.a * shock.state .  + sqrt(2) * sd.a
* eta.nodes
  return cond.future.tech.shock
end

function fix.point(x)
  global initial
  global state
  global soln
  global choice.variable
  cond.future.tech = cond.future.shock(state[2])
```

```
  cond.expect.g = 0.0
  cond.expect.v = 0.0
  for k = 1 :  number.eta.nodes
    cond.expect.g += chebyshev.evaluate(g.weights, [x[1],
cond.future.tech[k]], order, domain) * pi^(-0.5) * eta.weights[k]
    cond.expect.v += chebyshev.evaluate(v.weights, [x[1],
cond.future.tech[k]], order, domain) * pi^(-0.5) * eta.weights[k]
  end
  ff = zeros(3)
  ff[1] = (1.0 - (phi/2) * choice.variable[1]^2) * exp(state[2]) *
x[2] - x[1]
  ff[2] = (choice.variable[1] * (1.0 + choice.variable[1]) + ((1.0
- epsilon) / 2) * choice.variable[1]^2 - (1.0 - epsilon) / phi) * (x[1]
- theta * state[1])^(-sigma) * exp(state[2]) * x[2] - (epsilon / phi)
* chi * (1.0 - x[2])^(-psi) * x[2] - beta * cond.expect.g
  if sigma == 1.00
    ff[3] = log(x[1] - theta * state[1]) + chi * ((1.0 - x[2])^(1.0
- psi) - 1.0) / (1.0 - psi) + beta * cond.expect.v - x[3]
  else
    ff[3] = ((x[1] - theta * state[1])^(1.0 - sigma) - 1.0) / (1.0
- sigma) + chi * ((1.0-x[2])^(1.0 - psi) - 1.0) / (1.0 - psi) + beta
* cond.expect.v - x[3]
  end
  return ff
end

function bellman.equation(choice.v)
  global initial
  global state
  global soln
  global choice.variable
  choice.variable = choice.v
  soln = newton(fix.point, initial, tol2, maxiters)
  cond.future.tech = cond.future.shock(state[2])
  cond.expect.value = 0.0
  for k = 1 :  number.eta.nodes
    cond.expect.value += chebyshev.evaluate(v.weights, [soln[1],
cond.future.tech[k]], order, domain) * pi^(-0.5) * eta.weights[k]
  end
  if sigma == 1
    value = log(soln[1] - theta * state[1]) + chi * ((1.0 - soln[2])^(1.0
- psi) - 1.0) / (1.0 - psi) + beta * cond.expect.value
  else
    value = ((soln[1] - theta * state[1])^(1.0 - sigma) - 1.0) / (1.0
- sigma) + chi * ((1.0-soln[2])^(1.0 - psi) - 1.0) / (1.0 - psi) +
beta * cond.expect.value
  end
  return -value
end

const beta = 0.99
const chi = 2.50
const sigma = 2.00
const psi = 4.00
const phi = 80.00
const epsilon = 11.0
```

```
const theta = 0.60
const rho.a = 0.95
const sd.a = 0.008

const tol = 1e-6
const tol2 = 1e-8
const maxiters = 1000

const number.c.nodes = 11
const c.max = 0.50
const c.min = 0.40
const c.domain = [c.max, c.min]
const (c.nodes, c.weights) = gauss.chebyshev(number.c.nodes, c.domain)
const order.c = 5

const number.a.nodes = 11
const a.max = 3 * sqrt(sd.a^2 / (1.0 - rho.a^2))
const a.min = -3 * sqrt(sd.a^2 / (1.0 - rho.a^2))
const a.domain = [a.max, a.min]
const (a.nodes, a.weights) = gauss.chebyshev(number.a.nodes, a.domain)
const order.a = 5

const number.eta.nodes = 9
const (eta.nodes, eta.weights) = hermite(number.eta.nodes)

const order = [order.c, order.a]
const domain = [c.domain a.domain]

inflation = ones(number.c.nodes, number.a.nodes) * (0.00)
labour = ones(number.c.nodes, number.a.nodes) * 0.45
consumption = ones(number.c.nodes, number.a.nodes) * 0.45
v = ones(number.c.nodes, number.a.nodes) * -1200.00
g = zeros(number.c.nodes, number.a.nodes)

new.inflation = similar(inflation)
new.labour = similar(labour)
new.consumption = similar(consumption)
new.v = similar(v)
new.g = similar(g)

v.weights = chebyshev.weights(v, (c.nodes, a.nodes), order, domain)
g.weights = chebyshev.weights(g, (c.nodes, a.nodes), order, domain)


state = zeros(2)
choice.variable = zeros(1)
soln = zeros(3)
initial = zeros(3)

len = Inf
while len > tol
  if psi == 1.00
   error("Review parameter psi (logarithmic form)")
  end
  v.weights = chebyshev.weights(v, (c.nodes, a.nodes), order, domain)
  g.weights = chebyshev.weights(g, (c.nodes, a.nodes), order, domain)
  for i = 1 :  number.c.nodes
   for j = 1 :  number.a.nodes
    state = [c.nodes[i], a.nodes[j]]
    choice.v = inflation[i,j]
```

```
      initial = [consumption[i,j], labour[i,j], v[i,j]]
      (b0, f.opt, retcode) = newton.raphson(bellman.equation, [choice.v],
tol2, maxiters)
      new.inflation[i,j] = b0[1]
      new.consumption[i,j] = soln[1]
      new.labour[i,j] = soln[2]
      new.v[i,j] = soln[3]
      new.g[i,j] = (soln[1] - theta * state[1])^(-sigma) * exp(state[2])
* soln[2] * b0[1] * (1.0 + b0[1])
      end
   end
   len = maximum(abs, new.v-v)
   consumption = -0.3 * consumption + 1.3 * copy(new.consumption)
   labour = -0.3 * labour + 1.3 * copy(new.labour)
   inflation = -0.3 * inflation + 1.3 * copy(new.inflation)
   v = -0.3 * v + 1.3 * copy(new.v)
   g = -0.3 * g + 1.3 * copy(new.g)
end

consumption.weights = chebyshev.weights(consumption, (c.nodes, a.nodes),
order, domain)
inflation.weights = chebyshev.weights(inflation, (c.nodes, a.nodes),
order, domain)
labour.weights = chebyshev.weights(labour, (c.nodes, a.nodes), or-
der, domain)

real.rate = zeros(number.c.nodes, number.a.nodes)
nominal.rate = zeros(number.c.nodes, number.a.nodes)

for i = 1 :  number.c.nodes
   for j = 1 :  number.a.nodes
    state = [c.nodes[i], a.nodes[j]]
    cond.future.tech = cond.future.shock(state[2])
    cond.expect.real = 0.0
    cond.expect.nominal = 0.0
    for k = 1 :  number.eta.nodes
      cond.expect.real += (chebyshev.evaluate(consumption.weights, [con-
sumption[i,j], cond.future.tech[k]], order, domain)
- theta * consumption[i,j])^(-sigma) * pi^(-0.5) * eta.weights[k]
      cond.expect.nominal += (((chebyshev.evaluate(consumption.weights,
[consumption[i,j], cond.future.tech[k]], order, domain)
- theta * consumption[i,j])^(-sigma)) / (1.0 +
chebyshev.evaluate(inflation.weights, [consumption[i,j],
cond.future.tech[k]], order, domain))) * pi^(-0.5) * eta.weights[k]
    end
    real.rate[i,j] = ((consumption[i,j] - theta * state[1])^(-sigma))
/ (beta * cond.expect.real) - 1.0
    nominal.rate[i,j] = ((consumption[i,j] - theta * state[1])^(-sigma))
/ (beta * cond.expect.nominal) - 1.0
   end
end

real.rate.weights = chebyshev.weights(real.rate, (c.nodes, a.nodes),
order, domain)
nominal.rate.weights = chebyshev.weights(nominal.rate, (c.nodes, a.nodes),
order, domain)
```

```
import Random
Random.seed!(123456)
burn.in = 10000
simulation.length = 1000000 + burn.in

labour.simulated = zeros(simulation.length)
inflation.simulated = zeros(simulation.length)
real.rate.simulated = zeros(simulation.length)
real.wage.simulated = zeros(simulation.length)
nominal.rate.simulated = zeros(simulation.length)
consumption.simulated = zeros(simulation.length)
output.simulated = zeros(simulation.length)
tech.shock.simulated = zeros(simulation.length + 1)
tech.innovations = randn(simulation.length + 1)

consumption.simulated[1] = 0.45

for i = 2 :  simulation.length
  labour.simulated[i] = chebyshev.evaluate(labour.weights, [consumption.simulatec
1], tech.shock.simulated[i]], order, domain)
  inflation.simulated[i] = chebyshev.evaluate(inflation.weights, [consumption.sir
1], tech.shock.simulated[i]], order, domain)
  real.rate.simulated[i] = chebyshev.evaluate(real.rate.weights, [consumption.sir
1], tech.shock.simulated[i]], order, domain)
  nominal.rate.simulated[i] = chebyshev.evaluate(nominal.rate.weights,
[consumption.simulated[i-1], tech.shock.simulated[i]], order, domain)
  consumption.simulated[i] = chebyshev.evaluate(consumption.weights,
[consumption.simulated[i-1], tech.shock.simulated[i]], order, domain)
  real.wage.simulated[i] = chi * (1.0 - labour.simulated[i])^(-psi)
* (consumption.simulated[i] - theta * consumption.simulated[i-1])^(sigma)
  output.simulated[i] = consumption.simulated[i] * (1.0 - phi/2 *
inflation.simulated[i]^2)^(-1)
  tech.shock.simulated[i+1] = rho.a * tech.shock.simulated[i] + sd.a
* tech.innovations[i+1]
end

mean.inflation = mean(inflation.simulated[burn.in+1 :  simulation.length])
mean.consumption = mean(consumption.simulated[burn.in+1 :  simula-
tion.length])
mean.labour = mean(labour.simulated[burn.in+1 :  simulation.length])
mean.output = mean(output.simulated[burn.in+1 :  simulation.length])
mean.real.rate = mean(real.rate.simulated[burn.in+1 :  simulation.length])
mean.nominal.rate = mean(nominal.rate.simulated[burn.in+1 :  simu-
lation.length])
mean.real.wage = mean(real.wage.simulated[burn.in+1 :  simulation.length])
mean.welfare = chebyshev.evaluate(v.weights, [mean.consumption, 0],
order, domain)
std.inflation = std(inflation.simulated[burn.in+1 :  simulation.length])
std.consumption = std(consumption.simulated[burn.in+1 :  simulation.length])
std.labour = std(labour.simulated[burn.in+1 :  simulation.length])
std.output = std(output.simulated[burn.in+1 :  simulation.length])
std.real.rate = std(real.rate.simulated[burn.in+1 :  simulation.length])
std.nominal.rate = std(nominal.rate.simulated[burn.in+1 :  simula-
tion.length])
std.real.wage = std(real.wage.simulated[burn.in+1 :  simulation.length])
dev.inflation = (inflation.simulated[burn.in+1 :  simulation.length]
.- mean.inflation) * 400
```

```
dev.consumption = (consumption.simulated[burn.in+1 : simulation.length]
./ mean.consumption .- 1.0) * 100
dev.labour = (labour.simulated[burn.in+1 : simulation.length]
./ mean.labour .- 1.0) * 100
dev.output = (output.simulated[burn.in+1 : simulation.length]
./ mean.output .- 1.0) * 100
dev.real.rate = (real.rate.simulated[burn.in+1 : simulation.length]
.- mean.real.rate) * 400
dev.nominal.rate = (nominal.rate.simulated[burn.in+1 : simulation.length]
.- mean.nominal.rate) * 400
dev.real.wage = (real.wage.simulated[burn.in+1 : simulation.length]
./ mean.real.wage .- 1.0) * 100

a.nodes.alt = LinRange(a.min, a.max, number.a.nodes)
c.nodes.alt = LinRange(c.min, c.max, number.c.nodes)

Euler.lhs = zeros(number.c.nodes, number.a.nodes)
Euler.rhs = zeros(number.c.nodes, number.a.nodes)
Euler.diff = zeros(number.c.nodes, number.a.nodes)

for i = 1:number.c.nodes
  for j = 1:number.a.nodes
    state = [c.nodes.alt[i], a.nodes.alt[j]]
    cond.future.tech = cond.future.shock(state[2])
    consumption.ee = chebyshev.evaluate(consumption.weights, [state[1],
state[2]], order, domain)
    nominalrate.ee = chebyshev.evaluate(nominal.rate.weights, [state[1],
state[2]], order, domain)
    cond.consumption.ee = 0.0
    cond.inflation.ee = 0.0
    for k = 1:number.eta.nodes
     cond.consumption.ee += chebyshev.evaluate(consumption.weights,
[consumption.ee, cond.future.tech[k]], order, domain) * pi^(-0.5) *
eta.weights[k]
     cond.inflation.ee += chebyshev.evaluate(inflation.weights, [con-
sumption.ee, cond.future.tech[k]], order, domain) * pi^(-0.5)
* eta.weights[k]
    end
    Euler.lhs[i,j] = consumption.ee
    Euler.rhs[i,j] = theta * state[1] + (beta * (cond.consumption.ee
- theta * consumption.ee)^(-sigma) * (1.0 + nominalrate.ee)/(1.0 +
cond.inflation.ee))^(-1/sigma)
    Euler.diff[i,j] = (Euler.lhs[i,j] - Euler.rhs[i,j])/consumption.ee
  end
end
Euler.error = maximum(abs, Euler.diff)

policy.rule = zeros(number.c.nodes, 2)
policy.rule.3d = zeros(number.c.nodes, number.a.nodes)
c.policy.max = 0.47
c.policy.min = 0.435
c.policy.domain = [c.policy.max, c.policy.min]
(c.policy.nodes, c.policy.weights) = gauss.chebyshev(number.c.nodes,
c.policy.domain)
a.policy.max = 5 * sqrt(sd.a^2 / (1.0 - rho.a^2))
a.policy.min = -5 * sqrt(sd.a^2 / (1.0 - rho.a^2))
```

```
a.policy.domain = [a.policy.max, a.policy.min]
(a.policy.nodes, a.policy.weights) = gauss.chebyshev(number.a.nodes,
a.policy.domain)
c.fixed = mean.consumption
a.fixed = 0.00
domain.policy = [c.policy.domain a.policy.domain]
for i = 1 :  number.c.nodes
  state = [c.policy.nodes[i], a.fixed]
  policy.rule[i,1] = chebyshev.evaluate(nominal.rate.weights, [state[1],
state[2]], order, domain.policy)
end
for j = 1 :  number.a.nodes
  state = [c.fixed, a.policy.nodes[j]]
  policy.rule[j,2] = chebyshev.evaluate(nominal.rate.weights, [state[1],
state[2]], order, domain.policy)
end
policy.rule
for i = 1 :  number.c.nodes
  for j = 1 :  number.a.nodes
   state = [c.policy.nodes[i], a.policy.nodes[j]]
   policy.rule.3d[i,j] = chebyshev.evaluate(nominal.rate.weights,
[state[1], state[2]], order, domain.policy)
  end
end
policy.rule.3d

import Random
Random.seed!(123456)

const impulse.length = 101
const repetition = 10000

consumption.response.pos = zeros(impulse.length)
consumption.response.neg = zeros(impulse.length)
labour.response.pos = zeros(impulse.length)
inflation.response.pos = zeros(impulse.length)
real.rate.response.pos = zeros(impulse.length)
nominal.rate.response.pos = zeros(impulse.length)
real.wage.response.pos = zeros(impulse.length)
output.response.pos = zeros(impulse.length)

for i = 1:repetition
  consumption.base = zeros(impulse.length)
  labour.base = zeros(impulse.length)
  inflation.base = zeros(impulse.length)
  real.rate.base = zeros(impulse.length)
  nominal.rate.base = zeros(impulse.length)
  real.wage.base = zeros(impulse.length)
  output.base = zeros(impulse.length)
  technology.base = zeros(impulse.length+1)
  consumption.perturbed.pos = zeros(impulse.length)
  labour.perturbed.pos = zeros(impulse.length)
  inflation.perturbed.pos = zeros(impulse.length)
  real.rate.perturbed.pos = zeros(impulse.length)
  nominal.rate.perturbed.pos = zeros(impulse.length)
  real.wage.perturbed.pos = zeros(impulse.length)
  output.perturbed.pos = zeros(impulse.length)
```

```
  technology.perturbed.pos = zeros(impulse.length+1)
  consumption.perturbed.neg = zeros(impulse.length)
  technology.perturbed.neg = zeros(impulse.length + 1)
  tech.innovations = sd.a * randn(impulse.length+1)
  random.initial.date = rand(1:simulation.length)
  consumption.base[1] = consumption.simulated[random.initial.date-
1]
  consumption.perturbed.pos[1] = consumption.simulated[random.initial.date-
1]
  consumption.perturbed.neg[1] = consumption.simulated[random.initial.date-
1]
  technology.base[2] = tech.shock.simulated[random.initial.date]
  technology.perturbed.pos[2] = tech.shock.simulated[random.initial.date]
+ sd.a
  technology.perturbed.neg[2] = tech.shock.simulated[random.initial.date]
- sd.a
  for j = 2 :  impulse.length
    consumption.base[j] = chebyshev.evaluate(consumption.weights, [consumpti
1], technology.base[j]], order, domain)
    consumption.perturbed.pos[j] = chebyshev.evaluate(consumption.weights,
[consumption.perturbed.pos[j-1], technology.perturbed.pos[j]], or-
der, domain)
    consumption.perturbed.neg[j] = chebyshev.evaluate(consumption.weights,
[consumption.perturbed.neg[j-1], technology.perturbed.neg[j]], or-
der, domain)
    labour.base[j] = chebyshev.evaluate(labour.weights, [consumption.base[j-
1], technology.base[j]], order, domain)
    labour.perturbed.pos[j] = chebyshev.evaluate(labour.weights, [consumptic
1], technology.perturbed.pos[j]], order, domain)
    inflation.base[j] = chebyshev.evaluate(inflation.weights, [consumption.b
1], technology.base[j]], order, domain)
    inflation.perturbed.pos[j] = chebyshev.evaluate(inflation.weights,
[consumption.perturbed.pos[j-1], technology.perturbed.pos[j]], or-
der, domain)
    real.rate.base[j] = chebyshev.evaluate(real.rate.weights, [consumption.b
1], technology.base[j]], order, domain)
    real.rate.perturbed.pos[j] = chebyshev.evaluate(real.rate.weights,
[consumption.perturbed.pos[j-1], technology.perturbed.pos[j]], or-
der, domain)
    nominal.rate.base[j] = chebyshev.evaluate(nominal.rate.weights,
[consumption.base[j-1], technology.base[j]], order, domain)
    nominal.rate.perturbed.pos[j] = chebyshev.evaluate(nominal.rate.weights,
[consumption.perturbed.pos[j-1], technology.perturbed.pos[j]], or-
der, domain)
    real.wage.base[j] = chi * (1.0 - labour.base[j])^(-psi) * (con-
sumption.base[j] - theta * consumption.base[j-1])^(sigma)
    real.wage.perturbed.pos[j] = chi * (1.0 - labour.perturbed.pos[j])^(-
psi) * (consumption.perturbed.pos[j] - theta * consumption.perturbed.pos[j-
1])^(sigma)
    output.base[j] = consumption.base[j] * (1.0 - phi/2 * inflation.base[j]^
1)
    output.perturbed.pos[j] = consumption.perturbed.pos[j] * (1.0 -
phi/2 * inflation.perturbed.pos[j]^2)(-1)
    consumption.response.pos[j] += log(consumption.perturbed.pos[j]
```

```
/ consumption.base[j])
    consumption.response.neg[j] += log(consumption.perturbed.neg[j]
/ consumption.base[j])
    labour.response.pos[j] += log(labour.perturbed.pos[j] / labour.base[j])
    inflation.response.pos[j] += inflation.perturbed.pos[j] - infla-
tion.base[j]
    real.rate.response.pos[j] += real.rate.perturbed.pos[j]
- real.rate.base[j]
    nominal.rate.response.pos[j] += nominal.rate.perturbed.pos[j] -
nominal.rate.base[j]
    real.wage.response.pos[j] += log(real.wage.perturbed.pos[j] / real.wage.base[
    output.response.pos[j] += log(output.perturbed.pos[j]
/ output.base[j])
    technology.base[j + 1] = rho.a * technology.base[j] + tech.innovations[j+1]
    technology.perturbed.pos[j + 1] = rho.a * technology.perturbed.pos[j]
+ tech.innovations[j+1]
    technology.perturbed.neg[j + 1] = rho.a * technology.perturbed.neg[j]
+ tech.innovations[j+1]
   end
end

consumption.response.pos = 100 * (consumption.response.pos / repe-
tition)
consumption.response.neg = 100 * (consumption.response.neg / repe-
tition)
labour.response.pos = 100 * (labour.response.pos / repetition)
inflation.response.pos = 400 * (inflation.response.pos / repetition)
real.rate.response.pos = 400 * (real.rate.response.pos / repetition)
nominal.rate.response.pos = 400 * (nominal.rate.response.pos / rep-
etition)
real.wage.response.pos = 100 * (real.wage.response.pos / repetition)
output.response.pos = 100 * (output.response.pos / repetition)
```

A.2 Central Banks with a Present Bias: Numerical Solution and Simulation

In order to find C_t, H_t, and π_t that solve the central bank's maximisation problem the following steps are implemented:

I Compute Gauss-Chebyshev nodes for technology $A_t, \{a_i\}_{i=1}^{N_A}$, consumption $C_{t-1}, \{c_j\}_{j=1}^{N_C}$, degree of patience $\delta_t, \{\delta_k\}_{k=1}^{N_\delta}$, and elasticity of substitution between intermediate goods $\varepsilon_t, \{\varepsilon_l\}_{l=1}^{N_\varepsilon}$. Compute Gauss-Hermite nodes and weights for the technology shock $\eta_t^A, \{\eta_m\}_{m=1}^{N_{\eta^A}}$, the patience shock $\eta_t^\delta, \{\eta_n\}_{n=1}^{N_{\eta^\delta}}$, and the markup shock $\eta_t^\varepsilon, \{\eta_o\}_{o=1}^{N_{\eta^\varepsilon}}$. Initialise the convergence tolerance, *tol*.

II Conjecture value functions $\tilde{V}(a_i, c_j, \delta_k, \varepsilon_l)$ and $\tilde{W}(a_i, c_j, \delta_k, \varepsilon_l)$, and $\tilde{G}(a_i, c_j, \delta_k, \varepsilon_l)$ $\forall i, j, k, l$.

III For each node $(a_i, c_j, \delta_k, \varepsilon_l)$

  i Determine the set of nodes for $a', \{a'_m\}_{m=1}^{N_{\eta^A}}$, $\delta', \{\delta'_n\}_{n=1}^{N_{\eta^\delta}}$, and $\varepsilon', \{\varepsilon'_o\}_{o=1}^{N_{\eta^\varepsilon}}$, according to $a'_m = \rho_A \cdot a_i + \eta_m$, $m = 1, ..., N_{\eta^A}$, $\delta'_n = (1-\rho_\delta) \cdot \overline{\delta} + \rho_\delta \cdot \delta_k + \eta_n^\delta$, $n = 1, ..., N_{\eta^\delta}$, and $\varepsilon'_o = (1-\rho_\varepsilon) \cdot \overline{\varepsilon} + \rho_\varepsilon \cdot \varepsilon_l + \eta_o^\varepsilon$, $o = 1, ..., N_{\eta^\varepsilon}$.

  ii Taking π_{ijkl} as given, choose C_{ijkl} and H_{ijkl} to solve

$$W(a_i,c_j,\delta_k,\varepsilon_l) = \max\left[\frac{(C_{ijkl}-\theta\cdot c_j)^{1-\sigma}-1}{1-\sigma}+\chi\cdot\frac{(1-H_{ijkl})^{1-\psi}-1}{1-\psi}+\beta\cdot E_t\tilde{W}(a'_m,C_{ijkl},\delta'_n,\varepsilon'_o)\right]$$

subject to

$$C_{ijkl} = \left(1-\frac{\phi}{2}\cdot\pi^2_{ijkl}\right)\cdot a_i\cdot H_{ijkl},$$
$$\pi_{ijkl}\cdot(1+\pi_{ijkl})+\frac{1-\varepsilon'_o}{2}\cdot\pi^2_{ijkl} = \frac{1-\varepsilon'_o}{\phi}+\frac{\varepsilon'_o}{\phi}\cdot\chi\cdot\frac{(1-H_{ijkl})^{-\psi}}{(C_{ijkl}-\theta\cdot c_j)^{-\sigma}\cdot a_i}+\beta\cdot\frac{E_t\tilde{G}(a'_m,C_{ijkl})}{(C_{ijkl}-\theta\cdot c_j)^{-\sigma}\cdot H_{ijkl}}.$$

This yields $C(a_i,c_j,\delta_k,\varepsilon_l,\pi_{ijkl})$, $H(a_i,c_j,\delta_k,\varepsilon_l,\pi_{ijkl})$, and $V(a_i,c_j,\delta_k,\varepsilon_l,\pi_{ijkl})$.

iii Choose π_{ijkl} to maximise the Bellman equation

$$V(a_i,c_j,\pi_{ij}) = \max\left[\frac{(C(a_i,c_j,\delta_k,\varepsilon_l,\pi_{ijkl})-\theta\cdot c_j)^{1-\sigma}-1}{1-\sigma}\right.$$
$$\left.+\chi\frac{(1-H(a_i,c_j,\delta_k,\varepsilon_l,\pi_{ijkl}))^{1-\psi}-1}{1-\psi}+\delta'_n\cdot\beta\cdot E_t\tilde{W}(a'_m,C(a_i,c_j,\delta_k,\varepsilon_l,\pi_{ijkl}),\delta'_n,\varepsilon'_o)\right].$$

This gives $\pi(a_i,c_j,\delta_k,\varepsilon_l)$, $C(a_i,c_j,\delta_k,\varepsilon_l)$, and $H(a_i,c_j,\delta_k,\varepsilon_l)$. $W(a_i,c_j,\delta_k,\varepsilon_l)$ and $V(a_i,c_j,\delta_k,\varepsilon_l)$ can be recovered.

IV If $||V-\tilde{V}||<tol$, stop. Otherwise set $\tilde{V}=V$, compute $\tilde{G}$ as

$$\tilde{G}(a_j,C_{ijkl}) = (C_{ijkl}-\theta\cdot c_j)^{-\sigma}\cdot a_i\cdot H_{ijkl}\cdot\pi_{ijkl}\cdot(1+\pi_{ijkl}),$$

and return to step III.

I choose $N_A=11$, $N_C=11$, $N_\delta=11$, and $N_\varepsilon=11$; $N_{\eta^A}=9$, $N_{\eta^\delta}=9$, and $N_{\eta^\varepsilon}=9$.

Once the model is numerically solved, the solution is used to simulate the economy for N=1,010,000 periods. The first 10,000 periods are later discarded, and the stochastic steady state is the average over the remaining 1,000,000 periods. The algorithm used to simulate the model is:

I Set the number of observations N, and choose an initial value for consumption, C_0.

II Simulate the AR(1) processes for technology, patience, and elasticity of substitution, according to $\ln A_t = \rho\cdot\ln A_{t-1}+\eta^A_t$, $\ln\delta_t = (1-\rho_\delta)\cdot\ln\overline{\delta}+\rho_\delta\cdot\ln\delta_{t-1}+\eta^\delta_t$, and $\ln\varepsilon_t = (1-\rho_\varepsilon)\cdot\ln\overline{\varepsilon}+\rho_\varepsilon\cdot\ln\varepsilon_{t-1}+\eta^\varepsilon_t$.

III Use the numerical solution previously obtained to get C_t, H_t, and π_t, for $t=1,...,N$.

IV Compute output and wage following

$$Y_t = \left(1-\frac{\phi}{2}\cdot\pi_t^2\right)^{-1}\cdot C_t,$$
$$w_t = \chi\cdot\frac{(1-H_t)^{-\psi}}{(C_t-\theta\cdot C_{t-1})^{-\sigma}},$$

for $t=1,...,N$.

V Compute nominal interest rate

$$R_t = E_t\left[\frac{1+\pi_{t+1}}{\beta\cdot[(C_{t+1}-\theta\cdot C_t)^{-\sigma}]}\right]\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}-1,$$

and real interest rate

$$r_t = \frac{(C_t-\theta\cdot C_{t-1})^{-\sigma}}{\beta\cdot E_t\left[(C_{t+1}-\theta\cdot C_t)^{-\sigma}\right]}-1,$$

for $t=1,...,N$, using Gauss-Hermite quadrature to evaluate expectations.

I compute Euler equation errors to get an approximation of the size of the uncertainty of my figures. The aggregated Euler equation for consumption states that, analytically,

$$(C_t - \theta \cdot C_{t-1})^{-\sigma} - \beta \cdot E_t \left[\frac{1+R_t}{1+\pi_{t+1}} \cdot (C_{t+1} - \theta \cdot C_t)^{-\sigma} \right] = 0. \tag{A.2}$$

As above, I define the Euler error as the left-hand side of equation (A.2) computed with equally spaced nodes rather than Gauss-Chebyshev nodes for technology and consumption. The results are reported in Chapter 3 are in the order of E-5 or smaller, giving me confidence in the accuracy of the numerical solutions I discuss.

Generalised Impulse Response Functions (GIRFs) are generated by comparing two paths: one with the shock object of analysis, and one without. Both paths are stochastic: the system is always subject to technology, patience, and elasticity disturbances. For each set of GIRFs presented in the text, I superimpose an additional technology, patience, or markup shock to one of the two paths. This process is repeated for 10,000 different initial draws of perturbed pairs of paths (note that the pairs of paths are otherwise identical, until the additional shock is imposed on one), and the results averaged into a single pair of impulse response functions.

The Code

```
using GaussQuadrature, ChebyshevApprox, DataFrames, CSV, Distribu-
tions, LinearAlgebra, Plots

function cond.future.shock.tech(tech.shock.state)
  cond.future.tech.shock = rho.a * tech.shock.state .+ sqrt(2) * sd.a
* eta.a.nodes
  return cond.future.tech.shock
end

function cond.future.shock.patience(patience.shock.state)
  cond.future.delta.shock = (1.0 - rho.delta) * log(delta.bar) .+
rho.delta * patience.shock.state .+ sqrt(2) * sd.delta * eta.delta.nodes
  return cond.future.delta.shock
end

function cond.future.shock.markup(markup.shock.state)
  cond.future.markup.shock = (1.0 - rho.epsilon) * log(epsilon.bar)
.+ rho.epsilon * markup.shock.state .+ sqrt(2) * sd.epsilon * eta.epsilon.nodes
  return cond.future.markup.shock
end

function fix.point(x)
  global initial
  global state
  global soln
  global choice.variable
  cond.future.tech = cond.future.shock.tech(state[2])
  cond.future.delta = cond.future.shock.patience(state[3])
  cond.future.epsilon = cond.future.shock.markup(state[4])
  cond.expect.g = 0.0
  cond.expect.w = 0.0
  for m = 1 :  number.eta.a.nodes
   for n = 1 :  number.eta.delta.nodes
    for o = 1 :  number.eta.epsilon.nodes
     cond.expect.g += chebyshev.evaluate(g.weights, [x[1], cond.future.tech[m],
cond.future.delta[n], cond.future.epsilon[o]], order, domain) * pi^(-
1.5) * eta.a.weights[m] * eta.delta.weights[n] * eta.epsilon.weights[o]
     cond.expect.w += chebyshev.evaluate(w.weights, [x[1], cond.future.tech[m],
```

```
cond.future.delta[n], cond.future.epsilon[o]], order, domain) * pi^(-
1.5) * eta.a.weights[m] * eta.delta.weights[n] * eta.epsilon.weights[o]
      end
    end
  end
  ff = zeros(3)
  ff[1] = (1.0 - (phi/2) * choice.variable[1]^2) * exp(state[2]) *
x[2] - x[1]
  ff[2] = (choice.variable[1] * (1.0 + choice.variable[1]) + ((1.0
- exp(state[4]))/2) * choice.variable[1]^2 - (1.0 - exp(state[4]))/phi)
* (x[1] - theta * state[1])^(-sigma) * exp(state[2]) * x[2] - (exp(state[4])
* chi * (1.0-x[2])^(-psi) * x[2] - beta * cond.expect.g
  if sigma == 1.00
    ff[3] = log(x[1]-theta * state[1]) + chi * ((1.0-x[2])^(1.0-psi)-
1.0)/(1.0-psi) + beta * cond.expect.w - x[3]
  else
    ff[3] = ((x[1]-theta * state[1])^(1.0-sigma)-1.0)/(1.0-sigma) +
chi * ((1.0-x[2])^(1.0-psi)-1.0)/(1.0-psi) + beta * cond.expect.w -
x[3]
  end
  return ff
end

function bellman.equation(choice.v)
  global initial
  global state
  global soln
  global choice.variable
  choice.variable = choice.v
  soln = newton(fix.point,initial,tol2,maxiters)
  cond.future.tech = cond.future.shock.tech(state[2])
  cond.future.delta = cond.future.shock.patience(state[3])
  cond.future.epsilon = cond.future.shock.markup(state[4])
  cond.expect.value = 0.0
  for m = 1 :  number.eta.a.nodes
    for n = 1 :  number.eta.delta.nodes
      for o = 1 :  number.eta.epsilon.nodes
        cond.expect.value += chebyshev.evaluate(w.weights, [soln[1],
cond.future.tech[m], cond.future.delta[n], cond.future.epsilon[o]],
order, domain) * pi^(-1.5) * eta.a.weights[m] * eta.delta.weights[n]
* eta.epsilon.weights[o]
      end
    end
  end
  if sigma == 1
    value = log(soln[1] - theta * state[1]) + chi * ((1.0 - soln[2])^(1.0-
psi) - 1.0) / (1.0 - psi) + exp(state[3]) * beta * cond.expect.value
  else
    value = ((soln[1] - theta * state[1])^(1.0-sigma) - 1.0) / (1.0
- sigma) + chi * ((1.0 - soln[2])^(1.0-psi) - 1.0) / (1.0 - psi) +
exp(state[3]) * beta * cond.expect.value
  end
  return -value
end

const beta = 0.99
```

```
const chi = 2.50
const sigma = 2.00
const psi = 4.00
const phi = 80.00
const theta = 0.60
const rho.a = 0.95
const sd.a = 0.008
const delta.bar = 0.90
const rho.delta = 0.70
const sd.delta = 0.025
const epsilon.bar = 11.0
const rho.epsilon = 0.85
const sd.epsilon = 0.05

const tol = 1e-6
const tol2 = 1e-8
const maxiters = 1000

const number.c.nodes = 11
const c.max = 0.60
const c.min = 0.30
const c.domain = [c.max, c.min]
const c.nodes = chebyshev.nodes(number.c.nodes,c.domain)
const order.c = 5

const number.a.nodes = 11
const a.max = 3 * sqrt(sd.a^2 / (1.0 - rho.a^2))
const a.min = -3 * sqrt(sd.a^2 / (1.0 - rho.a^2))
const a.domain = [a.max, a.min]
const a.nodes = chebyshev.nodes(number.a.nodes,a.domain)
const order.a = 5

const number.delta.nodes = 11
const delta.max = log(delta.bar) + 3 * sqrt(sd.delta^2 / (1.0 - rho.delta^2))
const delta.min = log(delta.bar) - 3 * sqrt(sd.delta^2 / (1.0 - rho.delta^2))
const delta.domain = [delta.max, delta.min]
const delta.nodes = chebyshev.nodes(number.delta.nodes,delta.domain)
const order.delta = 5

const number.epsilon.nodes = 11
const epsilon.max = log(epsilon.bar) + 3 * sqrt(sd.epsilon^2 / (1.0
- rho.epsilon^2))
const epsilon.min = log(epsilon.bar) - 3 * sqrt(sd.epsilon^2 / (1.0
- rho.epsilon^2))
const epsilon.domain = [epsilon.max, epsilon.min]
const epsilon.nodes = chebyshev.nodes(number.epsilon.nodes,epsilon.domain)
const order.epsilon = 5

const number.eta.a.nodes = 9
const (eta.a.nodes,eta.a.weights) = hermite(number.eta.a.nodes)

const number.eta.delta.nodes = 9
const (eta.delta.nodes,eta.delta.weights) = hermite(number.eta.delta.nodes)


const number.eta.epsilon.nodes = 9
const (eta.epsilon.nodes,eta.epsilon.weights) = hermite(number.eta.epsilon.nodes)


const order = [order.c, order.a, order.delta, order.epsilon]
```

```
const domain = [c.domain a.domain delta.domain epsilon.domain]

inflation = zeros(number.c.nodes, number.a.nodes, number.delta.nodes,
number.epsilon.nodes)
labour = ones(number.c.nodes, number.a.nodes, number.delta.nodes, num-
ber.epsilon.nodes) * 0.45
consumption = ones(number.c.nodes, number.a.nodes, number.delta.nodes,
number.epsilon.nodes) * 0.45
v = ones(number.c.nodes, number.a.nodes, number.delta.nodes, number.epsilon.
* -800.00
w = ones(number.c.nodes, number.a.nodes, number.delta.nodes, number.epsilon.
* -800.00
g = zeros(number.c.nodes, number.a.nodes, number.delta.nodes, num-
ber.epsilon.nodes)

new.inflation = similar(inflation)
new.labour = similar(labour)
new.consumption = similar(consumption)
new.v = similar(v)
new.w = similar(w)
new.g = similar(g)

v.weights = chebyshev.weights(v, (c.nodes,a.nodes, delta.nodes, ep-
silon.nodes), order, domain)
w.weights = chebyshev.weights(w, (c.nodes,a.nodes, delta.nodes, ep-
silon.nodes), order, domain)
g.weights = chebyshev.weights(g, (c.nodes, a.nodes, delta.nodes, ep-
silon.nodes), order, domain)

state = zeros(4)
choice.variable = zeros(1)
soln = zeros(3)
initial = zeros(3)

len = Inf
while len > tol
  if psi == 1.00
   error("Review parameter psi (logarithmic form)")
  end
  v.weights .= chebyshev.weights(v, (c.nodes, a.nodes, delta.nodes,
epsilon.nodes), order, domain)
  w.weights .= chebyshev.weights(w, (c.nodes, a.nodes, delta.nodes,
epsilon.nodes), order, domain)
  g.weights .= chebyshev.weights(g, (c.nodes, a.nodes, delta.nodes,
epsilon.nodes), order, domain)
  for i = 1 :  number.c.nodes
   for j = 1 :  number.a.nodes
    for k = 1 :  number.delta.nodes
     for l = 1 :  number.epsilon.nodes
      state = [c.nodes[i], a.nodes[j], delta.nodes[k], epsilon.nodes[l]]
      choice.v = inflation[i,j,k,l]
      initial = [consumption[i,j,k,l], labour[i,j,k,l], v[i,j,k,l]]
      (b0,f.opt,retcode) = newton.raphson(bellman.equation,[choice.v],tol2
      new.inflation[i,j,k,l] = b0[1]
      new.consumption[i,j,k,l] = soln[1]
      new.labour[i,j,k,l] = soln[2]
      new.w[i,j,k,l] = soln[3]
      new.v[i,j,k,l] = -f.opt
```

```
        new.g[i,j,k,l] = (soln[1] - theta * state[1])^(-sigma) * exp(state[2])
* soln[2] * b0[1] * (1.0 + b0[1])
       end
      end
     end
    end
    len = maximum(abs,new.v-v)
    consumption .= new.consumption
    labour .= new.labour
    inflation .= new.inflation
    v .= new.v
    w .= new.w
    g .= new.g
end
consumption.weights = chebyshev.weights(consumption, (c.nodes, a.nodes,
delta.nodes, epsilon.nodes), order, domain)
inflation.weights = chebyshev.weights(inflation, (c.nodes, a.nodes,
delta.nodes, epsilon.nodes), order, domain)
labour.weights = chebyshev.weights(labour (c.nodes, a.nodes, delta.nodes,
epsilon.nodes), order, domain)
real.rate = zeros(number.c.nodes, number.a.nodes, number.delta.nodes,
number.epsilon.nodes)
nominal.rate = zeros(number.c.nodes, number.a.nodes, number.delta.nodes,
number.epsilon.nodes)
for i = 1 :  number.c.nodes
    for j = 1 :  number.a.nodes
     for k = 1 :  number.delta.nodes
      for l = 1 :  number.epsilon.nodes
       state = [c.nodes[i], a.nodes[j], delta.nodes[k], epsilon.nodes[l]]
       cond.future.tech = cond.future.shock.tech(state[2])
       cond.future.delta = cond.future.shock.patience(state[3])
       cond.future.epsilon = cond.future.shock.markup(state[4])
       cond.expect.real = 0.0
       cond.expect.nominal = 0.0
       for m = 1 :  number.eta.a.nodes
        for n = 1:number.eta.delta.nodes
         for o = 1:number.eta.epsilon.nodes
          cond.expect.real += (chebyshev.evaluate(consumption.weights,
[consumption[i,j,k,l], cond.future.tech[m], cond.future.delta[n], cond.future.eps
order, domain) - theta * consumption[i,j,k,l])^(-sigma) * pi^(-1.5)
* eta.a.weights[m] * eta.delta.weights[n] * eta.epsilon.weights[o]
          cond.expect.nominal += (((chebyshev.evaluate(consumption.weights,
[consumption[i,j,k,l], cond.future.tech[m], cond.future.delta[n], cond.future.eps
order, domain) - theta * consumption[i,j,k,l])^(-sigma)) / (1.0 + cheby-
shev.evaluate(inflation.weights, [consumption[i,j,k,l], cond.future.tech[m],
cond.future.delta[n], cond.future.epsilon[o]], order, domain))) * pi^(-
1.5) * eta.a.weights[m] * eta.delta.weights[n] * eta.epsilon.weights[o]
         end
        end
       end
       real.rate[i,j,k,l] = ((consumption[i,j,k,l] - theta * state[1])^(-
sigma)) / (beta * cond.expect.real) - 1.0
       nominal.rate[i,j,k,l] = ((consumption[i,j,k,l] - theta * state[1])^(-
sigma)) / (beta * cond.expect.nominal) - 1.0
```

```
      end
    end
  end
end
real.rate.weights = chebyshev.weights(real.rate, (c.nodes, a.nodes,
delta.nodes, epsilon.nodes), order, domain)
nominal.rate.weights = chebyshev.weights(nominal.rate, (c.nodes, a.nodes,
delta.nodes, epsilon.nodes), order, domain)

import Random
Random.seed!(123456)
burn.in = 10000
simulation.length = 1000000 + burn.in

labour.simulated = zeros(simulation.length)
inflation.simulated = zeros(simulation.length)
real.rate.simulated = zeros(simulation.length)
real.wage.simulated = zeros(simulation.length)
nominal.rate.simulated = zeros(simulation.length)
consumption.simulated = zeros(simulation.length)
output.simulated = zeros(simulation.length)
welfare.simulated = zeros(simulation.length)
tech.simulated = zeros(simulation.length+1)
tech.change.sim = randn(simulation.length+1)
delta.simulated = zeros(simulation.length+1)
delta.change.sim = randn(simulation.length+1)
epsilon.simulated = zeros(simulation.length+1)
epsilon.change.sim = randn(simulation.length+1)

consumption.simulated[1] = 0.45
for i = 2:simulation.length
  labour.simulated[i] = chebyshev.evaluate(labour.weights, [consumption.sim
1], tech.simulated[i], delta.simulated[i], epsilon.simulated[i]], or-
der, domain)
  inflation.simulated[i] = chebyshev.evaluate(inflation.weights, [consumpti
1], tech.simulated[i], delta.simulated[i], epsilon.simulated[i]], or-
der, domain)
  real.rate.simulated[i] = chebyshev.evaluate(real.rate.weights, [consumpti
1], tech.simulated[i], delta.simulated[i], epsilon.simulated[i]], or-
der, domain)
  nominal.rate.simulated[i] = chebyshev.evaluate(nominal.rate.weights,
[consumption.simulated[i-1], tech.simulated[i], delta.simulated[i],
epsilon.simulated[i]], order, domain)
  consumption.simulated[i] = chebyshev.evaluate(consumption.weights,
[consumption.simulated[i-1], tech.simulated[i], delta.simulated[i],
epsilon.simulated[i]], order, domain)
  real.wage.simulated[i] = chi * (1.0 - labour.simulated[i])^(-psi)
* (consumption.simulated[i] - theta * consumption.simulated[i-1])^(sigma)
  output.simulated[i] = consumption.simulated[i] * (1.0 - phi/2 *
inflation.simulated[i]^2)^(-1)
  welfare.simulated[i] = chebyshev.evaluate(v.weights, [consumption.simulat
1], tech.simulated[i], delta.simulated[i], epsilon.simulated[i]], or-
der, domain)
  tech.simulated[i+1] = rho.a * tech.simulated[i] + sd.a * tech.change.sim[
  delta.simulated[i+1] = (1 - rho.delta) * log(delta.bar) + rho.delta
* delta.simulated[i] + sd.delta * delta.change.sim[i+1]
```

```
  epsilon.simulated[i+1] = (1 - rho.epsilon) * log(epsilon.bar) +
rho.epsilon * epsilon.simulated[i] + sd.epsilon * epsilon.change.sim[i+1]
end
mean.delta = mean(delta.simulated[burn.in+1:simulation.length])
mean.epsilon = mean(epsilon.simulated[burn.in+1:simulation.length])
mean.inflation = mean(inflation.simulated[burn.in+1:simulation.length])
mean.consumption = mean(consumption.simulated[burn.in+1:simulation.length])
mean.labour = mean(labour.simulated[burn.in+1:simulation.length])
mean.output = mean(output.simulated[burn.in+1:simulation.length])
mean.real.rate = mean(real.rate.simulated[burn.in+1:simulation.length])
mean.nominal.rate = mean(nominal.rate.simulated[burn.in+1:simulation.length])
mean.real.wage = mean(real.wage.simulated[burn.in+1:simulation.length])
mean.welfare = mean(welfare.simulated[burn.in+1:simulation.length])
std.inflation = std(inflation.simulated[burn.in+1:simulation.length])
std.consumption = std(consumption.simulated[burn.in+1:simulation.length])
std.labour = std(labour.simulated[burn.in+1:simulation.length])
std.output = std(output.simulated[burn.in+1:simulation.length])
std.real.rate = std(real.rate.simulated[burn.in+1:simulation.length])
std.nominal.rate = std(nominal.rate.simulated[burn.in+1:simulation.length])
std.real.wage = std(real.wage.simulated[burn.in+1:simulation.length])
std.welfare = std(welfare.simulated[burn.in+1:simulation.length])
dev.inflation = (inflation.simulated[burn.in+1:simulation.length]
.- mean.inflation) * 400
dev.consumption = (consumption.simulated[burn.in+1:simulation.length]
./ mean.consumption .- 1.0) * 100
dev.labour = (labour.simulated[burn.in+1:simulation.length] ./ mean.labour
.- 1.0) * 100
dev.output = (output.simulated[burn.in+1:simulation.length] ./ mean.output
.- 1.0) * 100
dev.real.rate = (real.rate.simulated[burn.in+1:simulation.length]
.- mean.real.rate) * 400
dev.nominal.rate = (nominal.rate.simulated[burn.in+1:simulation.length]
.- mean.nominal.rate) * 400
dev.real.wage = (real.wage.simulated[burn.in+1:simulation.length]
./ mean.real.wage .- 1.0) * 100

c.nodes.alt = LinRange(c.min,c.max,number.c.nodes)
a.nodes.alt = LinRange(a.min,a.max,number.a.nodes)
delta.nodes.alt = LinRange(delta.min,delta.max,number.delta.nodes)
epsilon.nodes.alt = LinRange(epsilon.min,epsilon.max,number.epsilon.nodes)


Euler.lhs = zeros(number.c.nodes, number.a.nodes, number.delta.nodes,
number.epsilon.nodes)
Euler.rhs = zeros(number.c.nodes, number.a.nodes, number.delta.nodes,
number.epsilon.nodes)
Euler.diff = zeros(number.c.nodes, number.a.nodes, number.delta.nodes,
number.epsilon.nodes)
for i = 1:number.c.nodes
  for j = 1 :  number.a.nodes
   for k = 1 :  number.delta.nodes
    for l = 1 :  number.epsilon.nodes
      state = [c.nodes.alt[i], a.nodes.alt[j], delta.nodes.alt[k],
epsilon.nodes.alt[l]]
      cond.future.tech = cond.future.shock.tech(state[2])
```

```
      cond.future.delta = cond.future.shock.patience(state[3])
      cond.future.epsilon = cond.future.shock.markup(state[4])
      consumption.ee = chebyshev.evaluate(consumption.weights, [state[1],
state[2], state[3], state[4]], order, domain)
      nominalrate.ee = chebyshev.evaluate(nominal.rate.weights, [state[1],
state[2], state[3], state[4]], order, domain)
      cond.consumption.ee = 0.0
      cond.inflation.ee = 0.0
      for m = 1:number.eta.a.nodes
       for n = 1:number.eta.delta.nodes
        for o = 1:number.eta.epsilon.nodes
         cond.consumption.ee += chebyshev.evaluate(consumption.weights,
[consumption.ee, cond.future.tech[m], cond.future.delta[n], cond.future.epsi
order, domain) * pi^(-1.5) * eta.a.weights[m] * eta.delta.weights[n]
* eta.epsilon.weights[o]
         cond.inflation.ee += chebyshev.evaluate(inflation.weights,
[consumption.ee, cond.future.tech[m], cond.future.delta[n], cond.future.epsi
order, domain) * pi^(-1.5) * eta.a.weights[m] * eta.delta.weights[n]
* eta.epsilon.weights[o]
        end
       end
      end
      Euler.lhs[i,j,k,l] = consumption.ee
      Euler.rhs[i,j,k,l] = theta * state[1] + (beta * (cond.consumption.ee
- theta * consumption.ee)^(-sigma) * (1.0 + nominalrate.ee) / (1.0
+ cond.inflation.ee))^(-1/sigma)
      Euler.diff[i,j,k,l] = (Euler.lhs[i,j,k,l] - Euler.rhs[i,j,k,l])/consum
     end
    end
  end
end
Euler.error = maximum(abs,Euler.diff)

policy.rule.c = zeros(number.c.nodes)
policy.rule.a = zeros(number.a.nodes)
policy.rule.delta = zeros(number.delta.nodes)
policy.rule.epsilon = zeros(number.epsilon.nodes)
c.policy.max = 0.47
c.policy.min = 0.43
c.policy.domain = [c.policy.max, c.policy.min]
(c.policy.nodes, c.policy.weights) = gauss.chebyshev(number.c.nodes,
c.policy.domain)
a.policy.max = 5 * sqrt(sd.a^2 / (1.0 - rho.a^2))
a.policy.min = -5 * sqrt(sd.a^2 / (1.0 - rho.a^2))
a.policy.domain = [a.policy.max, a.policy.min]
(a.policy.nodes, a.policy.weights) = gauss.chebyshev(number.a.nodes,
a.policy.domain)
a.policy.domain = [a.policy.max, a.policy.min]
delta.policy.max = log(delta.bar) + 5 * sqrt(sd.delta^2 / (1.0 - rho.delta^2
delta.policy.min = log(delta.bar) - 5 * sqrt(sd.delta^2 / (1.0 - rho.delta^2
delta.policy.domain = [delta.policy.max, delta.policy.min]
(delta.policy.nodes, delta.policy.weights) = gauss.chebyshev(number.delta.no
delta.policy.domain)
epsilon.policy.max = log(epsilon.bar) + 5 * sqrt(sd.epsilon^2 / (1.0
- rho.epsilon^2))
```

```
epsilon.policy.min = log(epsilon.bar) - 5 * sqrt(sd.epsilon^2 / (1.0
- rho.epsilon^2))
epsilon.policy.domain = [epsilon.policy.max, epsilon.policy.min]
(epsilon.policy.nodes, epsilon.policy.weights) = gauss.chebyshev(number.epsilon.n
epsilon.policy.domain)
c.fixed = mean.consumption
a.fixed = 0.00
delta.fixed = mean.delta
epsilon.fixed = mean.epsilon
domain.policy = [c.policy.domain a.policy.domain delta.policy.domain
epsilon.policy.domain]
for i = 1 :  number.c.nodes
  state = [c.policy.nodes[i], a.fixed,delta.fixed, epsilon.fixed]
  policy.rule.c[i] = chebyshev.evaluate(nominal.rate.weights, [state[1],
state[2], state[3], state[4]], order, domain.policy)
end
for j = 1:number.a.nodes
  state = [c.fixed, a.policy.nodes[j], delta.fixed, epsilon.fixed]
  policy.rule.a[j] = chebyshev.evaluate(nominal.rate.weights, [state[1],
state[2], state[3], state[4]], order, domain.policy)
end
for k = 1 :  number.delta.nodes
  state = [c.fixed, a.fixed, delta.policy.nodes[k], epsilon.fixed]
  policy.rule.delta[k] = chebyshev.evaluate(nominal.rate.weights, [state[1],
state[2], state[3], state[4]], order, domain.policy)
end
for l = 1 :  number.c.nodes
  state = [c.fixed, a.fixed, delta.fixed, epsilon.policy.nodes[l]]
  policy.rule.epsilon[l] = chebyshev.evaluate(nominal.rate.weights,
[state[1], state[2], state[3], state[4]], order, domain.policy)
end

import Random
Random.seed!(123456)
const impulse.length = 101
const repetition = 10000

consumption.response.tech = zeros(impulse.length)
consumption.response.delta = similar(consumption.response.tech)
consumption.response.eps = similar(consumption.response.tech)
labour.response.tech = zeros(impulse.length)
labour.response.delta = similar(labour.response.tech)
labour.response.eps = similar(labour.response.tech)
inflation.response.tech = zeros(impulse.length)
inflation.response.delta = similar(inflation.response.tech)
inflation.response.eps = similar(inflation.response.tech)
real.rate.response.tech = zeros(impulse.length)
real.rate.response.delta = similar(real.rate.response.tech)
real.rate.response.eps = similar(real.rate.response.tech)
nominal.rate.response.tech = zeros(impulse.length)
nominal.rate.response.delta = similar(nominal.rate.response.tech)
nominal.rate.response.eps = similar(nominal.rate.response.tech)
real.wage.response.tech = zeros(impulse.length)
real.wage.response.delta = similar(real.wage.response.tech)
real.wage.response.eps = similar(real.wage.response.tech)
```

```
output.response.tech = zeros(impulse.length)
output.response.delta = similar(output.response.tech)
output.response.eps = similar(output.response.tech)

for i = 1:repetition
  consumption.base = zeros(impulse.length)
  labour.base = zeros(impulse.length)
  inflation.base = zeros(impulse.length)
  real.rate.base = zeros(impulse.length)
  nominal.rate.base = zeros(impulse.length)
  real.wage.base = zeros(impulse.length)
  output.base = zeros(impulse.length)
  technology.base = zeros(impulse.length+1)
  delta.base = zeros(impulse.length+1)
  epsilon.base = zeros(impulse.length+1)
  consumption.perturbed.tech = zeros(impulse.length)
  consumption.perturbed.delta = similar(consumption.perturbed.tech)
  consumption.perturbed.eps = similar(consumption.perturbed.tech)
  labour.perturbed.tech = zeros(impulse.length)
  labour.perturbed.delta = similar(labour.perturbed.tech)
  labour.perturbed.eps = similar(labour.perturbed.tech)
  inflation.perturbed.tech = zeros(impulse.length)
  inflation.perturbed.delta = similar(inflation.perturbed.tech)
  inflation.perturbed.eps = similar(inflation.perturbed.tech)
  real.rate.perturbed.tech = zeros(impulse.length)
  real.rate.perturbed.delta = similar(real.rate.perturbed.tech)
  real.rate.perturbed.eps = similar(real.rate.perturbed.tech)
  nominal.rate.perturbed.tech = zeros(impulse.length)
  nominal.rate.perturbed.delta = similar(nominal.rate.perturbed.tech)
  nominal.rate.perturbed.eps = similar(nominal.rate.perturbed.tech)
  real.wage.perturbed.tech = zeros(impulse.length)
  real.wage.perturbed.delta = similar(real.wage.perturbed.tech)
  real.wage.perturbed.eps = similar(real.wage.perturbed.tech)
  output.perturbed.tech = zeros(impulse.length)
  output.perturbed.delta = similar(output.perturbed.tech)
  output.perturbed.eps = similar(output.perturbed.tech)
  technology.perturbed.tech = zeros(impulse.length+1)
  technology.perturbed.delta = similar(technology.perturbed.tech)
  technology.perturbed.eps = similar(technology.perturbed.tech)
  delta.perturbed.tech = zeros(impulse.length+1)
  delta.perturbed.delta = similar(delta.perturbed.tech)
  delta.perturbed.eps = similar(delta.perturbed.tech)
  epsilon.perturbed.tech = zeros(impulse.length+1)
  epsilon.perturbed.delta = similar(epsilon.perturbed.tech)
  epsilon.perturbed.eps = similar(epsilon.perturbed.tech)
  tech.innovations = sd.a * randn(impulse.length+1)
  delta.changes = sd.delta * randn(impulse.length+1)
  epsilon.changes = sd.epsilon * randn(impulse.length+1)
  random.initial.date = rand(1:simulation.length)
  consumption.base[1] = consumption.simulated[random.initial.date-
1]
  consumption.perturbed.tech[1] = consumption.simulated[random.initial.date
1]
  consumption.perturbed.delta[1] = consumption.simulated[random.initial.dat
1]
```

```
  consumption.perturbed.eps[1] = consumption.simulated[random.initial.date-
1]
  technology.base[2] = tech.simulated[random.initial.date]
  technology.perturbed.tech[2] = tech.simulated[random.initial.date]
+ sd.a
  technology.perturbed.delta[2] = tech.simulated[random.initial.date]
  technology.perturbed.eps[2] = tech.simulated[random.initial.date]
  delta.base[2] = delta.simulated[random.initial.date]
  delta.perturbed.tech[2] = delta.simulated[random.initial.date]
  delta.perturbed.delta[2] = delta.simulated[random.initial.date]
+ sd.delta
  delta.perturbed.eps[2] = delta.simulated[random.initial.date]
  epsilon.base[2] = epsilon.simulated[random.initial.date]
  epsilon.perturbed.tech[2] = epsilon.simulated[random.initial.date]
  epsilon.perturbed.delta[2] = epsilon.simulated[random.initial.date]
  epsilon.perturbed.eps[2] = epsilon.simulated[random.initial.date]
+ sd.epsilon
  for j = 2 :  impulse.length
   consumption.base[j] = chebyshev.evaluate(consumption.weights, [consumption.ba
1], technology.base[j], delta.base[j], epsilon.base[j]], order, do-
main)
   consumption.perturbed.tech[j] = chebyshev.evaluate(consumption.weights,
[consumption.perturbed.tech[j-1], technology.perturbed.tech[j], delta.perturbed.t
epsilon.perturbed.tech[j]], order, domain)
   consumption.perturbed.delta[j] = chebyshev.evaluate(consumption.weights,
[consumption.perturbed.delta[j-1], technology.perturbed.delta[j], delta.perturbec
epsilon.perturbed.delta[j]], order, domain)
   consumption.perturbed.eps[j] = chebyshev.evaluate(consumption.weights,
[consumption.perturbed.eps[j-1], technology.perturbed.eps[j], delta.perturbed.eps
epsilon.perturbed.eps[j]], order, domain)
   labour.base[j] = chebyshev.evaluate(labour.weights, [consumption.base[j-
1], technology.base[j], delta.base[j], epsilon.base[j]], order, do-
main)
   labour.perturbed.tech[j] = chebyshev.evaluate(labour.weights, [consumption.pe
1], technology.perturbed.tech[j], delta.perturbed.tech[j], epsilon.perturbed.tech
order, domain)
   labour.perturbed.delta[j] = chebyshev.evaluate(labour.weights,
[consumption.perturbed.delta[j-1], technology.perturbed.delta[j], delta.perturbec
epsilon.perturbed.delta[j]], order, domain)
   labour.perturbed.eps[j] = chebyshev.evaluate(labour.weights, [consumption.per
1], technology.perturbed.eps[j], delta.perturbed.eps[j], epsilon.perturbed.eps[j]
order, domain)
   inflation.base[j] = chebyshev.evaluate(inflation.weights, [consumption.base[j
1], technology.base[j], delta.base[j], epsilon.base[j]], order, do-
main)
   inflation.perturbed.tech[j] = chebyshev.evaluate(inflation.weights,
[consumption.perturbed.tech[j-1], technology.perturbed.tech[j], delta.perturbed.t
epsilon.perturbed.tech[j]], order, domain)
   inflation.perturbed.delta[j] = chebyshev.evaluate(inflation.weights,
[consumption.perturbed.delta[j-1], technology.perturbed.delta[j], delta.perturbec
epsilon.perturbed.delta[j]], order, domain)
   inflation.perturbed.eps[j] = chebyshev.evaluate(inflation.weights,
[consumption.perturbed.eps[j-1], technology.perturbed.eps[j], delta.perturbed.eps
epsilon.perturbed.eps[j]], order, domain)
```

```
    real.rate.base[j] = chebyshev.evaluate(real.rate.weights, [consumption.b
1], technology.base[j], delta.base[j], epsilon.base[j]], order, do-
main)
    real.rate.perturbed.tech[j]v= chebyshev.evaluate(real.rate.weights,
[consumption.perturbed.tech[j-1], technology.perturbed.tech[j], delta.pertu
epsilon.perturbed.tech[j]], order, domain)
    real.rate.perturbed.delta[j] = chebyshev.evaluate(real.rate.weights,
[consumption.perturbed.delta[j-1], technology.perturbed.delta[j], delta.pert
epsilon.perturbed.delta[j]], order, domain)
    real.rate.perturbed.eps[j] = chebyshev.evaluate(real.rate.weights,
[consumption.perturbed.eps[j-1], technology.perturbed.eps[j], delta.perturbe
epsilon.perturbed.eps[j]], order, domain)
    nominal.rate.base[j] = chebyshev.evaluate(nominal.rate.weights,
[consumption.base[j-1], technology.base[j], delta.base[j], epsilon.base[j]],
order, domain)
    nominal.rate.perturbed.tech[j] = chebyshev.evaluate(nominal.rate.weights
[consumption.perturbed.tech[j-1], technology.perturbed.tech[j], delta.pertu
epsilon.perturbed.tech[j]], order, domain)
    nominal.rate.perturbed.delta[j] = chebyshev.evaluate(nominal.rate.weight
[consumption.perturbed.delta[j-1], technology.perturbed.delta[j], delta.pert
epsilon.perturbed.delta[j]], order, domain)
    nominal.rate.perturbed.eps[j] = chebyshev.evaluate(nominal.rate.weights,
[consumption.perturbed.eps[j-1], technology.perturbed.eps[j], delta.perturbe
epsilon.perturbed.eps[j]], order, domain)
    real.wage.base[j] = chi * (1.0 - labour.base[j])^(-psi) * (con-
sumption.base[j] - theta * consumption.base[j-1])^(sigma)
    real.wage.perturbed.tech[j] = chi * (1.0 - labour.perturbed.tech[j])^(-
psi) * (consumption.perturbed.tech[j]-theta * consumption.perturbed.tech[j-
1])^(sigma)
    real.wage.perturbed.delta[j] = chi * (1.0 - labour.perturbed.delta[j])^(
psi) * (consumption.perturbed.delta[j] - theta * consumption.perturbed.delta
1])^(sigma)
    real.wage.perturbed.eps[j] = chi * (1.0 - labour.perturbed.eps[j])^(-
psi) * (consumption.perturbed.eps[j]-theta * consumption.perturbed.eps[j-
1])^(sigma)
    output.base[j]= consumption.base[j] * (1.0 - phi/2 * inflation.base[j]^2
1)
    output.perturbed.tech[j] = consumption.perturbed.tech[j] * (1.0
- phi/2 * inflation.perturbed.tech[j]^2)^(-1)
    output.perturbed.delta[j] = consumption.perturbed.delta[j] * (1.0
- phi/2 * inflation.perturbed.delta[j]^2)^(-1)
    output.perturbed.eps[j] = consumption.perturbed.eps[j] * (1.0 -
phi/2 * inflation.perturbed.eps[j]^2)(-1)
    consumption.response.tech[j] += log(consumption.perturbed.tech[j]
/ consumption.base[j])
    consumption.response.delta[j] += log(consumption.perturbed.delta[j]
/ consumption.base[j])
    consumption.response.eps[j] += log(consumption.perturbed.eps[j]
/ consumption.base[j])
    labour.response.tech[j] += log(labour.perturbed.tech[j] / labour.base[j]
    labour.response.delta[j] += log(labour.perturbed.delta[j] / labour.base[
    labour.response.eps[j] += log(labour.perturbed.eps[j] / labour.base[j])
    inflation.response.tech[j] += inflation.perturbed.tech[j] - in-
flation.base[j]
```

```
    inflation.response.delta[j] += inflation.perturbed.delta[j] - in-
flation.base[j]
    inflation.response.eps[j] += inflation.perturbed.eps[j] - infla-
tion.base[j]
    real.rate.response.tech[j] += real.rate.perturbed.tech[j] - real.rate.base[j]
    real.rate.response.delta[j] += real.rate.perturbed.delta[j] - real.rate.base[
    real.rate.response.eps[j] += real.rate.perturbed.eps[j] - real.rate.base[j]
    nominal.rate.response.tech[j] += nominal.rate.perturbed.tech[j]
- nominal.rate.base[j]
    nominal.rate.response.delta[j] += nominal.rate.perturbed.delta[j]
- nominal.rate.base[j]
    nominal.rate.response.eps[j] += nominal.rate.perturbed.eps[j] -
nominal.rate.base[j]
    real.wage.response.tech[j] += log(real.wage.perturbed.tech[j] /
real.wage.base[j])
    real.wage.response.delta[j] += log(real.wage.perturbed.delta[j]
/ real.wage.base[j])
    real.wage.response.eps[j] += log(real.wage.perturbed.eps[j] / real.wage.base[
    output.response.tech[j] += log(output.perturbed.tech[j] / out-
put.base[j])
    output.response.delta[j] += log(output.perturbed.delta[j] / out-
put.base[j])
    output.response.eps[j] += log(output.perturbed.eps[j] / output.base[j])
    technology.base[j+1] = rho.a * technology.base[j] + tech.innovations[j+1]
    technology.perturbed.tech[j+1] = rho.a * technology.perturbed.tech[j]
+ tech.innovations[j+1]
    technology.perturbed.delta[j+1] = rho.a * technology.perturbed.delta[j]
+ tech.innovations[j+1]
    technology.perturbed.eps[j+1] = rho.a * technology.perturbed.eps[j]
+ tech.innovations[j+1]
    delta.base[j+1] = (1 - rho.delta) * log(delta.bar) + rho.delta
* delta.base[j] + delta.changes[j+1]
    delta.perturbed.tech[j+1] = (1 - rho.delta) * log(delta.bar) +
rho.delta * delta.perturbed.tech[j] + delta.changes[j+1]
    delta.perturbed.delta[j+1] = (1 - rho.delta) * log(delta.bar) +
rho.delta * delta.perturbed.delta[j] + delta.changes[j+1]
    delta.perturbed.eps[j+1] = (1 - rho.delta) * log(delta.bar) + rho.delta
* delta.perturbed.eps[j] + delta.changes[j+1]
    epsilon.base[j+1] = (1 - rho.epsilon) * log(epsilon.bar) + rho.epsilon
* epsilon.base[j] + epsilon.changes[j+1]
    epsilon.perturbed.tech[j+1] = (1 - rho.epsilon) * log(epsilon.bar)
+ rho.epsilon * epsilon.perturbed.tech[j] + epsilon.changes[j+1]
    epsilon.perturbed.delta[j+1] = (1 - rho.epsilon) * log(epsilon.bar)
+ rho.epsilon * epsilon.perturbed.delta[j] + epsilon.changes[j+1]
    epsilon.perturbed.eps[j+1] = (1 - rho.epsilon) * log(epsilon.bar)
+ rho.epsilon * epsilon.perturbed.eps[j] + epsilon.changes[j+1]
   end end

consumption.response.tech = 100 * (consumption.response.tech / rep-
etition)
consumption.response.delta = 100 * (consumption.response.delta / rep-
etition)
consumption.response.eps = 100 * (consumption.response.eps / repe-
tition)
labour.response.tech = 100 * (labour.response.tech / repetition)
```

```
labour.response.delta = 100 * (labour.response.delta / repetition)
labour.response.eps = 100 * (labour.response.eps / repetition)
inflation.response.tech = 400 * (inflation.response.tech / repeti-
tion)
inflation.response.delta = 400 * (inflation.response.delta / repe-
tition)
inflation.response.eps = 400 * (inflation.response.eps / repetition)
real.rate.response.tech = 400 * (real.rate.response.tech / repeti-
tion)
real.rate.response.delta = 400 * (real.rate.response.delta / repe-
tition)
real.rate.response.eps = 400 * (real.rate.response.eps / repetition)
nominal.rate.response.tech = 400 * (nominal.rate.response.tech / rep-
etition)
nominal.rate.response.delta = 400 * (nominal.rate.response.delta /
repetition)
nominal.rate.response.eps = 400 * (nominal.rate.response.eps / rep-
etition)
real.wage.response.tech = 100 * (real.wage.response.tech / repeti-
tion)
real.wage.response.delta = 100 * (real.wage.response.delta / repe-
tition)
real.wage.response.eps = 100 * (real.wage.response.eps / repetition)
output.response.tech = 100 * (output.response.tech / repetition)
output.response.delta = 100 * (output.response.delta / repetition)
output.response.eps = 100*(output.response.eps/repetition)
```

B. Calculations

B.1 Benveniste-Scheinkman Condition

As discussed in Section 3.3.6, the first order conditions from the value function optimisation of the impatient discretionary central bank are

$$\begin{aligned}
\frac{\partial V(C_{t-1},A_t,\delta_t,\varepsilon_t)}{\partial C_t}: \quad & (C_t-\theta\cdot C_{t-1})^{-\sigma}+\delta_t\cdot\beta\cdot E_tW_1(C_t,A_{t+1},\delta_{t+1},\varepsilon_{t+1})-\gamma_t \\
& +\sigma\cdot\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma-1}\cdot A_t\cdot H_t\cdot\lambda_t \\
& +\beta\cdot E_tG_1(C_t,A_{t+1})\cdot\lambda_t=0, \\
\frac{\partial V(C_{t-1},A_t,\delta_t,\varepsilon_t)}{\partial H_t}: \quad & -\chi\cdot(1-H_t)^{-\psi}+\gamma_t\cdot\left(1-\frac{\phi}{2}\cdot\pi_t^2\right)\cdot A_t \\
& -\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot A_t\cdot\lambda_t \\
& +\frac{\varepsilon_t}{\phi}\cdot\chi\cdot\left[\psi\cdot(1-H_t)^{-\psi-1}\cdot H_t+(1-H_t)^{-\psi}\right]\cdot\lambda_t=0, \\
\frac{\partial V(C_{t-1},A_t,\delta_t,\varepsilon_t)}{\partial \pi_t}: \quad & -\phi\cdot\gamma_t\cdot\pi_t-\left(1+2\cdot\pi_t+(1-\varepsilon_t)\cdot\pi_t\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma}\cdot\lambda_t=0.
\end{aligned}$$

Benveniste and Scheinkman (1979) condition: now let $C_t\equiv C(C_{t-1},A_t,\delta_t,\varepsilon_t)$, $H_t\equiv H(C_{t-1},A_t,\delta_t,\varepsilon_t)$ and $\pi_t\equiv\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)$. The problem in equation (3.49) can now be formulated as

$$\begin{aligned}
W(C_{t-1},A_t,\delta_t,\varepsilon_t)= & \frac{(C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1})^{1-\sigma}-1}{1-\sigma}+\chi\cdot\frac{(1-H(C_{t-1},A_t,\delta_t,\varepsilon_t))^{1-\varphi}-1}{1-\varphi} \\
& +\beta\cdot E_tW(C(C_{t-1},A_t,\delta_t,\varepsilon_t),A_{t+1},\delta_{t+1},\varepsilon_{t+1}) \\
& +\gamma_t\cdot\left[\left(1-\frac{\phi}{2}\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)^2\right)\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t)-C(C_{t-1},A_t,\delta_t,\varepsilon_t)\right] \\
& -\lambda_t\cdot\Bigg[\left(\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot(1+\pi(C_{t-1},A_t,\delta_t,\varepsilon_t))+\frac{1-\varepsilon_t}{2}\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)^2-\frac{1-\varepsilon_t}{\phi}\right) \\
& \cdot\left(C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1}\right)^{-\sigma}\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t) \\
& -\frac{\varepsilon_t}{\phi}\cdot\chi\cdot\left(1-H(C_{t-1},A_t,\delta_t,\varepsilon_t)\right)^{-\varphi}\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t) \\
& -\beta\cdot E_tG(C(C_{t-1},A_t),A_{t+1})\Bigg],
\end{aligned}$$

and we get

$$
\begin{aligned}
\frac{\partial W(C_{t-1},A_t,\delta_t,\varepsilon_t)}{\partial C_{t-1}} &= (C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1})^{-\sigma}\cdot C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&-\theta\cdot(C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1})^{-\sigma}\\
&-\chi\cdot(1-H(C_{t-1},A_t,\delta_t,\varepsilon_t))^{-\varphi}\cdot H_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&+\beta\cdot E_tW_1(C(C_{t-1},A_t,\delta_t,\varepsilon_t),A_{t+1},\delta_{t+1},\varepsilon_{t+1})\cdot C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&-\gamma_t\cdot\phi\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\pi_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&+\gamma_t\cdot\left(1-\frac{\phi}{2}\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)^2\right)\cdot H_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&-\gamma_t\cdot C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)-\big(\pi_1(C_{t-1},A_t,\delta_t,\varepsilon_t)+2\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\pi_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&+(1-\varepsilon_t)\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\pi_2(C_{t-1},A_t,\delta_t,\varepsilon_t)\big)\\
&\cdot(C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1})^{-\sigma}\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\lambda_t\\
&+\sigma\cdot\left(\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot(1+\pi(C_{t-1},A_t,\delta_t,\varepsilon_t))+\frac{1-\varepsilon_t}{2}\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)^2-\frac{1-\varepsilon_t}{\phi}\right)\\
&\cdot(C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1})^{-\sigma-1}\cdot C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\lambda_t\\
&-\sigma\cdot\theta\cdot\left(\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot(1+\pi(C_{t-1},A_t,\delta_t,\varepsilon_t))+\frac{1-\varepsilon_t}{2}\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)^2-\frac{1-\varepsilon_t}{\phi}\right)\\
&(C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1})^{-\sigma-1}\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\lambda_t\\
&-\left(\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot(1+\pi(C_{t-1},A_t,\delta_t,\varepsilon_t))+\frac{1-\varepsilon_t}{2}\cdot\pi(C_{t-1},A_t,\delta_t,\varepsilon_t)^2-\frac{1-\varepsilon_t}{\phi}\right)\\
&\cdot(C(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta\cdot C_{t-1})^{-\sigma}H_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\lambda_t\\
&+\frac{\varepsilon_t}{\phi}\cdot\chi\cdot\Big[\varphi\cdot(1-H(C_{t-1},A_t,\delta_t,\varepsilon_t))^{-\varphi-1}\cdot H(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot H_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&+(1-H(C_{t-1},A_t,\delta_t,\varepsilon_t))^{-\varphi}\cdot H_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\Big]\cdot\lambda_t\\
&+\beta\cdot E_tG_1(C(C_{t-1},A_t),\delta_{t+1})\cdot C_2(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot\lambda_t.
\end{aligned}
$$

Making use of the first order conditions for labour and inflation many terms cancel out and the solution can be simplified to

$$
\begin{aligned}
W_1(C_{t-1},A_t,\delta_t,\varepsilon_t) &= (C_t-\theta\cdot C_{t-1})^{-\sigma}(C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta)-\gamma_t\cdot C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\\
&+\sigma\cdot\left[\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right](C_t-\theta\cdot C_{t-1})^{-\sigma-1}\cdot H_t\cdot\lambda_t\cdot(C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)-\theta)\\
&+\beta\cdot E_tW_1(C_t,A_{t+1},\delta_{t+1})\cdot C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)+\beta\cdot E_tG_1(C(C_{t-1},A_t),\delta_{t+1})\cdot C_1(C_{t-1},A_t,\delta_t,\varepsilon_t)\cdot
\end{aligned}
$$

From the first order condition for consumption we know that

$$
\begin{aligned}
\beta E_tW_1(C_t,A_{t+1},\delta_{t+1}) &= -\frac{1}{\delta}(C_t-\theta\cdot C_{t-1})^{-\sigma}+\frac{1}{\delta}\cdot\gamma_t-\frac{1}{\delta}\cdot\beta\cdot E_tG_1(C_t,A_{t+1})\cdot\lambda_t\\
&-\frac{1}{\delta}\cdot\sigma\left(\pi_t\cdot(1+\pi_t)+\frac{1-\varepsilon_t}{2}\cdot\pi_t^2-\frac{1-\varepsilon_t}{\phi}\right)\cdot(C_t-\theta\cdot C_{t-1})^{-\sigma-1}\cdot H_t\cdot\lambda_t,
\end{aligned}
$$

which we can substitute into $W_1(C_{t-1}, A_t, \delta_t, \varepsilon_t)$ to get

$$\begin{aligned}
W_1(C_{t-1}, A_t, \delta_t, \varepsilon_t) &= (C_t - \theta \cdot C_{t-1})^{-\sigma} \cdot (C_1(C_{t-1}, A_t, \delta_t, \varepsilon_t) - \theta) \\
&- \gamma_t \cdot C_1(C_{t-1}, A_t, \delta_t, \varepsilon_t) - \beta \cdot E_t W_1(C_t, \delta_{t+1}) \cdot (C_1(C_{t-1}, A_t, \delta_t, \varepsilon_t) - \delta_t) \\
&+ \sigma \cdot \left[\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon_t}{2} \cdot \pi_t^2 - \frac{1-\varepsilon_t}{\phi}\right] \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma-1} \cdot H_t \cdot \lambda_t (C_1(C_{t-1}, A_t, \delta_t, \varepsilon_t) - \theta) \\
&- \frac{1}{\delta} \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma} + \frac{1}{\delta} \cdot \gamma_t - \frac{1}{\delta} \cdot \beta \cdot E_t G_1(C_t, A_{t+1}) \cdot \lambda_t \\
&- \frac{1}{\delta} \cdot \sigma \cdot \left(\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon_t}{2} \cdot \pi_t^2 - \frac{1-\varepsilon_t}{\phi}\right) \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma-1} \cdot H_t \cdot \lambda_t
\end{aligned}$$

By using the first order condition for consumption it simplifies to

$$\begin{aligned}
W_2(C_{t-1}, A_t, \delta_t, \varepsilon_t) &= -\theta (C_t - \theta \cdot C_{t-1})^{-\sigma} \\
&- \theta \cdot \sigma \cdot \left[\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon_t}{2} \cdot \pi_t^2 - \frac{1-\varepsilon_t}{\phi}\right] (C_t - \theta \cdot C_{t-1})^{-\sigma-1} \cdot H_t \cdot \lambda_t.
\end{aligned}$$

Advancing by one period, multiplying by β, and substituting back into the first order condition for consumption we finally obtain

$$\begin{aligned}
&(C_t - \theta \cdot C_{t-1})^{-\sigma} + \delta_t \cdot \beta \cdot \theta \cdot E_t \left[(C_{t+1} - \theta \cdot C_t)^{-\sigma}\right] \\
&+ \sigma \cdot \left(\pi_t \cdot (1+\pi_t) + \frac{1-\varepsilon_t}{2} \cdot \pi_t^2 - \frac{1-\varepsilon_t}{\phi}\right) \cdot (C_t - \theta \cdot C_{t-1})^{-\sigma-1} \cdot H_t \cdot \lambda_t \\
&- \delta_t \cdot \beta \cdot \theta \cdot \sigma \cdot E_t \left[\left(\pi_{t+1} \cdot (1+\pi_{t+1}) + \frac{1-\varepsilon_t}{2} \cdot \pi_{t+1}^2 - \frac{1-\varepsilon_t}{\phi}\right)(C_{t+1} - \theta \cdot C_t)^{-\sigma-1} \cdot H_{t+1} \cdot \lambda_{t+1}\right] \\
&- \gamma_t + \beta \cdot E_t G_1(C_t, A_{t+1}) \cdot \lambda_t = 0.
\end{aligned}$$

C. Data

C.1 Political Pressure: Datasets

Legend:

GEM	World Bank Global Economic Monitor
DPI	World Bank Database for Political Institutions
WDI	World Bank World Development Indicators
G	Garriga (2016) CBI Index
ACI	Aizenman, Chinn, and Ito (2008) Policy Indexes
B	Binder (2021) Pressure Data

Table C.1: Datasets, by Central Bank

Central Bank	Country	GEM	DPI	WDI	G	ACI	B
Central Bank of Afghanistan	Afghanistan	✓	✓	✓	✓	✓	✓
Bank of Albania	Albania	✓	✓	✓	✓	✓	✓
Bank Of Algeria	Algeria	✓	✓	✓	✓	✓	✓
National Bank of Angola	Angola		✓	✓		✓	✓
Central Bank of Argentina	Argentina		✓	✓	✓	✓	✓
Central Bank of Armenia	Armenia	✓	✓	✓	✓	✓	✓
Central Bank of Aruba	Aruba			✓		✓	
Reserve Bank of Australia	Australia		✓	✓	✓	✓	✓
Central Bank of Azerbaijan	Azerbaijan	✓	✓	✓	✓	✓	✓
Central Bank of West African States (BCEAO)	Benin	✓	✓	✓	✓	✓	✓
	Burkina Faso	✓	✓	✓	✓	✓	✓
	Cote d'Ivoire	✓	✓	✓	✓	✓	✓
	Guinea-Bissau		✓	✓	✓	✓	
	Mali		✓	✓	✓	✓	
	Niger	✓	✓	✓	✓	✓	✓
	Senegal	✓	✓	✓	✓	✓	✓
	Togo	✓	✓	✓	✓	✓	✓
Bank of Central African States (BEAC)	Cameroon	✓	✓	✓	✓		
	Central African Republic	✓	✓	✓	✓	✓	✓
	Chad	✓	✓	✓	✓	✓	✓
	Congo, Rep.	✓	✓	✓	✓	✓	✓
	Equatorial Guinea	✓	✓	✓	✓	✓	✓
	Gabon	✓	✓	✓	✓	✓	✓
Central Bank of The Bahamas	Bahamas, The	✓	✓	✓	✓	✓	✓
Central Bank of Bahrain	Bahrain	✓	✓	✓	✓	✓	✓
Bangladesh Bank	Bangladesh	✓	✓	✓	✓	✓	✓

Central Bank of Barbados	Barbados	✓	✓	✓	✓	✓	✓
National Bank of the Republic of Belarus	Belarus	✓	✓	✓	✓	✓	✓
Central Bank of Belize	Belize	✓	✓	✓	✓	✓	
Bermuda Monetary Authority	Bermuda			✓		✓	
Royal Monetary Authority of Bhutan	Bhutan		✓	✓	✓	✓	
Central Bank of Bolivia	Bolivia	✓	✓	✓	✓	✓	✓
Central Bank of Bosnia and Herzegovina	Bosnia and Herzegovina	✓	✓	✓	✓	✓	✓
Bank of Botswana	Botswana	✓	✓	✓	✓	✓	✓
Central Bank of Brazil	Brazil	✓	✓	✓	✓	✓	✓
Monetary Authority of Brunei Darussalam	Brunei		✓	✓		✓	
Bulgarian National Bank	Bulgaria	✓	✓	✓	✓	✓	✓
Bank of the Republic of Burundi	Burundi	✓	✓	✓	✓	✓	
Bank of Cape Verde	Cabo Verde	✓	✓	✓	✓	✓	
National Bank of Cambodia	Cambodia	✓	✓	✓	✓	✓	✓
Bank of Canada	Canada	✓	✓	✓	✓	✓	✓
Cayman Islands Monetary Authority	Cayman Islands			✓		✓	
Central Bank of Chile	Chile	✓	✓	✓	✓	✓	✓
People's Bank of China	China	✓	✓	✓	✓	✓	✓
Central Bank of Colombia	Colombia	✓	✓	✓	✓	✓	✓
Central Bank of the Comros	Comoros	✓	✓	✓	✓	✓	
Central Bank of the Congo	Congo, Dem. Rep.	✓	✓	✓	✓	✓	✓
Central Bank of Costa Rica	Costa Rica	✓	✓	✓	✓	✓	✓
Croatian National Bank	Croatia	✓	✓	✓	✓	✓	✓
Central Bank of Cuba	Cuba		✓	✓	✓	✓	✓
Central Bank of Curacao and Sint Maarten	Curacao			✓			
	Sint Maarten			✓			
Czech National Bank	Czech Republic	✓	✓	✓	✓	✓	✓
Danmarks Nationalbank	Denmark	✓	✓	✓	✓	✓	✓
Central Bank of Djibouti	Djibouti	✓	✓	✓	✓	✓	
Central Bank of the Dominican Republic	Dominican Republic	✓	✓	✓	✓	✓	✓
European Central Bank (ECB)	Austria	✓	✓	✓	✓	✓	✓
	Belgium	✓	✓	✓	✓	✓	✓
	Cyprus	✓	✓	✓	✓	✓	✓
	Estonia	✓	✓	✓	✓	✓	✓
	Finland	✓	✓	✓	✓	✓	✓
	France	✓	✓	✓	✓	✓	✓
	Germany	✓	✓	✓	✓	✓	✓
	Greece	✓	✓	✓	✓	✓	✓
	Ireland	✓	✓	✓	✓	✓	✓
	Italy	✓	✓	✓	✓	✓	✓
	Latvia	✓	✓	✓	✓	✓	✓
	Lithuania	✓	✓	✓	✓	✓	✓
	Luxembourg	✓	✓	✓	✓	✓	✓
	Malta	✓	✓	✓	✓	✓	✓
	Netherlands	✓	✓	✓	✓	✓	✓
	Portugal	✓	✓	✓	✓	✓	✓
	Slovakia	✓	✓	✓	✓	✓	✓
	Slovenia	✓	✓	✓	✓	✓	✓
	Spain	✓	✓	✓	✓	✓	✓
Eastern Caribbean Central Bank (ECCB)	Anguilla						

	Antigua and Barbuda	✓		✓	✓	✓	✓
	Dominica	✓		✓	✓	✓	✓
	Grenada	✓	✓	✓	✓	✓	✓
	Montserrat						
	St. Kitts and Nevis	✓		✓	✓	✓	
	St. Lucia	✓	✓	✓	✓	✓	✓
	St. Vincent and the Grenadines	✓		✓	✓	✓	✓
Central Bank of Ecuador	Ecuador	✓	✓	✓	✓	✓	✓
Central Bank of Egypt	Egypt, Arab Rep.	✓	✓	✓	✓	✓	✓
Central Reserve Bank of El Salvador	El Salvador	✓	✓	✓	✓	✓	✓
Bank of Eritrea	Eritrea		✓	✓		✓	
Central Bank of Eswatini	Eswatini	✓	✓	✓		✓	
National Bank of Ethiopia	Ethiopia		✓	✓	✓	✓	✓
Reserve Bank of Fiji	Fiji	✓	✓	✓	✓	✓	
Central Bank of The Gambia	Gambia, The	✓	✓	✓	✓	✓	
National Bank of Georgia	Georgia	✓	✓	✓	✓	✓	✓
Bank of Ghana	Ghana	✓	✓	✓	✓	✓	✓
Bank of Guatemala	Guatemala	✓	✓	✓	✓	✓	✓
Central Bank of the Republic of Guinea	Guinea	✓	✓	✓	✓	✓	✓
Bank of Guyana	Guyana	✓	✓	✓	✓	✓	✓
Bank of the Republic of Haiti	Haiti	✓	✓	✓	✓	✓	✓
Central Bank of Honduras	Honduras	✓	✓	✓	✓	✓	✓
Hong Kong Monetary Authority	Hong Kong SAR, China	✓		✓		✓	✓
Hungarian National Bank	Hungary	✓	✓	✓	✓	✓	✓
Central Bank of Iceland	Iceland	✓	✓	✓	✓	✓	✓
Reserve Bank of India	India	✓	✓	✓	✓	✓	✓
Bank Indonesia	Indonesia	✓	✓	✓	✓	✓	✓
Central Bank of the Islamic Republic of Iran	Iran, Islamic Rep.		✓	✓	✓	✓	✓
Iraqi Central Bank	Iraq		✓	✓	✓	✓	✓
-	Isle of Man			✓			
Bank of Israel	Israel	✓	✓	✓	✓	✓	✓
Bank of Jamaica	Jamaica	✓	✓	✓	✓	✓	✓
Bank of Japan	Japan	✓	✓	✓	✓	✓	✓
Central Bank of Jordan	Jordan	✓	✓	✓	✓	✓	✓
National Bank of Kazakhstan	Kazakhstan	✓	✓	✓	✓	✓	✓
Central Bank of Kenya	Kenya	✓	✓	✓	✓	✓	✓
-	Kiribati	✓		✓		✓	
Central Bank of the DPR of Korea	Korea, DPR		✓				
Bank of Korea	Korea, Rep.	✓	✓	✓	✓	✓	✓
Central Bank of Kosovo	Kosovo	✓		✓			
Central Bank of Kuwait	Kuwait		✓	✓	✓	✓	✓
National Bank of the Kyrgyz Republic	Kyrgyz Republic	✓	✓	✓	✓	✓	✓
Bank of the Lao PDR	Lao, PDR	✓	✓	✓	✓	✓	✓
Banque du Liban	Lebanon	✓	✓	✓	✓	✓	✓
Central Bank of Lesotho	Lesotho	✓	✓	✓	✓	✓	
Central Bank of Liberia	Liberia	✓	✓	✓	✓	✓	
Central Bank of Libya	Libya	✓	✓	✓	✓	✓	✓
Monetary Authority of Macao	Macao SAR, China			✓			
Central Bank of Madagascar	Madagascar	✓	✓	✓	✓	✓	
Reserve Bank of Malawi	Malawi	✓	✓	✓	✓	✓	

Central Bank of Malaysia	Malaysia	✓	✓	✓	✓	✓	✓
Maldives Monetary Authority	Maldives	✓	✓	✓	✓	✓	
-	Marshall Islands			✓		✓	
Central Bank of Mauritania	Mauritania	✓	✓	✓	✓	✓	
Bank of Mauritius	Mauritius	✓	✓	✓	✓	✓	✓
Bank of Mexico	Mexico	✓	✓	✓	✓	✓	✓
-	Micronesia, Fed. Sts.			✓		✓	
National Bank of Moldova	Moldova	✓	✓	✓	✓	✓	
Bank of Mongolia	Mongolia	✓	✓	✓	✓	✓	✓
Central Bank of Montenegro	Montenegro	✓		✓	✓	✓	✓
Bank Al-Maghrib	Morocco	✓	✓	✓	✓	✓	✓
Bank of Mozambique	Mozambique	✓	✓	✓	✓	✓	✓
Central Bank of Myanmar	Myanmar		✓	✓	✓	✓	✓
Bank of Namibia	Namibia	✓	✓	✓	✓	✓	✓
-	Nauru			✓			
Nepal Rastra Bank	Nepal	✓	✓	✓	✓	✓	
-	New Caledonia			✓		✓	
Reserve Bank of New Zealand	New Zealand		✓	✓	✓	✓	✓
Central Bank of Nicaragua	Nicaragua	✓	✓	✓	✓	✓	✓
Central Bank of Nigeria	Nigeria	✓	✓	✓	✓	✓	✓
National Bank of North Macedonia	North Macedonia	✓	✓	✓	✓	✓	✓
-	Northern Mariana Islands			✓			
Norges Bank	Norway	✓	✓	✓	✓	✓	✓
Central Bank of Oman	Oman	✓	✓	✓	✓	✓	✓
State Bank of Pakistan	Pakistan	✓	✓	✓	✓	✓	✓
-	Palau			✓		✓	
Palestine Monetary Authority	Palestine	✓		✓		✓	✓
National Bank of Panama	Panama	✓	✓	✓	✓	✓	✓
Bank of Papua New Guinea	Papua New Guinea		✓	✓	✓	✓	
Central Bank of Paraguay	Paraguay	✓	✓	✓	✓	✓	
Central Reserve Bank of Peru	Peru	✓	✓	✓	✓	✓	✓
Bangko Sentral ng Pilipinas	Philippines	✓	✓	✓	✓	✓	✓
National Bank of Poland	Poland	✓	✓	✓	✓	✓	✓
-	Puerto Rico			✓			
Qatar Central Bank	Qatar	✓	✓	✓	✓	✓	✓
National Bank of Romania	Romania	✓	✓	✓	✓	✓	✓
Bank of Russia	Russian Federation	✓	✓	✓	✓	✓	✓
National Bank of Rwanda	Rwanda	✓	✓	✓	✓	✓	✓
Central Bank of Samoa	Samoa	✓	✓	✓	✓	✓	
Central Bank of the Republic of San Marino	San Marino	✓		✓	✓	✓	
Central Bank of Sao Tome and Principe	Sao Tome and Principe	✓		✓	✓	✓	
Saudi Arabian Monetary Authority	Saudi Arabia	✓	✓	✓	✓	✓	✓
National Bank of Serbia	Serbia	✓		✓	✓	✓	✓
Central Bank of Seychelles	Seychelles	✓		✓	✓	✓	
Bank of Sierra Leone	Sierra Leone	✓	✓	✓	✓	✓	
Monetary Authority of Singapore	Singapore	✓	✓	✓	✓	✓	✓
Central Bank of Solomon Islands	Solomon Islands	✓	✓	✓	✓	✓	
Central Bank of Somalia	Somalia		✓		✓	✓	
South African Reserve Bank	South Africa	✓	✓	✓	✓	✓	✓

Bank of South Sudan	South Sudan			✓			✓
Central Bank of Sri Lanka	Sri Lanka			✓	✓	✓	✓
Central Bank of Sudan	Sudan		✓	✓	✓	✓	✓
Central Bank of Suriname	Suriname	✓	✓	✓	✓	✓	
Sveriges Riksbank	Sweden	✓	✓	✓	✓	✓	✓
Swiss National Bank	Switzerland	✓	✓	✓	✓	✓	✓
Central Bank of Syria	Syria		✓	✓	✓	✓	✓
Central Bank of the Republic of China (Taiwan)	Taiwan, China	✓	✓		✓	✓	✓
National Bank of Tajikistan	Tajikistan	✓	✓	✓	✓	✓	✓
Bank of Tanzania	Tanzania		✓	✓	✓	✓	✓
Bank of Thailand	Thailand	✓	✓	✓	✓	✓	✓
Banco Central de Timor-Leste	Timor-Leste		✓	✓	✓	✓	
National Reserve Bank of Tonga	Tonga	✓		✓	✓	✓	
Central Bank of Trinidad and Tobago	Trinidad and Tobago	✓	✓	✓	✓	✓	✓
Central Bank of Tunisia	Tunisia	✓	✓	✓	✓	✓	
-	Turk Cyprus		✓				
Central Bank of the Republic of Turkey	Turkey	✓	✓	✓	✓	✓	✓
Central Bank of Turkmenistan	Turkmenistan		✓	✓	✓	✓	✓
-	Turks and Caicos Islands			✓			
-	Tuvalu			✓			
Bank of Uganda	Uganda	✓	✓	✓	✓	✓	✓
National Bank of Ukraine	Ukraine		✓	✓	✓	✓	✓
Central Bank of the United Arab Emirates	United Arab Emirates	✓	✓	✓	✓	✓	✓
Bank of England	United Kingdom	✓	✓	✓	✓	✓	✓
Federal Reserve System	United States of America	✓	✓	✓	✓		✓
Central Bank of Uruguay	Uruguay	✓	✓	✓	✓	✓	✓
Central Bank of the Republic of Uzbekistan	Uzbekistan		✓	✓	✓	✓	✓
Reserve Bank of Vanuatu	Vanuatu		✓	✓	✓	✓	
Central Bank of Venezuela	Venezuela, RB		✓	✓	✓	✓	✓
State Bank of Vietnam	Vietnam	✓	✓	✓	✓	✓	✓
Central Bank of Yemen	Yemen, Rep.	✓		✓	✓	✓	✓
Bank of Zambia	Zambia	✓	✓	✓	✓	✓	✓
Reserve Bank of Zimbabwe	Zimbabwe		✓	✓	✓	✓	✓

C.2 Political Pressure: by Country

Table C.2: Pressure and Succumb, by Country/Central Bank

Country/Central Bank	No. Pressure	No. Succumb
Algeria	7	6
Angola	28	11
Argentina	18	10
Bank of Central African States (BEAC)	3	3
Brazil	5	0
China	1	1

Colombia	2	0
Costa Rica	1	0
European Central Bank (ECB)	1	1
Ecuador	2	1
Egypt, Arab Rep.	1	1
Ethiopia	2	0
Guinea	4	1
Hungary	1	0
India	9	6
Iran, Islamic Rep.	8	0
Japan	8	2
Korea, Rep.	2	0
Lao, PDR	1	0
Lebanon	1	1
Mexico	5	0
Myanmar	23	19
Nigeria	1	0
Philippines	2	0
Poland	2	0
Russian Federation	5	1
Serbia	1	1
Sri Lanka	7	2
Sudan	2	1
Syria	11	0
Thailand	3	0
Turkey	28	23
Uganda	1	1
Ukraine	2	0
United Kingdom	1	1
United States of America	5	1
Venezuela, RB	23	23
Vietnam	4	3
Yemen, Rep.	6	0
Zimbabwe	10	0
Total	***250***	***118***

C.3 Political Pressure: T-test Tables

Results of pairwise t-tests for categories in Tables 4.4 and 4.8, for Pressure and Succumb.
The results read as *mean(Column)-mean(Row)*. The difference between means is expressed as a fraction on the interval [0,1], i.e. percentage divided by 100.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$ (one-tailed).

Table C.3: Pressure (top) and Succumb (bottom), by Income Category

	High	Upper-middle	Lower-middle
Upper-middle	-0.03***		
	(0.007)		
Lower-middle	-0.05***	-0.02**	
	(0.008)	(0.009)	
Low	-0.02**	0.01	0.03***
	(0.010)	(0.010)	(0.011)

	High	Upper-middle	Lower-middle
Upper-middle	-0.22**		
	(0.093)		
Lower-middle	-0.21**	0.01	
	(0.093)	(0.074)	
Low	-0.46***	-0.24**	-0.25**
	(15.184)	(0.126)	(0.126)

Table C.4: Pressure (left) and Succumb (right), by Debt

	High
Low	-0.00
	(0.013)

	Top 5%
Bottom 95%	0.13**
	(0.055)

	High
Low	-0.36***
	(0.147)

	Top 5%
Bottom 95%	-0.19
	(0.186)

Table C.5: Pressure (left) and Succumb (right), by Corruption Perception Index

	High
Low	-0.03***
	(0.006)

	High
Low	0.08
	(0.066)

Table C.6: Pressure (left) and Succumb (right), by Checks & Balances

	High
Low	-0.02*
	(0.010)

	High
Low	-0.05
	(0.158)

Table C.7: Pressure (top) and Succumb (bottom), by Political System

	Presidential	Assembly-el. President
Assembly-el. President	0.03***	
	(0.011)	
Parliamentary	0.02***	-0.01
	(0.007)	(0.011)

	Presidential	Assembly-el. President
Assembly-el. President	-0.30	
	(0.215)	
Parliamentary	-0.16*	0.14
	(0.098)	(0.228)

Table C.8: Pressure (top) and Succumb (bottom), by Party Orientation

	Right	Centre	Left
Centre	-0.00		
	(0.012)		
Left	-0.02***	-0.02**	
	(.009)	(0.012)	
Other	-0.04***	-0.04***	-0.01
	(0.009)	(0.012)	(0.009)

	Right	Centre	Left
Centre	-0.02		
	(0.193)		
Left	-0.25**	-0.22	
	(0.121)	(0.182)	
Other	-0.34***	-0.32*	-0.09*
	(0.110)	(0.175)	(0.090)

Table C.9: Pressure (left) and Succumb (right), by Nationalism

	Not Nationalist
Nationalist	-0.08***
	(0.015)

	Not Nationalist
Nationalist	0.29***
	(0.076)

Table C.10: Pressure, by Party Orientation and Nationalism

	Nationalist Right & Centre	Non Nat. Right, Centre & Left	Non Nationalist Other
Non Nat. Right, Centre & Left	-0.02***		
	(0.004)		
Non Nationalist Other	-0.05***	-0.03***	
	(0.006)	(0.007)	
Nationalist Left & Other	-0.13***	-0.11***	-0.08***
	(0.017)	(0.017)	(0.018)

Table C.11: Pressure (top) and Succumb (bottom), by CBI Index

	High	Upper-middle	Lower-middle
Upper-middle	0.01		
	(0.008)		
Lower-middle	-0.01*	-0.02***	
	(0.009)	(0.009)	
Low	0.01**	0.00	0.03***
	(0.070)	(0.007)	(0.008)

	High	Upper-middle	Lower-middle
Upper-middle	0.00		
	(0.098)		
Lower-middle	0.11	0.11	
	(0.087)	(0.093)	
Low	0.31***	0.31***	0.20***
	(0.095)	(0.101)	(0.091)

Table C.12: Pressure (left) and Succumb (right), by Monetary Independence Index

	High
Low	-0.00
	(0.007)

	High
Low	0.12**
	(0.072)

Table C.13: Pressure (left) and Succumb (right), by Exchange Rate Stability Index

	High
Low	-0.04**
	(0.006)

	High
Low	0.05
	(0.074)

Table C.14: Pressure (left) and Succumb (right), by Financial Openness Index

	High
Low	-0.07***
	(0.063)

	High
Low	-0.29***
	(0.080)

Table C.15: Monetary Independence Index, by Pressure

	Obs.	Mean MI	Std. Error
Not Pressured	54	0.46	0.015
Pressured	48	0.44	0.016
Combined	102	0.45	0.011
Difference		0.02	0.021

Table C.16: Exchange Rate Stability Index, by Pressure

	Obs.	Mean ERS	Std. Error
Not Pressured	56	0.60	0.035
Pressured	53	0.51	0.035
Combined	109	0.45	0.025
Difference		0.09**	0.049

Table C.17: Financial Openness Index, by Pressure

	Obs.	Mean FO	Std. Error
Not Pressured	56	0.64	0.047
Pressured	53	0.47	0.050
Combined	109	0.45	0.035
Difference		0.18***	0.069

D. Robustness Checks

D.1 Overconsumption Externality: Robustness

This Appendix discusses the robustness of the model to the parameterisation of risk aversion and the substitutability of labour. It finds that risk-aversion motives play a more relevant (quantitative) role, while the inter-temporal substitutability of labour has a marginal effect on the behaviour of consumers with external habits. When risk aversion is higher the real rate decreases significantly more, and the inflation bias is smaller.

As per Table D.1 and Figure D.1, risk aversion is directly related to inflation and its volatility, and inversely related to real interest rate. The less risk-averse consumers are, the higher their real interest rate is, and the smaller the drop is as habits get stronger: their precautionary-savings motives are weaker, they demand less insurance against volatility, and hence their real rate is higher. Lower risk aversion is also associated to a bigger inflation bias. With lower risk aversion the effect of external consumption habits on prices is amplified: inflation drops by more, and it also becomes even more volatile. Naturally the nominal interest rate also drops by more when consumers are less risk-averse.

Table D.2 and Figure D.2 show that changing the value for the substitutability of labour has barely any impact on the results. The inflation bias is not related to the households' preferences in choosing between consumption and labour.

Table D.1: Stochastic Steady State by Degrees of Habit, by σ

	$\sigma = 1.00$		benchmark		$\sigma = 3.00$	
Degree of habit (θ)	0.00	0.60	0.00	0.60	0.00	0.60
Inflation	2.005	-17.650	1.007	-7.386	0.690	-4.521
	(0.000)	(0.236)	(0.005)	(0.176)	(0.005)	(0.148)
Consumption	0.171	0.244	0.298	0.447	0.379	0.571
	(0.437)	(0.575)	(0.553)	(0.890)	(0.610)	(1.077)
Labour	0.171	0.265	0.298	0.453	0.379	0.574
	(0.000)	(0.080)	(0.205)	(0.263)	(0.355)	(0.395)
Output	0.172	0.265	0.298	0.453	0.379	0.574
	(0.437)	(0.653)	(0.554)	(0.921)	(0.610)	(1.095)
Real rate	4.028	4.025	4.014	3.974	3.995	3.894
	(0.515)	(0.691)	(0.751)	(2.238)	(0.976)	(3.683)
Nominal rate	6.053	-13.800	5.031	-3.482	4.692	-0.667
	(0.518)	(0.785)	(0.749)	(2.295)	(0.973)	(3.720)
Wage	0.909	0.835	0.909	0.896	0.909	0.904
	(2.318)	(1.966)	(2.318)	(2.217)	(2.318)	(2.268)
Welfare	-239.62	-358.96	-393.33	-886.07	-563.16	-1,903.96
	(42.86)	(38.31)	(140.55)	(275.21)	(289.35)	(1,005.25)
$max\|\|$Euler error$\|\|$	6.40E-05	3.12E-05	5.16E-05	5.40E-5	5.23E-05	7.51E-05

Note: inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

Table D.2: Stochastic Steady State by Degrees of Habit, by ψ

	$\psi = 3.00$		benchmark		$\psi = 5.00$	
Degree of habit (θ)	0.00	0.60	0.00	0.60	0.00	0.60
Inflation	1.070	-7.556	1.007	-7.386	0.960	-7.234
	(0.005)	(0.181)	(0.005)	(0.176)	(0.004)	(0.174)
Consumption	0.330	0.507	0.298	0.447	0.272	0.403
	(0.600)	(1.000)	(0.553)	(0.890)	(0.515)	(0.808)
Labour	0.330	0.514	0.298	0.453	0.272	0.408
	(0.242)	(0.305)	(0.205)	(0.263)	(0.179)	(0.232)
Output	0.331	0.514	0.298	0.453	0.272	0.408
	(0.601)	(1.037)	(0.554)	(0.921)	(0.515)	(0.834)
Real rate	4.015	3.977	4.014	3.974	4.013	3.972
	(0.734)	(2.152)	(0.751)	(2.238)	(0.764)	(2.317)
Nominal rate	5.096	-3.651	5.031	-3.482	4.983	-3.330
	(0.731)	(2.214)	(0.749)	(2.295)	(0.762)	(2.369)
Wage	0.909	0.895	0.909	0.896	0.909	0.896
	(2.318)	(2.212)	(2.318)	(2.217)	(2.318)	(2.221)
Welfare	-356.61	-797.89	-393.33	-886.07	-427.78	-968.13
	(126.38)	(243.98)	(140.55)	(275.21)	(153.73)	(304.05)
$max\|\|$Euler error$\|\|$	4.93E-05	5.19E-05	5.16E-05	5.40E-5	5.33E-05	5.60E-05

Note: inflation, real rate and nominal rate are annualised and in percentages; consumption, labour, output, wage, and welfare are quarterly and in real units. Standard deviations, in brackets, are in percentage points.

Figure D.1: Steady State Values by Degrees of Habit, by σ

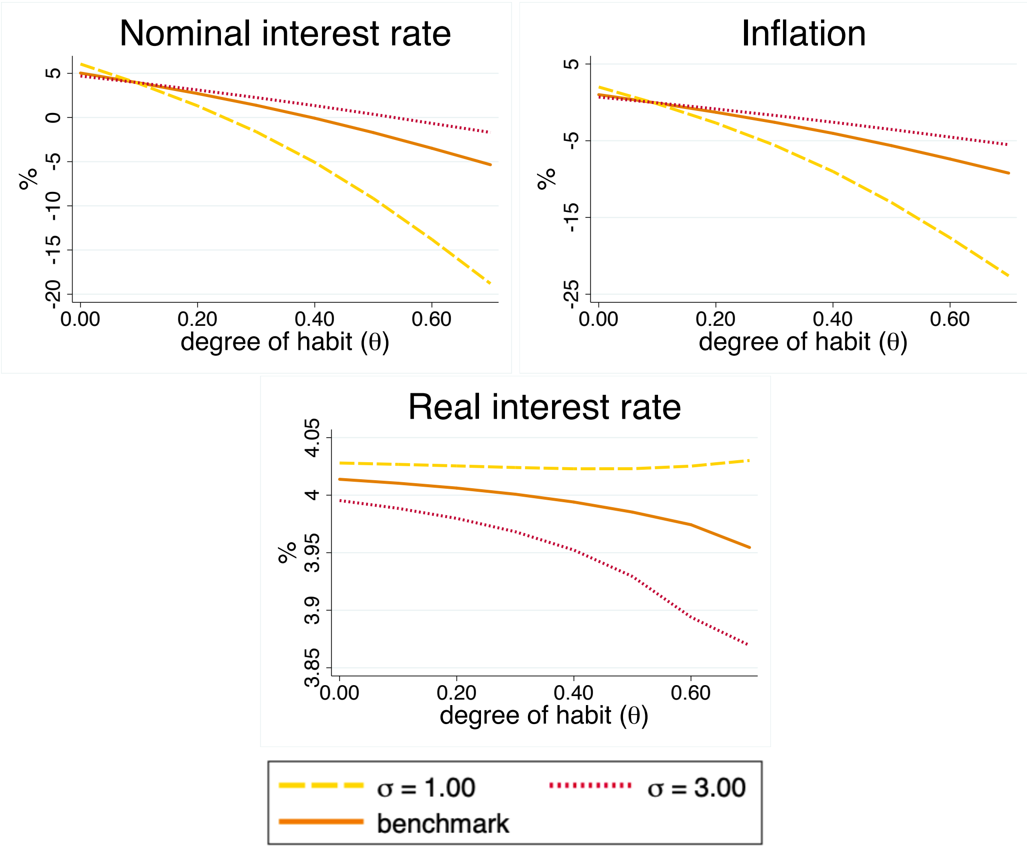

Figure D.2: Steady State Values by Degrees of Habit, by ψ