Abstract

This paper evaluates the welfare cost of business cycles and the effects of stabilisation policies in an estimated New-Keynesian DSGE model tailored to the specificities of a small open emerging economy and applied to South Africa. This framework includes i) heterogeneous households that differ with respect to access to financial and capital markets; ii) idiosyncratic risks in the labour markets; iii) two production sectors consisting of commodities and secondary products; and iv) trade and financial linkages with the rest of the world. Welfare analysis shows that households excluded from the asset markets are more vulnerable to business cycles fluctuation especially because of their inability to insure against labour market idiosyncratic risks. Moreover, some business cycles shocks are welfare enhancing for financially included households while this is unlikely for others. Monetary policy rules that respond aggressively to inflation improve the welfare of the economy. Depending on the nature of the idiosyncratic risks, aggressive output responses could benefit excluded households. Although financially excluded households gain more from these stabilization monetary policies, their welfare costs remain substantial.

JEL classifications: E3, E52, E32, C51

Keywords: Monetary Policy, Welfare, Emerging Markets, SOE, DSGE, Bayesian

*DeFiPP (CRED & CeReFiM)-University of Namur and National Bank of Belgium. Email to: jolan.mohimont@nbb.be. I am grateful to Romain Houssa, Christoph Gortz, John Fender, Kaushik Mitra, Pei Kuang, Christoph Otrok, Raf Wouters, Nicola Viegi, Jean-Marie Baland, Yuliya Rychalovska and Paul Reding for useful comments. I also benefited from participation at the 5th Belgian Macro Workshop (Sep. 2017, Namur), the St Louis Doctoral Workshop (Dec. 2017, Brussels), the Cred Workshop (Feb. 2018, Namur), the NBB internal seminar (May 2018, Brussels) and the 24th Computing in Economics and Finance (June 2018, Milan).
1 Introduction

Emerging countries face large business cycle shocks - such as commodity term of trade shocks - exacerbated by incomplete financial markets. These specificities generate strong GDP and price fluctuations and consumption tends to be more volatile than output. Moreover, aggregate volatility could hide much larger consumption fluctuations at the household’s level and could even cause large income dispersion, especially in a context of low financial inclusion.\(^1\) In a typical New-Keynesian DSGE model, business cycle shocks combine to idiosyncratic risks - such as Calvo price and wage rigidities or unemployment risks - to breed potentially large income dispersion. It is generally assumed that households trade in state-contingent asset markets to edge against those idiosyncratic risks. Households therefore remain homogeneous: they all have access to the same consumption basket. In this context, fluctuations in aggregate income - not individual income - matter for welfare. While this assumption preserves the representative agent frameworks, its empirical validity is questionable. In fact, an extensive body of research applied to the US challenges the perfect financial markets hypothesis and shows that it has an impact on welfare cost estimates.\(^2\) When agents face idiosyncratic risks in the labour market, the welfare costs of business cycles are much larger for those excluded from the credit markets and for those with little wealth. Moreover, this assumption is at odd with the fact that a significant share of households are excluded from financial markets in emerging countries. However, this issue has been ignored and the typical NK-DSGE model with perfect insurance markets has been used to measure welfare and perform monetary policy analyses.

This paper evaluates the welfare cost of business cycles and the effects of stabilisation policies in an estimated New-Keynesian DSGE model with labour market idiosyncratic risks and imperfect financial markets inclusion. The model is tailored to an emerging economy (South Africa) and inspired from Houssa et al. (2018). It consists of two blocks: a domestic small open emerging economy and a foreign economy which captures the exposure of the domestic economy to development in the rest of the world. Two alternative versions of the model are considered to capture idiosyncratic risks in the labour market. The first version introduces monopolistic competition with Calvo wage rigidities (henceforth EHL) developed in Erceg et al. (2000). This feature has been widely applied in the DSGE literature and therefore offers a natural benchmark to test

\(^1\)Breen and García-Peñalosa (2005) show that business cycle volatility (measured as the standard deviation of GDP growth) causes larger income dispersion (measured as Gini coefficients) on a large set of developed and developing countries. Park and Mercado (2015), Naceur and Zhang (2016) and Turégano and Herrero (2018) find a negative link between financial access and income inequality.

\(^2\)Imrohoroglu (1989) introduced imperfect financial markets and unemployment risks to study the welfare costs of business cycles. Many papers followed her lead including Atkeson and Phelan (1994), Krusell and Smith (1999), Beaudry and Pages (2001), Gomes et al. (2001), Krebs (2007) and many others.
the influence of idiosyncratic risks. The second version develops search and matching frictions with staggered wage bargaining (hereafter GTT) following Gertler and Trigari (2009) and Thomas (2008). These ingredients have been shown to better describe the dynamic of labour markets and fit the institutional framework in South Africa. The model also incorporates two dimensions that are particularly relevant to characterise the business cycle in a small open emerging economy. First, it includes two categories of households that differ with respect to access to capital and financial markets. Households excluded from these markets own no physical capital or bonds and simply consume their entire labour income in every period as in Mankiw (2000). In addition, they do not trade in state-contingent asset markets and do not insure against idiosyncratic risks. Second, there are two different types of goods in the domestic and foreign economies: primary and secondary products. The emerging economy exports commodities whose prices are endogenously determined in the foreign block. Within this framework, monetary policy is modelled as Taylor rule with interest rate smoothing and responds to CPI-inflation deviation from target, to the GDP growth rate and to changes in the nominal exchange rate. This rule reflects the gradual move among emerging economies from exchange rate management to inflation targeting that followed the currency crisis in the 1990s and accommodates output stabilisation motives. The model is estimated with Bayesian methods on South African and US data. The welfare costs of business cycles are expressed as a fraction of consumption following Lucas (1987) and measured using a second order approximation to the model.

The results show that the welfare costs of business cycles are relatively large for each category of households in the emerging economy confirming a previous strand of empirical research (see Pallage and Robe (2003) and Houssa (2013)). This measure differs in the sense that it relies on a structural model whose parameters are estimated on a large set of observed variables. As argued by Otrok (2001), estimated models bring discipline to the choice of parameters and capture agents endogenous responses to shocks. Moreover, this paper shows that the welfare costs are much larger for households excluded from asset markets especially because of their inability to insure against labour market idiosyncratic risks. Indeed, while their costs represent 1.5 to 8 times those endured by included households, they would approximately be equal if they could mute the

---

3 This feature captures the unequal access to capital and financial markets. In middle income countries, only 55% of the population over 15 years has an account at a financial institution (compared to 63% in SA and 92% in the US) and only 21% has some form of formal savings (26% in SA 56% in the US). World Bank, Financial Inclusion Database, 2011-2017 average.

4 Many developing and emerging countries are dependent on commodities. UNCTAD (2016) considers 91 developing countries as "commodity dependant". They include all countries with a commodity exports to total merchandises exports ratio above 60% for the 2014-2015 period. South Africa is just below this threshold with 55% in that period.

5 Since February 2000, the South African Reserve Bank (SARB) operates in a formal inflation targeting framework with a dual objective of consumer price and output stabilisation. Similar Taylor rules have been widely used to describe monetary policy in South Africa (e.g. Ortiz and Sturzenegger (2007)).
idiosyncratic risk. Business cycle swings illustrate the idiosyncratic risk mechanism. In the EHL framework, a typical economic downturn encourages households to reduce their wage. But wages rigidities entail wage dispersion: only a fraction of agents adjust while others simply index their wages. Monopolistic competition then implies that households stuck with relatively high hourly wages suffer a drastic drop in hours worked and labour income. In the GTT framework, the same downturn leads to a drop in wages for the fraction of households facing wage renegotiations as well as to a rise in unemployment. In both versions of the model, financially included households trade in state-contingent securities to mute these risks while luckless excluded households have to cut on consumption expenditures. Since households are risk averse, this consumption dispersion has a detrimental aggregate welfare effect.

This paper subsequently decomposes the welfare effects of different types of shocks. It finds that both domestic demand and supply shocks have large welfare effects hinting that there is both scope and limitation for demand management policies. Foreign shocks also have important welfare repercussions in the emerging economy. Surprisingly, some business cycles shocks - such as foreign commodity supply shocks - could be welfare increasing for financially included households while this is not as likely for the other category. Commodity price fluctuations offer option effects: firms have the opportunity to transfer production from low commodity price periods to high commodity price periods in order to increase their average income per unit. These gains dominate the adverse welfare effects of aggregate fluctuations when the elasticity of factor supply is sufficiently large and when agents have an effective mean to store wealth in capital or foreign bonds.\(^6\)

The estimated Taylor Rule captures the behaviour of the South African Reserve Bank, which consistently responded to inflation fluctuations. Moreover, it placed an average weight on GDP growth and a smaller weight on the change in the nominal exchange rate. This paper finds that a more aggressive anti-inflation stance would bring sizeable and robust welfare gains for each category of households. The optimal simple rule (computed at the mode of estimated parameters) depends on the assumptions made in the labour market.\(^7\) In the EHL framework, a strong and immediate response to inflation deviation from target maximises welfare for each type of agents. In the GTT version, excluded households benefit from an immediate and strong response to inflation and output, while included households desire to place a moderate weight on output. From an

\(^6\)Lester et al. (2014) and Cho et al. (2015) show that TFP shocks could be welfare enhancing in a RBC model and describe similar option effects.

\(^7\)Simple rules determine the response of policy variables as a function of a small number of easily observable macroeconomic indicators (such as inflation, output and exchange rate measures). Their simplicity and efficiency make them particularly attractive as stabilisation tools. Optimal simple monetary policy rules often deliver a virtually identical level of welfare compared to the optimal Ramsey policy. See for e.g. Schmitt-Grohe and Uribe (2007) and Gali and Monacelli (2005). These rules were also used in NK-DSGE model adapted to fit small open emerging countries specificities by Hove et al. (2015), Iyer (2016) and Prasad and Zhang (2015).
utilitarian perspective, the optimal rule is a compromise. The welfare gains associated to these optimal simple rules compared to the benchmark are relatively large. Included households would be ready to give-up 0.13% and 0.25% of consumption to implement the optimal simple rule in the EHL and GTT frameworks; respectively. Excluded households gain even more: they would renounce to 0.62% and 0.39% of consumption in the EHL and GTT environments. Most of these gains come from mitigating the effects of domestic demand shocks. However, the welfare cost of business cycles remains substantial. Included households would abandon 0.38% of consumption to insulate the economy from aggregate fluctuations in the EHL framework and 0.45% in the GTT variant. Excluded households still endure larger costs equivalent to 1.72% and 0.84% of consumption in these two different versions.

The remainder of this chapter is organised as follows. Section two reviews the relevant literature. Section three describes the labour market institutions in South Africa. Section four presents the model and section five the empirical strategy. Section six shows the results. Finally, section seven concludes.

2 State of the art

2.1 The welfare cost of business cycles

In a seminal work, Lucas (1987) measured the welfare cost of aggregate fluctuations based on a specification of preferences and a time series representation of the aggregate consumption process. He considered a standard CRRA utility function and a trend-stationary IID consumption process matching the mean and variance of US data. Moreover, he assumed the existence of market where individuals can insure against idiosyncratic risks. He expressed a welfare loss as a fraction of consumption that agents would be willing to pay in order to avoid aggregate consumption fluctuations. Using US data over the 1947-2001 period, Lucas (2003) calculates that the welfare costs of business cycles would be as lower than one-tenth of a percent of permanent consumption. The literature then produced different competing models whose welfare costs estimates range from minor to substantial in advanced countries.

Departures from Lucas assumptions include a variety of utility functions and different processes governing consumption flows. Obstfeld (1994) and Dolmas (1998) experiment with different consumption processes - including persistent and permanent disturbances - and with utility functions distinguishing between risk aversion and intertemporal elasticity of substitution - such as Epstein and Zin (1989) preferences (EZ) - leading to potentially larger welfare costs estimates. Storesletten et al. (2001) show that households consumption is persistent in US data, and that their
variance is larger during aggregate downturns. They model aggregate TFP shocks that interact with heteroskedastic and persistent shocks to individual labour market productivity. They find that the costs associated to business cycle fluctuations are relatively large, even for moderate levels of risk aversion. Tallarini (2000) uses EZ preferences in order to increase the risk aversion coefficient while holding the intertemporal elasticity of substitution constant. This strategy improves the predictions of a stochastic growth model and also results in large welfare costs.

Discrepancies in welfare cost estimates and their dependence on the utility function call for a consistent treatment of its parameters. Otrok (2001) argues that an estimated business cycle model would bring discipline to the choice of preferences and consumption process. He evaluates welfare costs in a RBC model with parameters estimated on US consumption and investment data and finds that welfare costs are close to Lucas (1987) estimates. Lester et al. (2014) and Cho et al. (2015) extend the debate by arguing that macroeconomic volatility might have a positive effect on welfare. Although households prefer smooth consumption plans, firms might benefit from mean-preserving productivity fluctuations. Indeed, they have the opportunity to use more inputs when their marginal productivity is high. This strategy raises their average productivity levels. Volatility can be welfare increasing when these options effects dominate the costs of consumption fluctuations. This is more likely when the elasticity of factor supply is large and when households have a mean (such as capital) to transfer wealth across periods. This result illustrates the importance of using a model that capture agents reactions to shocks when measuring the welfare costs of business cycles. Moreover, it means that the welfare costs of business cycles are unlikely to be large in RBC models with perfect asset markets. However, New Keynesian models usually attribute larger welfare costs to business cycle fluctuations even when using this assumption. From the New-Keynesian perspective, recessions feature inefficient drops in output, below its natural level. In addition to aggregate consumption and hours fluctuations, those models generates additional welfare costs arising from prices and wages rigidities.

Other studies challenge agents homogeneity and the perfect market hypothesis allowing each individual households to insure against idiosyncratic risks. Imrohoruglu (1989) considers employment idiosyncratic risks together with imperfect credit markets in the form of liquidity constraints. Business cycles are characterised by good times (high employment probability) and bad times (low employment probability). When agents only have access to a simple storage technology (with no borrowing opportunities), business cycles generate costs that are four to five times larger compared to the perfect insurance market environment. However, when agents are allowed to borrow (at an exogenous rate set to 8%), the costs are substantially reduced and closer to Lucas experiment. Building on this study, Krusell and Smith (1999) and Krusell et al. (2009) additionally consider the fact that wealth is heavily concentrated in the US. In the presence of borrowing constraints,
the welfare costs of business cycles are much larger for households with little wealth. Indeed, prolonged periods of unemployment quickly exhaust poor households wealth with large welfare effects.

The literature also studied the interaction between aggregate and idiosyncratic risks. Atkeson and Phelan (1994) consider wage and employment idiosyncratic risks. In their model, agents can trade in risk-free bonds but not in state-contingent assets. The interest rate is endogenous. They argue that counter-cyclical policies could directly reduce income risks faced by each individuals or simply reduce the correlation in earnings by stabilising the unemployment rate. In the latter case, individual risks are unaffected. The only gain offered by stabilisation policies is to stabilise the interest rate: it avoids interest rate rises during downturns when more agents want to borrow to smooth consumption. Since interest rate fluctuations are small in US data, they find that welfare gains of such policies are extremely low. However, Beaudry and Pages (2001) emphasise that aggregate wage volatility could hide idiosyncratic risks that are caused by business cycle fluctuations. Eliminating aggregate fluctuations would also eliminate the idiosyncratic risk. Finding some middle ground, Santis (2007) builds a model with aggregate and independent idiosyncratic risks. Those two types of risks add-up. He argues that eliminating aggregate fluctuations might bring large welfare gains when agent already face substantial permanent idiosyncratic income shocks.

The literature described above focuses on the US. However, since Lucas (1987), it is clear that a crucial ingredient of the welfare cost of business cycles is consumption volatility. Countries with different levels of volatility would naturally experience different levels of welfare. Business cycles in emerging and developing economies display more volatility (see Agenor et al. (2000), Rand and Tarp (2002), Neumeyer and Perri (2005), Aguiar and Gopinath (2007) and Male (2011)). They experience sharper consumption fluctuations provoked by larger domestic and foreign shocks exacerbated by weaker resilience. Domestic shocks comprise volatile fiscal or monetary policies as well as shocks in the production sector such as extreme weather conditions. External shocks include sudden stops of capital inflows or abrupt changes in their terms of trade (e.g. Raddatz (2007) and Houssa et al. (2015)). In addition, their capacity to cope with different types of shocks is limited by lower international risk-sharing opportunities, less efficient stabilisations policies and heavier microeconomic regulations (Loayza et al. (2007)). Their financial sectors are incomplete and therefore do not offer enough instruments to adequately insure against all shocks and additionally tend to dry up in times of crisis. Heavier microeconomic regulations tend to hamper the reallocation of resources from low to high productive firms/sectors required to cope with shocks. These stylised facts indicate that the costs associated to business cycle fluctuations might be more important than the estimates provided for advanced countries. Pallage and Robe (2003) compared the costs of business cycles in advanced and developing countries in different environments (us-
ing different consumption processes and constrasting CRRA with EZ utility functions). They find that the cost of business cycle fluctuations ranges from 10 to 30 times their estimated values for the United States. Houssa (2013) estimates those costs for developed and developing countries with Bayesian methods accounting for parameter uncertainty. He finds that those costs are on average two to four times larger in developing countries, that they compare with a 1% increase in long-term growth for many developing countries and that oil producing and politically unstable countries would benefit the most from successful stabilising policies.

Reviewing these evidences shows that business cycles might be relatively more costly in developing and emerging countries for a variety of reason. First, as already studied in Pallage and Robe (2003) and Houssa (2013), excess consumption volatility translates into larger welfare costs. Second, since many households are excluded from financial markets in these economies, more agents should not be able to insure against idiosyncratic risks and to accumulate financial wealth. This could exacerbate the effects of aggregate volatility. Third, according to the New Keynesian tradition, inflation volatility (which is also larger in these countries) should also amplify the welfare cost of business cycles. These last two points motivate the measure of the costs of business cycles in a New-Keynesian DSGE model tailored to developing and emerging countries specificities. Structural models offer a natural laboratory for testing these effects and bring discipline to the exercise.

2.2 Stabilisation with monetary policy

Most advanced countries central banks recognise price stability as their primary objective. This is reflected in the gradual move, pioneered by New Zealand, towards a formal inflation targeting framework. The benefits of price stability are well recognised. Among other advantages, price stability ensures transparency of the price mechanism, reduces the inflation risk premium, prevent arbitrary redistribution of resources and ease contract formation. In addition, through its impact on aggregate demand, monetary policy can also influence output and employment. Some central banks such as the US Federal Reserve therefore explicitly aim at supporting activity. Small open economies also often add exchange rate considerations to their policies which can be affected through the uncovered interest rate parity condition.

Following the wave of currency crisis during the 1994-2001 period, many emerging economies began to implement inflation targeting (Frankel (2011)). However, in practice, emerging and developing countries tend to respond to exchange rate fluctuations by "leaning against the wind", supporting the "fear of floating hypothesis" (e.g. Calvo and Reinhart (2002) and Mohanty and Klau (2004)). Even in countries officially operating under floating regimes, central banks often react to
changes in the exchange rate. Their motivations include currency mismatches in balance sheets, the pass-through of exchange rate into prices, the impact of the exchange rate on net exports and large nominal or risk premium shocks, among others. Hausmann et al. (2001) find that countries with limited ability to borrow in domestic currency tend to tolerate less volatility in their exchange rate. In particular, the South African Reserve Bank (SARB) introduced a formal inflation targeting framework in 2000. It targets an average rate of consumer price inflation between 3 and 6%. Prior to this period, Ortiz and Sturzenegger (2007) estimate the Taylor rule in a NK-DSGE model. They find that the SARB responded consistently to inflation fluctuations and attached a larger weight on output, but a lower on the exchange rate when compared to other emerging economies. In a similar exercise, Peters (2016) finds that the inflation coefficient is positive and significant, while the output gap and exchange rate coefficients are also positive but insignificant.

Estimated DSGE models have become the standard toolkit for macroeconomic policy analysis. Much is known about solving these models (e.g. Uhlig (1995); Klein (2000) and Sims (2002)) and estimating (e.g. DeJong et al. (2000); Schorfheide (2000) and Otrok (2001)) as well as what modelling features are most relevant for understanding observed macroeconomic fluctuations in these economies (e.g. Smets and Wouters (2007) and Adolfson et al. (2007)). Those models have also been used to devise appropriate monetary (e.g. Gali and Monacelli (2005)) and fiscal policies (e.g. Ratto et al. (2009)). In fact, the central banks of most developed countries (e.g. the US Federal Reserve, the Bank of England, the European Central Bank) as well as policy institutions such as the International Monetary Fund all use estimated DSGE models for policy analysis. Monetary policy analysis in developing and emerging economies exploits similar models with few account for their specificities. However, some ingredients such as a large commodity sector (e.g. Mendoza (1995)), imported foreign intermediate inputs (e.g. Kose (2002)) and non-Ricardian households (e.g. Medina and Soto (2007)) have been proposed. Other considerations beyond the scope of this paper but specific to developing and emerging countries relate to the volatility of food prices and to the management of volatile aid flows.\footnote{Anand et al. (2015) study the optimal inflation measure that a developing country central bank should target. They build a three sectors model: an informal food sector, a formal non-traded good sector and a formal traded-good sector (capturing the role of commodities). In a context of credit-constrained households primarily working in the food sector and spending a large portion of their income in food, they find that it is preferable to target headline inflation than core inflation. The optimal index includes food but excludes imported goods.}

\footnote{Adam et al. (2009) build a two sectors DSGE model with sticky prices in the non-traded sector, currency substitution and volatile aid flows. Monetary policy operates through foreign exchange reserves management and government securities transactions with the private sector. When increased aid flows translate into lower domestic financing requirements (i.e. when all aid is not immediately spent), the decrease in domestic money supply encourages domestic households to substitute foreign currency into domestic currency. This generate an appreciation which has destabilising impacts for both prices and output. These can be mitigated with net foreign assets accumulation at the central bank as a response to appreciation.}
An early literature, mostly applied to the US, studied optimal monetary policy in simple models with price rigidities (e.g. Ireland (1997), Rotemberg and Woodford (1997, 1999) and Clarida et al. (1999)). These authors show that the Fed implicit inflation targeting framework adopted since the Volcker era successfully insulated the US economy from demand shocks. This literature argues that central bank (credible) commitment to respond to inflation is enough for monetary policy to be efficient as long as the private sector is forward-looking. However, these papers further argue that the Fed leaning against the wind policy was not optimal due to the identification of large supply disturbances. Optimal policy response to supply shocks requires the Fed to accommodate the change in output in order to stabilise prices. Barlevy (2004) supports the view that the benefit from stabilisation policies depends on the type of shocks responsible for macroeconomic fluctuations. Monetary and fiscal policies are well suited in order to stabilise fluctuations generated by demand (or nominal) shocks, but not in the case of supply (or real) shocks. He claims that the gains from post-war stabilisation policies in the US were substantial but that the benefits from further stabilisation could be small. However, in the absence of appropriate stabilisation policies, the welfare cost of business cycles would be much larger. Therefore, stabilisation policies should remain a priority. The literature has built on those models by gradually increasing their complexity to gain in realism. Schmitt-Grohe and Uribe (2007) study optimal simple monetary and fiscal rules in a NK-DSGE model. The model includes price stickiness, capital accumulation and demand for money origination from firms’ working capital and households’ cash in advance constraints. They calibrate the model on US data and compare the welfare costs of alternative Taylor rules coefficients (with interest rate smoothing and inflation and output responses) relative to the time-invariant stochastic equilibrium allocation associated with the Ramsey policy. They find that welfare gains from increasing the value of the inflation coefficient beyond the Taylor principle and from interest rate smoothing are extremely low. In addition, responding to output generates a large welfare loss. The conclusion reached by this first body of literature summarises as follow: with perfect financial markets and forward-looking agents, inflation targeting is the optimal monetary policy, but the extra gains from very aggressive inflation responses could be very low.

Erceg et al. (2000) extend the baseline NK-DSGE model to consider price and wage stickiness. The volatility in aggregate wage inflation causes dispersion in individual wages, which generates inefficient fluctuations in individual hours worked. In this context, it is impossible for the central bank to stabilise the output-gap and price and wage inflation rates at the same time. Strict inflation targeting becomes inefficient. Benigno and Woodford (2005) show that these results hold in the case of a distorted steady-state. However, Schmitt-Grohé and Uribe (2006) build a medium scale NK-DSGE model (including both capital and sticky wages) and find that the central bank should place more emphasis on price than on wage stability. Building on the Mortensen and Pissarides...
(1994) search and matching model, Gertler and Trigari (2009) introduce staggered wage bargaining in an otherwise standard NK-DSGE model. At every period, some firms and workers bargain over wages while others cannot re-adjust their wages. In this context, Thomas (2008) shows that pure inflation targeting is inefficient. Indeed, as real wages can deviate from their optimal level, the central bank can use inflation to adjust real wages and therefore faces a trade-off between price and employment stability. Overall, these studies suggest that price stability should remain the central concern of monetary policy but that it could be complemented with wage stabilisation objectives.

In small open economies, the CPI is affected by domestic and imported goods prices. The latter depends on the exchange rate. The literature compares the effects of stabilisation policies responding to each component of the CPI with rules focusing on the domestic price index. Moreover, it assesses the impact of different exchange rate rules such as a pure float, a managed float and a peg. Gali and Monacelli (2005) develop a SOE version of the canonical NK-DSGE model. They find that a Taylor rule based on domestic inflation is preferable in terms of welfare to a similar Taylor rule based on CPI and to an exchange rate peg. The optimal rule implies perfect stabilisation of the domestic price index. Kollmann (2002) considers monopolistic distortions and finds that the optimal rule consists of a strict response to the domestic price index which tolerates large fluctuations in the exchange rate and minimal fluctuations in the price index. In addition, Leitemo and Soderstrom (2005) show that the gains of integrating the exchange rate in the Taylor rule are generally low using a variety of models. However, Engel (2011) brings the issue of currency misalignment (the fact that prices can differ between countries when compared in the same currency) in an otherwise simple framework. Violations of the law of one price occur due to local-currency pricing and are inefficient. If prices are sticky in the importer’s currency, then targeting CPI delivers the optimal policy. In some developing and emerging countries, choosing the right price target is particularly important because imported goods prices display stronger fluctuations driven by volatile exchange rates. Devereux et al. (2006) construct a two sectors SOE model representing an emerging economy. They introduce imperfect exchange rate pass-through and lending constraints on external credit for investment (labelled in foreign currency) in an otherwise basic NK model. They find that the optimal monetary rule depends on the degree of exchange rate pass-through. In a high pass-through environment, the central bank should target the domestic non-traded good price index, while in the low pass-through case, it is preferable to target the consumer price index. Hove et al. (2015) study the optimal monetary policy response to exogenous term of trade shocks in a small scale SOE-DSGE model with tradables and non-tradables. Firms in the traded sector operate under perfect competition: there is no incomplete exchange rate pass-through. They calibrate their model to the South African economy and approximate welfare using loss functions with different weights on the variance of inflation, output-gap, interest rates and exchange rates. They find that
a CPI inflation targeting performs better than non-traded (domestic) inflation targeting. In addition, they find that exchange rate targeting has a detrimental aggregate welfare effect. This body of research shows that the choice of the optimal target - CPI vs a domestic price index - crucially depends on the exchange rate pass-through and to the exposure to term of trade shocks. Moreover, pure-floats usually beat managed-floats and pegs in these studies.

The literature has also recently advocated for the inclusion of different types of agents in a context of imperfect financial markets (e.g. Bilbiie (2008), Nisticò (2016), Cúrdia and Woodford (2016) and Bilbiie and Ragot (2017)). These papers motivations include the impact of imperfect financial markets on the interest rate transmission channel; the role of monetary policy on financial stability; and the link between monetary policy and inequality. In developing and emerging markets, many households are excluded from the asset markets. The literature has recently started to study this issue. Two studies applied to emerging countries are presented here in details. Iyer (2016) considers two types of households in an otherwise standard SOE-DSGE model and finds that exchange rate targeting stabilises the import-content of consumption for financially excluded households. Although inflation targeting remains the optimal monetary policy when financial inclusion is sufficiently high, exchange rate targeting is desirable in low financial inclusion environments. Prasad and Zhang (2015) include heterogeneous households and incomplete financial markets in a two-sector (tradable and non-tradeable goods) SOE-DSGE model. Prices are sticky in the non-traded sector and flexible in the tradable sector. Workers in the non-traded sector are hand to mouth consumers. They calibrate the model to an emerging economy and also find that exchange rate targeting has a detrimental aggregate welfare impact. However, when a positive productivity shock hits the home tradeable goods sector (which implies an appreciation), households in this sector fare better under exchange rate management in the short run. These two studies are closely related to the present paper. They both consider imperfect financial markets in emerging economies. However, they differ in the sense that households inside each group remain homogeneous.

The benefits from inflation targeting are relatively well established, both for advanced and emerging economies. However, these results were expected, in the sense that prices and wages fluctuations represent the largest part of the welfare costs of business cycles in these models. Indeed, a combination of relatively smooth aggregate consumption fluctuations and perfect financial markets generate relatively low costs of consumption fluctuations as in Lucas (1987) experiment for the US. These fluctuations are larger in emerging markets, but the extra volatility is also present in the price and wage indexes, thereby leading to similar optimal policies. The choice of the optimal price index remains debated. CPI is more likely to be favoured when the exchange rate pass-through is weak and when term of trade shocks are large. Usually, output and exchange rate
management do not improve welfare. In the present paper, business cycles fluctuations interact with idiosyncratic risks and imperfect assets markets. They could generate new trade-offs for monetary policy.

3 Background on the South African labour market

This section describes the South African labour market. Its objective is to isolate the empirically relevant features required to build the model presented in the next section. A striking characteristic of the South African labour market is its very large unemployment rate which fluctuated around 25% over the post-Apartheid period. Moreover, almost 65% of the unemployed have been without a job for over a year and many of them have never worked (Banerjee et al. (2008)). The literature has proposed a variety of potential explanations, some of which are based on the fact that wages seem disconnected to labour productivity and unemployment rates (e.g. Banerjee et al. (2008) and Klein (2012)).

Considering the key role played by the labour market in this paper, this section is devoted to the description of labour market legislations covering collective bargaining and the provision of unemployment benefits. In addition, the impact of labour unions on the performance of the South African labour market is discussed.

Legislative framework The most relevant regulations consist in the Labour Relation Act (LRA) of 1995, the Basic Conditions of Employment Act (BCEA) of 1997 and the amended Unemployment Insurance Act (UIA) of 2001. The LRA defines the rights of trade unions and regulates collective bargaining and the BCEA defines the basic conditions of employment. Collective bargaining on wages and employment conditions can take different forms. Inside the statutory system, trade unions and employers’ organisations meet in Bargaining Councils or in Statutory Councils. Outside the statutory system, negotiations can take place at the firm level or in centralised bargaining forums. Bargaining Councils are the central pillar of collective bargaining and they cover one third of the formal sector workforce (Bhorat et al. (2012)). They are formed by trade unions and employers’ organisations in a specific sector and area on a voluntary basis on the condition that they are sufficiently representative of firms and unions. The agreements reached by Bargaining Councils apply to all their members and can be extended to other non parties in the same sector and area. In practice, Bargaining Councils range from small local to large national organisations but they tend to merge into larger organisations. Other forms of collective bargaining are present

\footnote{Other reasons advanced to explain the high unemployment rate in South Africa are skill mismatches between labour supply and demand; a growing working age population; large reservation wages; concentration and regulations in the product market preventing small firms entry as well as a weak entrepreneurial culture inherited from the Apartheid period.}
in some specific sectors. In the mining sector, firms and unions bargain in centralised forums (gold and coal) or at the plant-level (platinum and diamond). The amended UIA establishes an unemployment insurance fund. Employers and employees contribute to the fund. The unemployed receive insurance benefits based on their wage over a period function of their employment duration (and capped at 34 weeks). The replacement rate varies between 38 and 60% of income with a lower rate for higher income levels. Those who have never worked and those occupied in the informal or public sectors are excluded from this scheme. The claiming rate (defined as the claimant to contributors ratio) is therefore relatively modest (about 6% in 2010 compared to the unemployment rate of about 25% in the same period). For more details on the institutional framework governing collective bargaining and the unemployment insurance scheme, the interested reader is referred to Godfrey et al. (2007), Bhorat et al. (2009) and Bhorat et al. (2013).

**Labour unions** Labour unions are important in South Africa and inherited from the role played by labour movements during the Apartheid period in the transition to democracy. Labour unions are organised in regional or national federations. The largest is the Congress of South African Trade Unions (COSATU) which covers more than 2 millions members. In addition to their influence in collective bargaining, labour unions also play an important political role. The COSATU is part of the tripartite alliance with the African National Congress and the South African Communist Party. Union density (expressed as a fraction of unionised workers to the total workforce) is relatively high in South Africa (37.5% compared to 30% on average in OECD countries), especially in the mining (80%) and public (70%) sectors (Bhorat et al. (2014)). Unions are believed to contribute to the poor performance of the South African labour market for various reasons. First, they reinforce an insider/outside dynamic. Indeed, job security is associated to union affiliation and job finding rates depend on past experience and networks (Fedderke (2012) and Anand et al. (2016)). Moreover, affiliated workers are generally older, more educated and are more likely to hold permanent employment positions with written labour contracts (Bhorat et al. (2012)). Second, labour unions and the Bargaining Councils framework allow workers to extract a wage premium. Controlling for union membership endogeneity, Bhorat et al. (2012) estimate that unionised workers covered by Bargaining Councils agreements earn a total premium of 16.4% over their non-unionised and uncovered counterparts. The increase in labour costs could raise unemployment. Indeed, Magruder (2012) finds that Bargaining Councils have adverse effects on employment creation, especially in small firms and von Fintel (2017) shows that union density is correlated to wages and has a negative impact on labour demand and employment. Third, various rigidities generate sticky non-clearing wages (Fedderke (2012)). In particular, wages in large firms with a high concentration of unionised workers are slow to adjust to unemployment rates (von Fintel (2016)).
For a detailed description of the state of labour unions in South Africa, see Bhorat et al. (2014) and Armstrong and Steenkamp (2008).

4 Model

The model consists of two blocks: a domestic small open emerging economy and the rest of the world. The domestic block extends the SOE-DSGE model proposed by Adolfson et al. (2007). It incorporates key emerging countries structural characteristics that are particularly relevant to the South African economy as described in Houssa et al. (forthcoming). These include: i) two categories of households to capture key differences between financially included and excluded households and ii) two different types of goods to account for the specific role of commodities in exports. In addition, there are two different versions of the model that differ according to the functioning of the labour market. The working of the enlarged model is summarized as follows.

The economy is populated by two types of households: optimising and rule of thumbs. Households derive utility from consumption of a composite good (consisting of both domestic and imported goods) and leisure. Consumption preferences are subject to habit formation. Optimising households accumulate financial wealth in the form of risk free domestic and foreign bonds. They build capital which is sector specific and subject to investment adjustment costs. The investment basket is a composite of domestic and imported inputs. Rule of thumb households are excluded from financial and capital markets and unable to accumulate wealth. They consume their entire income in each period. Contrary to optimising households, they have no access to state contingent claims and therefore cannot insure against idiosyncratic risks. Income heterogeneity thus translates into consumption heterogeneity with potentially important implications on individual consumption fluctuations and aggregate welfare.

There are two sorts of good: commodities and secondary products. Commodity goods are homogeneous and produced under perfect competition. Commodity producers combine capital, labour and land and sell their products in the world market. Secondary goods are produced in a perfectly competitive environment (but distributed by firms enjoying market power). Secondary good producers combine capital and labour to produce an undifferentiated intermediate goods. Distributors operate in three markets: domestic, import and export. Domestic distributors turn secondary goods into consumption and investment goods sold to households. Importing distributors turn foreign secondary goods into foreign consumption and investment goods sold to domestic households. Exporting distributors sell domestic secondary goods to foreign households. The distribution sector is composed of intermediate and aggregating firms. Each intermediate distributor is a monopoly supplier of its specific product and follows a price adjustment rule à-la Calvo (1983).
Nominal rigidities in importing and exporting sectors allow for short-run incomplete exchange rate pass-through to both import and export prices\textsuperscript{11}.

There are two different (and independent) versions of the labour market. The first version of the model follows Erceg et al. (2000) which introduce wage rigidities à-la Calvo (EHL version). Optimising households supply monopolistically a differentiated labour services and set their own hourly wage whenever they receive a random signal. Rule of thumb households mimic their optimising counterpart whenever they are allowed to reset their wages. All other workers simply index their wages. The second version takes inspiration from Gertler and Trigari (2009) and Thomas (2008). They propose search and matching frictions in the labour market with staggered wage bargaining (GTT version). Frictions generate unemployment and firm post vacancies to attract unemployed workers. At every period, a fraction of optimising workers regroup in unions and bargain with the firms over wages. An identical fraction of rule of thumb workers takes the outcome of this bargain as given. All other workers index their wages.

The government collects pay-roll, labour income, consumption and capital gain taxes. It follows a simple rule that determines its level of public consumption. The central bank sets the interest rate which depends on inflation, output growth and the change in exchange rate.

The rest of the world is a closed version of the domestic economy based on Smets and Wouters (2007). It is extended with a commodity sector. Commodity prices are endogenously determined in the foreign economy bloc assuming that the small open domestic economy has no impact on commodity prices. The following subsections describe the model in details.

4.1 Households

The economy is populated by two types of agents: optimising and rule of thumb households. Any \textsuperscript{ith} optimising household (or any \textsuperscript{ith} rule of thumb household) attains utility from consumption \(C_{i,t}\) and dis-utility from hours worked \(H_{i,t}\) at time \(t\). Its life-time utility is given by

\[
\mathbb{W}_{i,t} = E_0 \sum_{t=0}^{\infty} \beta^t U_{i,t} = E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_{i,t}/(\bar{C}_{t-1})^{1-\sigma_c})^{1-\sigma_c}}{1-\sigma_c} - A_h N_{i,t} \frac{(H_{i,t})^{1+\sigma_h}}{1+\sigma_h} \right],
\]

where \(E\) is the expectation operator and \(\beta\) is the discount factor. The term \(N_{i,t}\) represent employment and is equal to one when the agent is employed and zero otherwise. The parameters \(\sigma_c\) and \(\sigma_h\) denote the inverse of the inter-temporal elasticity of substitution for consumption and the

\textsuperscript{11}Compared to the traded/non traded good literature, this framework offers more flexibility by incorporating one non traded good: the final good sold by domestic distributors; and two traded goods: commodities (produced in a perfectly competitive environment) and final goods (sold by importing/exporting distributors). The traded and non traded final goods have different Phillips Curves.
inverse of the elasticity of work effort, respectively; $A_h$ is the relative importances of labour in the utility; $b$ an external multiplicative habits parameter and $\bar{C}_{t-1}$ is the lagged average value of consumption of a reference group.

The composite consumption basket $C_{i,t}$ for any household $i$ is given by the CES index of domestic and imported goods

$$C_{i,t} = \left[ (1 - \omega_c) \left( C^d_{i,t} \right)^{(\eta_c - 1)}/\eta_c + (\epsilon_{\omega,t} \omega_c) \left( C^m_{i,t} \right)^{(\eta_c - 1)}/\eta_c \right]^{\eta_c/(\eta_c - 1)},$$

(4.2)

where $C^d_t$ and $C^m_t$ denote consumption of the domestic and imported good, respectively, $\omega_c$ is the steady-state share of imports in consumption, $\epsilon_{\omega,t}$ a shock to the home bias and $\eta_c$ is the elasticity of substitution between domestic and foreign consumption goods.

### 4.1.1 Financially included and optimising households

There is a continuum of optimising households (OHs) indexed by $i \in (0, 1)$ with access to financial and capital markets. The representative agent maximizes the inter-temporal utility by choosing her consumption and investment levels, as well as domestic and foreign bond holdings. For any given period $t$, OHs face the same budget constraint which is given, in nominal terms, by

$$B_{i,t+1} + S_i B^i_{i,t+1} + (1 + \tau^c) P^c_i C_{i,t} + P^d_i \left( I^p_{i,t} + I^f_{i,t} \right)$$

$$= (1 - \tau^k) \left( R^{k,p}_{i,t} K^p_{i,t} + R^{k,f}_{i,t} K^f_{i,t} \right) + \frac{1 - \tau^v}{1 + \tau^v} W_{i,t} N_{i,t} + (1 - N_{i,t}) \sigma_t$$

$$+ T R_{i,t} + S C S_{i,t} + \epsilon_{b,t-1} R_{t-1} B_{i,t} + \epsilon_{b,t-1} R^*_{t-1} \Phi(A_{t-1}, \tilde{\phi}_{t-1}) S_i B^*_{i,t}$$

(4.3)

where the subscript $i$ indicator denotes the household’s choice variables, whereas the variables, without the subscript, are the economy-wide aggregates. The variable $W_{i,t} = W_i H_{i,t}$ represents the period $t$ hourly wage income and $W_{i,t}$ is the hourly wage rate. The term $\sigma_t$ captures unemployment benefits (set to a fraction of the average labour income in the economy). $B_t$ denotes the value of nominal domestic bonds, $S_i$ is the nominal exchange rate representing the amount of local currency per unit of foreign currency and $B^*_t$ the value of foreign bonds (in foreign currency). $R_t$ and $R^*_t$ are the domestic and foreign gross risk-free interest rates controlled by the monetary authority.

---

12 Multiplicative habits were introduced by Abel (1990) and Gali (1994).

13 The domestic financial markets are assumed to be complete, thus each financially included household can insure against any type of idiosyncratic risk through the purchase of the appropriate portfolio of state contingent securities. This prevents the frictions from causing these households to become heterogeneous, so the representative agent framework is still valid for this type of households.

14 In the EHL model, households set their hourly wage rate $W_{i,t}$ while in the GTT version firms and workers bargain over the period - monthly in their paper or quarterly in this paper - wage $W_{i,t}$.
respectively. The exogenous process $\varepsilon^c_{b_t}$ creates a wedge between policy and private interest rates. $P^c_t$ is the consumer price index and $P^i_t$ the investment good price index. Households invest $I^q_{ft}$ in private capital $K^q_f$ used in the secondary sector and $I^p_f$ in private capital $K^p_f$ used in the primary sector. $R^{k-p}_t$ and $R^{k-f}_t$ are the returns of capital in the primary and final sectors, respectively. The term $TR_{i,t}$ represents transfers from the government and the firms, $SCS_{i,t}$ is the household’s net cash income from participating in state contingent securities at time $t$. The government collects taxes on consumption $\tau^c$, pay-roll $\tau^w$, labour-income $\tau^l$ and capital-income $\tau^k$.

Country risk premium In equation (4.3), the term $R^*_{t-1} \Phi(A_{t-1}, \phi_{t-1})$ represents the risk-adjusted gross interest rate paid by foreign bonds (in foreign currency). The function $\Phi(.)$ captures the country risk premium function of the real aggregate net foreign asset position $A_t = \frac{S^*_t}{b^*_t}$ and a time varying shock to the risk premium $\phi_t$.$^{15}$

This function illustrates the imperfect integration in the international financial markets of the domestic economy and induces stationarity of the model.$^{16}$ Therefore, domestic households are charged a premium over the (exogenous) foreign interest rate $R^*_t$ if the domestic economy is a net borrower ($B^*_t < 0$), and receive a lower remuneration on their savings if the domestic economy is a net lender ($B^*_t > 0$).

Capital accumulation Capital and investment are sector specific. The capital accumulation rule is subject to investment adjustment costs and follows

$$K^q_{t+1} = (1 - \delta)K^q_t + \Upsilon_t F(I^q_t, I^q_{t-1}), \quad (4.4)$$

where $q \in (p, f)$ represents the primary or secondary sector and $\delta$ is the depreciation rate. The variable $\Upsilon_t$ is a stationary investment-specific technology shock common to both sectors and $F(I_t, I_{t-1})$ represents a function which turns investment into physical capital. The $F(I_t, I_{t-1})$ function is specified following Christiano et al. (2005) as:

$$F(I_t, I_{t-1}) = (1 - \tilde{S}(I_t/I_{t-1}))I_t, \quad (4.5)$$

where the function $\tilde{S}(I_t/I_{t-1})$ is defined by

$$\tilde{S}(I_t/I_{t-1}) = \phi^i_3 \left\{ \exp \left( \frac{I_t}{I_{t-1}} - 1 \right) + \exp \left( - \frac{I_t}{I_{t-1}} + 1 \right) - 2 \right\}, \quad (4.6)$$

$^{15}$The function $\Phi(A_t, \phi_t) = \exp(-\phi_t(A_t - \bar{A}) + \phi_t)$ is strictly decreasing in $A_t$ and satisfies $\Phi(\bar{A}, 0) = 1$. In particular, Adolfsen et al. (2007) set $\bar{A} = 0$.

with \( \tilde{S}(1) = \tilde{S}'(1) = 0 \) and \( \tilde{S}''(1) \equiv \tilde{S}'' = 2\phi \lambda > 0 \).

**Investment basket** The investment good \( (I^q) \) with \( q \in (p, f) \) is given by a CES aggregate of domestic \( (I^d_i, q) \) and imported investment inputs \( (I^m_i, q) \)

\[
I^q_i = \left[ (1 - \omega_i)^{\eta_i} (I^d_i, \eta_i^{-1})/\eta_i + (\epsilon_{w_t, \omega_i})^{1/\eta_i} (I^m_i, \eta_i^{-1})/\eta_i \right]^{\eta_i/\eta_i^{-1}},
\]

where \( \omega_i \) is the steady-state share of imports in investment and \( \eta_i \) is the elasticity of substitution between domestic and imported investment goods.

### 4.1.2 Rule of thumb households

There is a continuum of rule of thumb households (ROTHs) of mass 1 indexed by \( l \in (0, 1) \) with preferences given by (4.1). These households do not have access to financial and capital markets. Financial exclusion has two components. First, they are excluded from insurance markets and therefore unable to hedge against labour market idiosyncratic risks. Second, bonds markets exclusion - together with capital markets exclusion - imply that they are unable to transfer wealth inter-temporally. They consequently consume their entire labour income in every period. Their budget constraint is given by

\[
(1 + \tau^c)P^c_i C_{l,t} = \frac{1 - \tau^v}{1 + \tau^w} \bar{W}_{l,t} N_{l,t} + (1 - N_{l,t}) \bar{\sigma}_t,
\]

where \( \bar{W}_{l,t} = W_{l,t} H_{l,t} \). This specification allows for heterogeneity in households wages and introduces unemployment benefits \( \bar{\sigma}_t \).

### 4.2 Firms

There are two categories of goods in this model: primary commodities and secondary products.

#### 4.2.1 Commodity sector

Primary commodities are produced in the domestic and foreign blocks. While the rest of the model section focuses exclusively on the domestic economy, this subsection also describes the commodity market in the foreign economy in order to highlight how commodity prices are endogenously determined in the world market.

---

17 Rule of thumb households were introduced in Coenen and Straub (2005), Erceg et al. (2006) and Galí et al. (2007). These types of households have been introduced in DSGE models applied to developing countries by Medina and Soto (2007), Céspedes et al. (2012) and Prasad and Zhang (2015).
**Domestic commodity producers** The commodity good is produced under perfect competition in the domestic economy. Firms combine capital and labour to produce a commodity input \( Y^p_t \) and sell their production on the world market. The production function for primary producers is given by

\[
Y^p_{j,t} = Y^p_0 \varepsilon^p_t \left( \frac{\varepsilon_{k,t}^* K^p_{j,t}}{K^p_0} \right)^{\alpha_p} \left( \frac{L^p_{j,t}}{L^p_0} \right)^{(1-\alpha_p-\beta_p)},
\]

(4.9)

where the terms \( Y^p_0, K^p_0 \) and \( L^p_0 \) are normalising constants and only represent choices of units. The term \( \varepsilon^p_t \) is a pure commodity supply shock; \( \varepsilon_{k,t}^* \) is a capital augmenting technology shock common to the primary and secondary sectors, \( K^p_t \) is capital used in the mining sector, \( L^p_{j,t} = N^p_{j,t} H^p_{j,t} \) is the amount of labour equal to the number of employees multiplied by hours worked per employee. The stock of land is fixed and set to one for simplicity. The income shares of capital and land are given by \( \alpha_p \) and \( \beta_p \), respectively. The commodity sector captures the impact of world commodity price on the domestic economy.\(^{18}\)

**Foreign commodity market** World commodity price \( P^*_{t} \) is determined endogenously through the confrontation of the foreign supply and foreign demand for commodities. Foreign commodity supply is modelled as an exogenous AR(1) process

\[
Y^p_{t} = \rho^*_{t} Y^p_{t-1} + \varepsilon^*_{p,t},
\]

(4.10)

where \( \varepsilon^*_{p,t} \) is the foreign commodity supply shock which is assumed to be a MA process.

The foreign demand for commodity is determined by the foreign secondary good sector where it served as inputs. Foreign firms combine capital, labour and commodities to produce a secondary foreign goods:

\[
Y^*_t = Y^*_0 \left[ \beta^* \left( \frac{Y^p_{t}}{Y^*_0} \right)^{\frac{\sigma^*_p-1}{\sigma^*_p}} + (1-\beta^*) \left( \frac{\varepsilon^*_{k,t} K^*_t}{K^*_0} \right)^{\alpha^*} \left( \frac{L^*_t}{L^*_0} \right)^{(1-\alpha^*)} \right]^{\frac{\sigma^*_p}{\sigma^*_p-1}},
\]

(4.11)

where where \( L^*_t \) is labour, \( K^*_t \) is capital and \( \varepsilon^*_{k,t} \) is a capital efficiency shock. The terms \( Y^*_0, Y^p_{t} \)

---

\(^{18}\)Previous studies include for example Medina and Soto (2007) and Céspedes et al. (2012). This model departs from those works by assuming that commodity production is not exogenously given and require some inputs. With this respect, this specification is very similar to Kose (2002) who studies primary sector price shocks in a RBC model. It also relates to Hove et al. (2015) which examine monetary policy responses to commodity price fluctuations in a small calibrated NK DSGE model.
and $K_0^*$ are normalizing constants; $\beta^*$ is the (income) share of commodities in foreign secondary goods sector; $(1 - \beta^*)\alpha^*$ is the income share of capital and $\sigma_p^*$ is the elasticity of substitution between commodities and the other production factors. Equation (4.11) shows how foreign (supply or demand) shocks could be transmitted to the domestic economy through commodity prices. Typically, whenever foreign firms want to increase production, demand for commodity increases which is transmitted to commodity prices. The elasticity $\sigma_p^*$ is a key parameter that determines the strength of commodity price responses to changes in foreign demand for commodity.

### 4.2.2 Secondary sector

Domestic and foreign secondary goods are used for domestic and foreign consumption and investment as imperfect substitutes. Imperfect competition is introduced in three steeps: i) production of an un-differentiated secondary good, ii) its differentiation with brand-naming technology and finally iii) its aggregation into a consumption or investment good. Step one is performed by secondary good producers while steps two and three depends on intermediate and final distributors operating in the domestic, import and export markets.

**Secondary good producers** The secondary good is produced under perfect competition. Firms use capital $K^f$ and hire labour $L^f$ to produce an undifferentiated secondary good denoted $Y^f$. The production function for the secondary good is given by

$$Y^f_{j,t} = Y^f_0 \left( \frac{\epsilon_{k,t} K^f_{j,t}}{K^f_0} \right)^{\alpha_f} \left( \frac{L^f_{j,t}}{L^f_0} \right)^{(1 - \alpha_f)},$$

where the terms $Y^f_0$, $K^f_0$ and $L^f_0$ are normalising constants and only represent choices of units. $L^f_{j,t} = N^f_{j,t} H^f_{j,t}$. The term $\epsilon_{k,t}$ represents a capital augmenting technology shock common to the primary and secondary sectors and $\alpha_f$ is the capital income share.

**Domestic distributors** There are two types of domestic distributors: intermediate and final. There is a continuum of intermediate distributors, indexed by $j \in [0,1]$. Each intermediate distributor buys a homogeneous secondary good $Y^f$; turns it into a differentiated intermediate good (using a brand naming technology) and then sells it to a final distributor at price $P_{j,t}$. Every intermediate distributor is assumed to be a price taker in the secondary good markets (it purchases secondary goods at their marginal costs) and a monopoly supplier of its own variety (it sets its own price).
The intermediate distributor follows a price adjustment rule à-la Calvo (1983). Every period \( t \), with probability \( (1 - \xi_d) \), any intermediate distributor \( j \) is allowed to re-optimize its price by choosing the optimal price \( P_{j, t}^{\text{new}} \).\(^{19}\) With probability \( \xi_d \), it cannot re-optimize, and it simply indexes its price for period \( t + 1 \) according to the following rule:

\[
P_{j, t+1} = (\pi_t)^{\kappa_d}(\varepsilon_{\pi, t+1} \bar{\pi})^{1-\kappa_d}P_{j, t},
\]

where \( \pi_t = \frac{P_t}{P_{t-1}} \) is last period’s inflation, \( \bar{\pi} \) is the inflation target; \( \kappa_d \) is an indexation parameter and \( \varepsilon_{\pi, t+1} \) is a shock to the price indexation process.

The final distributor is an aggregator which uses a continuum of differentiated intermediate goods to produce the final homogeneous good, which is then used for consumption and investment by domestic households and sold at price \( P_t \). The final distributor is assumed to have the following CES production function:

\[
J^d_t = \left[ \int_0^1 \left( J^d_{j,t} \right)^{\varepsilon_d-1} d j \right]^{\frac{\varepsilon_d}{\varepsilon_d-1}}, 1 < \varepsilon_d,
\]

(4.13)

where \( J \in (C, I) \) refers to the consumption or investment good and \( \varepsilon_d \) is the elasticity of substitution between intermediate inputs. Consequently, the relative demand for input type \( j \) is given by

\[
J^d_{j,t} = \left( \frac{P_{j,t}}{P_t} \right)^{-\varepsilon_d} J^d_t
\]

(4.14)

where \( P_t \) is the price index defined by

\[
P_t = \left[ \int_0^1 P_{j,t}^{1-\varepsilon_d} d i \right]^{\frac{1}{1-\varepsilon_d}}
\]

(4.15)

**Exporting distributors** The intermediate exporting firm buys a homogeneous domestic good \( Y^f \) to domestic secondary producers, turns them into a type specific differentiated good using a brand naming technology and then sells it in the foreign market to an aggregator at price \( P^x_{j,t} \) expressed in foreign currency.

Domestic intermediate exporting firms follow a Calvo price setting rule and can optimally change their price only when they receive a random signal. In any period \( t \), each exporting firm has a probability \( (1 - \xi_x) \) to re-optimize its price by choosing \( P^x_{j,t} \).\(^{19}\) With probability \( \xi_x \) the importing firm cannot re-optimize at time \( t \) and, instead, it indexes its price according to the fol-

\(^{19}\)Since all distributors allowed to reset their prices are virtually identical and will always choose the same price the index \( j \) is dropped to simplify the notation.
following scheme: $P_{j,t+1}^x = (\pi_t^x)^{\kappa_t}(\bar{\pi})^{1-\kappa_t}P_{j,t}^x$ where $\pi_t^x = \frac{P_t}{P_{t-1}}$. This foreign currency price stickiness assumption implies short run incomplete exchange rate pass-through to the export price.

The aggregator produces final exported consumption and investment goods sold at price $P_t^x$ to foreign households. The final, composite, exported good aggregates a continuum of $j$ differentiated exported goods, each supplied by a different firm, according to

$$X_t^f = \left[ \int_0^1 \left( \tilde{X}_{j,t} - \frac{\epsilon_{x,j}}{\epsilon_{x}} \right) d\tilde{j} \right] \frac{\epsilon_{x}}{\epsilon_{x,j}}, \quad 1 < \epsilon_{x}. \tag{4.16}$$

where $\epsilon_{x}$ is the elasticity of substitution between intermediate inputs.

Assuming that aggregate foreign consumption and investment follow CES functions, foreign demand for the aggregate final exported good is defined by

$$X_t^f = \left( \frac{P_{j,t}^*}{P_t^x} \right)^{-\eta_f} X_t^x, \tag{4.17}$$

where $P_{j,t}^*$ is the price of the foreign good in foreign currency, $P_t^x$ is the export price (denominated in export market currency) and $X_t^x$ is foreign demand function of foreign consumption and investment. The coefficient $\eta_f$ is the foreign elasticity of substitution between foreign and domestic goods and allows for short run deviations from the law of one price.

**Importing distributors** The (foreign owned) intermediate importing firm buys a homogeneous foreign good in the world market. It turns it into a type specific good using a differentiating technology (brand naming) and then sells it in the domestic market to an aggregator at price $P_{j,t}^m$.

Foreign intermediate importing firms follow a Calvo price setting rule and can optimally change their price only when they receive a random signal. In any period $t$, each importing firm has a probability $(1 - \xi_m)$ to re-optimize its price by choosing $P_{j,t}^m$. With probability $\xi_m$ the importing firm cannot reoptimize at time $t$ and, instead, it indexes its price according to the following scheme:

$$P_{j,t+1}^m = (\pi_t^m)^{\kappa_m}(\bar{\pi})^{1-\kappa_m}P_{j,t}^m$$

where $\pi_t^m = \frac{P_t^m}{P_{t-1}}$. This local currency price stickiness assumption implies incomplete exchange rate pass-through to the consumption and investment import prices.

The aggregator produces final imported consumption and investment goods sold at price $P_t^m$ to households. The final imported consumption and investment goods are aggregated using a continuum of $j$ differentiated imported goods. Each are supplied according to

---

All importing firms that are allowed to re-optimize their price, in a given period, will choose the same price, therefore it is not necessary to use a firm index.

This assumption departs from Adolfson et al. (2007) by assuming that the imported good price is the same for both investment and consumption. In addition, importing firms buy the foreign input at their marginal costs to foreign producers (instead of foreign distributors).
\[ J_t^m = \left( \int_0^1 (J_{m,j,t}^m)^{\varepsilon_m-1} d\varepsilon \right)^{\varepsilon_m-1}, \quad 1 < \varepsilon_m, \]  

(4.18)

where \( J \in (C,I) \) and \( \varepsilon_m \) is the elasticity of substitution between intermediates in the imported consumption and investment sectors.

### 4.3 Labour market

This paper considers two alternative mechanisms generating sticky wages and labour income dispersion. The first model (EHL) introduces monopolistic competition and staggered nominal contracts in the labour market following Erceg et al. (2000). The second one (GTT) consists in search and matching frictions in the labour market with staggered nominal wage bargaining presented in Gertler and Trigari (2009) and Thomas (2008). The rest of the assumptions described in preceding and following subsections hold for both models.

#### 4.3.1 Monopolistic competition and staggered wage contracts

In this model, there are no real rigidities on the labour market. All workers are employed and all \( N \)s simplify to one in the households and firms sections. Optimising households supply monopolistically a differentiated labour service and set they own hourly wages whenever they receive a random signal. Rule of thumb households mimic their optimising counterpart whenever they are allowed to reset their wages. All other workers simply index their wages.

**Wage setting** Every OH \( i \) (and every ROTH \( j \)) is a monopoly supplier of a differentiated labour service and sets its own hourly wage \( W_{i,t} \) with an adjustment rule à-la Calvo. Households have a probability \((1 - \xi_w)\) to be allowed to re-set their wages. OHs set their wage to maximise their inter-temporal utility. ROTHs mimic OHs by setting the same wage\(^{22}\). Households that cannot re-optimize their wage follow an indexation mechanism described by

\[ W_{i,t+1} = (\pi_t^c)^{\kappa_w} (\varepsilon_{w,t+1} \bar{\pi})^{1-\kappa_w} W_{i,t}, \]  

(4.19)

such that they index their wages to last period consumer price inflation \( \pi_t^c = \frac{P_t^c}{P_{t-1}} \) and to the inflation target \( \bar{\pi} \). The wage-indexation parameter \( \kappa_w \) determines the relative importance of past consumer price inflation in the indexation process. The exogenous process \( \varepsilon_{w,t+1} \) is a wage-indexation shock.

\(^{22}\)This behaviour might reflect social norms or equality considerations. For example, Hall (2005) uses wage norms to rationalise its version of wage stickiness. Bewley (1999) describes the influence of social norms and equity considerations for wage decisions in the US.
Labour packer Each OH sells its labour \((h_{i,t})\) to a labour packer which transforms it into a homogeneous labour input \(H_t^O\) using the following production function:

\[
H_t^O = \left[ \int_0^1 (h_{i,t}) \frac{\varepsilon_w - 1}{\varepsilon_w} \, di \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}}, \quad 1 < \varepsilon_w < \infty, \tag{4.20}
\]

where \(\varepsilon_w\) is a labour demand elasticity. This labour packer takes the input price of the \(i^{th}\) differentiated labour input as given, as well as the price of the homogeneous labour services. Consequently, the relative labour demand for labour type \(i\) is given by

\[
h_{i,t} = \left( \frac{W_{i,t}}{W_t} \right)^{-\varepsilon_w} H_t^O \tag{4.21}
\]

where \(W_{i,t}\) is household \(j\) wage rate and \(W_t\) is the wage index defined by

\[
W_t = \left[ \int_0^1 W_{1,t}^{1-\varepsilon_w} \, di \right]^{\frac{1}{1-\varepsilon_w}} \tag{4.22}
\]

Each ROTH also sells its labour \((h_{j,t})\) to a labour packer which transforms it into a homogeneous labour input \(H_t^R\) using a technology analogous to (4.20). Hours worked by OHs and ROTHs are perfect substitutes and every households are employed. Therefore, the aggregate labour effort available to the economy is simply given by

\[
H_t = H_t^O + H_t^R = L_t \tag{4.23}
\]

Labour dispatchers Imperfect labour mobility is introduced following Horvath (2000) and Dagher et al. (2010). Labour dispatchers hire the aggregate labour package \(L_t = H_t\) at rate \(W_t\) and resell it to the primary and secondary firms at a rate \(W_t^p\) and \(W_t^f\), respectively. They allocate labour between primary and secondary sectors using the following technology:

\[
H_t = \left[ (1 - \omega_h)^{-1/\eta_h} (H_t^f)^{(1+\eta_h)/\eta_h} + \omega_h^{-1/\eta_h} (H_t^p)^{(1+\eta_h)/\eta_h} \right]^{\eta_h/(1+\eta_h)}, \tag{4.24}
\]

where \(H_t^p = L_t^p\) and \(H_t^f = L_t^f\) denote labour effort in the primary and final sectors, respectively. The parameter \(\omega_h\) is the steady-state share of primary sector employment in total employment and \(\eta_h\) is the elasticity of substitution between labour services provided in the two sectors. The intuition behind this specification is that there are costs associated to labour mobility such as sector specific skills. It implies that the wages effectively paid by the firms in the primary (\(W^p\)) and secondary
(\(W^f\)) sectors are given by:

\[
W^f_i = \left[ \frac{H^f_i}{(1 - \omega_h)H_i} \right]^{1/\eta_h} W_t, \tag{4.25}
\]

\[
W^p_i = \left[ \frac{H^p_i}{\omega_h H_i} \right]^{1/\eta_h} W_t, \tag{4.26}
\]

### 4.3.2 Search and matching with staggered wage bargaining

In the second model, search and matching frictions generate equilibrium unemployment. Firms post vacancies to attract unemployed workers. At every period and in each sector, a fraction of optimising workers form a union and bargain with the firms over wages per worker. The employment conditions obtained by unions apply to all their members and are extended to an identical fraction of rule of thumb workers. All other workers index their wages. The remainder of this subsection focuses on the primary sector. Equations in for the secondary sector are similar.

**The matching function** At every period, some unemployed workers are matched with a firm in the primary or secondary sectors. The number of matches in the primary (\(M^p\)) sector is given by

\[
M^p_i = \sigma_{m,p} (\mu_t) \sigma_m (V^p_i)^{1-\sigma_m} \tag{4.27}
\]

where \(\sigma_{m,p}\) is a scaling parameter and \(\sigma_m\) is the elasticity of matches to unemployment. The variable \(\mu_t\) is the unemployment rate and \(V^p_i\) is the number of vacancies posted in the primary sectors. The number of matches in the secondary sector (\(M^f\)) is analogous to (4.27). From this matching function, it is convenient to define the vacancy filling rates:

\[
q^p_i = \frac{M^p_i}{V^p_i} = \sigma_{m,p} \left( \frac{\mu_t}{V^p_i} \right)^{\sigma_m} \tag{4.28}
\]

as well as the job finding rate:

\[
p^p_i = \frac{M^p_i}{\mu_t} = \sigma_{m,p} \left( \frac{V^p_i}{\mu_t} \right)^{1-\sigma_m}. \tag{4.29}
\]

The secondary sector vacancy filling and job finding rates \(q^f_i\) and \(p^f_i\) are similar to equations (4.28) and (4.29). At every period, any worker faces the exogenous probability \(\delta_n\) to lose his job. Therefore, the laws of motion for aggregate employment in each sector and unemployment are
given by

\[
N_{t+1}^p = (1 - \delta_n)N_t^p + M_t^p \quad (4.30)
\]
\[
N_{t+1}^f = (1 - \delta_n)N_t^f + M_t^f \quad (4.31)
\]
\[
U_t = 2 - N_t^p - N_t^f \quad (4.32)
\]

**Vacancy posting and search costs** All unemployed - and only the unemployed - households are searching for a job at no cost. Firms post vacancies to attract new workers. The cost of posting vacancies for a firm in the primary sector is given by

\[
\frac{\chi}{1 + \theta} \left( \frac{V_j^p N_j^p}{N_j^p} \right)^{1+\theta} N_j^p P_t \quad (4.33)
\]

where \(\chi\) is a scaling parameter and \(\theta > 0\) implies that the cost of posting vacancies is convex. When a match is formed, the worker receives a wage randomly drawn from the present wage distribution.\(^{23}\)

**Households employment surplus** Any OH \(i\) employed in the primary sector with wage \(\bar{W}_{i,t}^p\) derives a surplus \(S_{i,t}^{w,p}\) which can be expressed in monetary units:

\[
S_{i,t}^{w,p} = \frac{\partial \bar{W}_{i,t}^p}{\partial N_i} \left( \frac{1}{\upsilon_t} \right) \quad (4.34)
\]

\[
= \bar{W}_{i,t}^p - \omega_t - \left[ \frac{U(H_i^p)}{\upsilon_t} + \upsilon_{t+1} \left( p_t^p S_{i,t+1}^{w,p} + p_t^f S_{i,t+1}^{w,f} \right) \right] + (1 - \delta_n) \beta \frac{\upsilon_{t+1}}{\upsilon_t} S_{i,t+1}^{w,p}
\]

where \(U(H_i)\) is the dis-utility from hours worked and \(\upsilon_t\) is the shadow value associated with constraint (4.3).\(^{24}\) The first two terms represent the nominal wage in excess to unemployment benefits. The terms in the brackets are the relative dis-utility of labour efforts (expressed in monetary units) and the discounted expected value from searching for a job when unemployed. The later depends on the probability to find a job in the primary or secondary sectors and on the average employees surplus in these sectors. The final term is the discounted future employee’s surplus conditional on keeping the job. The employee’s surplus in the final good sector \(S_{i,t}^{w,f}\) is the analogue of equation (4.34).

\(^{23}\)Since firms hire from a continuum of workers, it implies that firms consider the aggregate wage for their vacancy posting decision.

\(^{24}\)Therefore, \((1 - \delta_n)\beta \frac{\upsilon_{t+1}}{\upsilon_t} = (1 - \delta_n)\beta \frac{U(C_{t+1})}{U(C_t)} P_t\) is the stochastic discount factor.
Firms employment surplus Any firm $j$ in the primary sector derives a surplus from employment which can be expressed as the discounted value of current and future profits. The present value of profits in the primary sector is given by:

$$P_{j,t} = P^p_{j,t} - W_{j,t}N^p_{j,t} - \frac{\chi}{1+\theta} \left( \frac{V^p_{j,t}}{N^p_{j,t}} \right)^{1+\theta}(1+\theta)N^p_{j,t}P_t - K_t^p K_t^p + \beta \frac{\nu_{t+1}}{\nu_t} P_{j,t+1}$$

(4.35)

Therefore, the employer’s surplus $S_{f,p}^{f,p}$ is given by

$$S_{f,p}^{f,p} = \frac{\partial P_{j,t}}{\partial N_{j,t}}$$

(4.36)

where the first term is the value of output produced by one additional employee; the second term is the employee’s wage cost; the third term captures the vacancy posting savings from having an additional worker and the final term is the expected discounted future employer’s surplus conditional on keeping the worker. The employer’s surplus in the final good sector $S_{f,f}^{f,f}$ is the analogue of equation (4.36).

Wage bargaining At every period, a fraction $1 - \xi_w$ of workers in each firms receive a random signal. Optimising workers in each sectors regroup in sector specific unions to bargain with the firm over the wage per worker $W^*_p$. Following Thomas (2008), the outcome of the bargain consists in splitting the overall employment surplus $S_{f,p}^{f,p} + S_{w,p}^{w,p}$ between firms and workers. Wages are therefore set such that workers receive a fraction $1 - \omega_w$ of the surplus. Wages negotiated between unions and firms are extended to the fraction $1 - \xi_w$ of rule-of-thumb workers that received the same signal (but were not involved in the bargaining process). Workers that do not receive the signal simply index their wages following equation (4.19).

Hours decision Following Thomas (2008), hours worked at every periods in each sectors are determined to maximise the overall present employment surplus. Hours worked are therefore

$25$ It implies that firms remains identical regarding wage costs.

$26$ Since all firms inside a sector and all re-optimising households are identical, the employers and employees surplus are identical for each optimising households and the $j$ and $i$ indices can be dropped.

$27$ This assumption captures the institutional design presented in section 3. Indeed, employment conditions and wages negotiated at the Bargaining Councils level between firms and unions can be extended to non parties.
independent from wages and identical for each worker in a particular sector. The same conditions regarding hours works are also extended to ROTHs.

4.4 Public authorities

The public sector comprises a central bank and a government.

Central bank The monetary authority is assumed to follow a simple Taylor rule

\[ R_t = \rho_r R_{t-1} + (1 - \rho_r) \left( R + \tau_\pi \pi_t^c + \tau_{\Delta y} \left( \frac{Y_t - Y_{t-1}}{Y_{t-1}} \right) + \tau_{\Delta s} \left( \frac{S_t}{S_{t-1}} \right) \right) + \epsilon_{R,t}, \quad (4.37) \]

where \( \rho_r \) is the interest rate smoothing parameter, \( \tau_\pi \) is the response to current consumer price inflation, \( \tau_{\Delta y} \) to (real) output growth and \( \tau_{\Delta s} \) to the change in the nominal exchange rate. The exogenous process \( \epsilon_{R,t} \) is a monetary policy shock. Similar Taylor rules include Lubik and Schorfheide (2007), Ortiz and Sturzenegger (2007), Liu et al. (2009), Alpanda et al. (2011) and Hove et al. (2015) for models applied to South Africa and is consistent with the adoption in February 2000 of a formal inflation targeting framework.

Government The government collects taxes on consumption, labour and capital and follows a simple public consumption rule

\[ G_t = \rho_g G_{t-1} + (1 - \rho_g) \bar{G} + \epsilon_{g,t}, \quad (4.38) \]

where \( \bar{G} \) is the steady-state value of government spendings and \( \epsilon_{g,t} \) is a government spending shock. Government consumption is composed of domestic goods only.

4.5 Closing market conditions and definitions

In equilibrium the goods, labour and bonds markets have to clear. The final goods market is in equilibrium when the demand from domestic households, the government and the foreign households equals the production of the final good. This aggregate resource constraint reads:

\[ \left( C_t^d + I_t^d + G_t \right) \psi_t^d + X_t^f \psi_t^x \leq Y_t^f. \quad (4.39) \]

\(^{28}\)All firms inside a sector are identical and therefore have the same marginal labour productivity. In the utility, hours are separable and all optimising households have the same marginal utility from consumption. Therefore, all workers supply the same amount of hours to maximise the global current employment surplus.
where

\[ \nu^d_t = \int_0^1 \left( \frac{P_{i,b}}{P_i} \right)^{-\varepsilon_d} di \] (4.40)

is a measure of domestic price dispersion resulting to an input loss in the domestic distribution process (4.13) and

\[ \nu^x_t = \int_0^1 \left( \frac{P_{i,t}}{P_i} \right)^{-\varepsilon_x} di \] (4.41)

is a measure of export price dispersion resulting to an input loss in the export distribution process (4.16). Those two price dispersion measures are bounded from below one. They imply that price dispersion increases the amount of inputs \( Y^f \) required to produce domestically consumed goods \( C^d, I^d \) or \( G \) and exported goods \( X^f \).

The domestic bond market clears when the demand for liquidity from households equals the monetary injection by the central bank. Since the central bank money supply is perfectly inelastic at its policy rate it is not necessary to define it. The foreign bond market clears when the positions of the exporting and importing firms equal the households’ choice of foreign bond holdings. Foreign assets evolve according to:

\[
S^*_t B^*_{t+1} = R^*_{t-1} \Phi \left( A_{t-1}, \tilde{\phi}_{t-1} \right) S^*_t B^*_t + S_t \left( P^x X^f_t + P^p Y^p_t \right) - P^m_t \left( C^m_t + I^m_t \right), \quad (4.42)
\]

Finally, the GDP identity is defined by

\[ Y_t = C_t + I_t + G_t + X_t - M_t, \quad (4.43) \]

where \( I_t = I^p_t + I^f_t \); \( X_t = X^f_t + X^p_t \) and \( M_t = C^m_t + I^m_t \).

### 4.6 Aggregate Welfare

This subsection shows how to compute welfare for each types of households, in the two versions of the model, taking both aggregate and idiosyncratic risks into account.

**Optimising households aggregate utility** The aggregate utility level for OHs is given by

\[
U^\alpha_t = \int_0^1 \left[ \frac{(C_{i,t}/(C_{i-1}^\alpha)^{\beta})^{1-\sigma_c} - 1}{1 - \sigma_c} - A_{h,t} N_{i,t} \frac{(H_{i,t})^{1+\sigma_h}}{1 + \sigma_h} \right] di. \quad (4.44)
\]
Their access to complete domestic financial markets implies that all OHs have the same level of consumption at each period. In the EHL version, the fact that all households are employed and equation (4.21) entail that

$$U^o_t = \frac{\left( C^o_t / (C^o_{t-1})^b \right)^{1-\sigma_c} - 1}{1 - \sigma_c} - \frac{A_h(H^o_t)^{1+\sigma_h}}{1 + \sigma_h} \nu^h_t$$

(4.45)

where $C^o_t$ is the optimising households aggregate consumption level and

$$\nu^h_t = \int_0^1 \left( \frac{W_{i,t}}{W_t} \right)^{-\varepsilon_w(1+\sigma_i)} d i.$$  

(4.46)

The term $\nu^h_t \geq 1$ is a measure of hours worked dispersion (caused by wages dispersion) which results in an aggregate utility loss.

In the GTT version, the OHs aggregate utility becomes

$$U^o_t = \frac{\left( C^o_t / (C^o_{t-1})^b \right)^{1-\sigma_c} - 1}{1 - \sigma_c} - \frac{1}{2} \left( \frac{A_h N^p_t (H^p_t)^{1+\sigma_h}}{1 + \sigma_h} - \frac{A_h N^f_t (H^f_t)^{1+\sigma_h}}{1 + \sigma_h} \right)$$

(4.47)

where $N^p_t / 2$ and $N^f_t / 2$ represent the share of OHs employed in the primary and secondary sectors and hours worked can only differ between sectors.

**Rule of thumb households aggregate utility**  ROTHs aggregate level of utility is given by

$$U^R_t = \int_0^1 \left[ \left( \frac{C^R_t / (C^R_{t-1})^b}{1 - \sigma_c} - \frac{1}{1 + \sigma_h} \right) - \frac{A_h N^R_t (H^R_t)^{1+\sigma_h}}{1 + \sigma_h} \right] d j.$$  

(4.48)

They have no access to the financial market and have therefore no opportunity to insure against labour market idiosyncratic risks. In the EHL version, the fact that all households are employed and equations (4.21) and (4.8) imply that

$$U^R_t = \frac{\left( C^R_t / (C^R_{t-1})^b \right)^{1-\sigma_c} \nu^c_t - 1}{1 - \sigma_c} - \frac{A_h,\sigma_t (H^R_t)^{1+\sigma_h}}{1 + \sigma_h} \nu^h_t$$

(4.49)

where $C^R_t$ is the rule of thumb households aggregate consumption level and

$$\nu^c_t = \int_0^1 \left( \frac{W_{i,t}}{W_t} \right)^{(1-\varepsilon_w)(1-\sigma_c)} d j.$$  

(4.50)
The term $\nu^c_t$ is a measure of consumption dispersion generated by (uninsured) labour income risks and the term $\nu^h_t$ captures the hours dispersion presented in equation (4.46).

In the GTT version, the ROTHs aggregate utility becomes

$$U^R_t = \frac{1}{2} \left\{ N^p_t \left( \frac{C^R_{i,1}}{(C^R_{i-1})^b} \right)^{1-\sigma_c} \nu^c_{i,1} - 1 \right\} + \frac{1}{2} \left\{ N^f_t \left( \frac{C^R_{i,1}}{(C^R_{i-1})^b} \right)^{1-\sigma_c} \nu^c_{i,1} - 1 \right\} (4.51)$$

where $C^R_{i,1}$, $C^R_{i,2}$, and $C^R_{i,3}$ represent the average consumption level of ROTHs employed in the primary sector, employed in the secondary sector or unemployed, respectively. These consumption levels are computed using equation (4.8). The terms $\nu^c_{i,1}$ and $\nu^c_{i,2}$ represent labour income dispersion in the primary and secondary sector, respectively. They are the analogue versions of equation (4.50) where $W_{i,j,1}$ and $W_{i,j,2}$ replace $W_{i,j,1}$ and $\varepsilon_w = 0$.

5 Empirical Methodology

This section presents the methodology. First, the different shocks introduced in the model are classified according to their types in order to reflect their potential implications for monetary policy efficiency and to ease the exposition of results. Second, it describes the value of calibrated parameters. Third, it outlines the estimation methods and the dataset. Finally, it defines the welfare cost measures.

5.1 Structural shocks

Table 1 reports the 18 innovations analysed in this paper. In order to summarize their implication for monetary policy and to ease the exposition of key results, these shocks are classified: first according to their origin and then according to their type.

There are three broad categories of shocks defined according to their origin: domestic, foreign, and SOE shocks. Domestic and foreign shocks are disturbances that are unambiguously identified from domestic and foreign origins, respectively. SOE shocks, on the other hand, are disturbances that may have both domestic and foreign origins. In particular, the country risk premium shock could be explained by a change in domestic country risk (beyond what is captured by the net foreign asset position) or by a change in foreign risk aversion leading to a revision of the price of exchange rate risks. It is therefore labelled as a SOE shock.
### Table 1: Structural shocks

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Process</th>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foreign shocks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wedge</td>
<td>$\varepsilon_{b,t}^*$</td>
<td>AR(1)</td>
<td>AD* Wedge btw policy and private interest rates</td>
</tr>
<tr>
<td>Government demand</td>
<td>$\varepsilon_{g,t}^*$</td>
<td>AR(1)</td>
<td>AD* Government consumption shock</td>
</tr>
<tr>
<td>Monetary policy</td>
<td>$\varepsilon_{R,t}^*$</td>
<td>IID</td>
<td>AD* Deviation from Taylor Rule</td>
</tr>
<tr>
<td>Productivity</td>
<td>$\varepsilon_{k,t}^*$</td>
<td>AR(1)</td>
<td>(R)AS* Capital specific productivity shock</td>
</tr>
<tr>
<td>Investment specific</td>
<td>$\dot{Y}_{t}$</td>
<td>AR(1)</td>
<td>(R)AS* Investment efficiency shock</td>
</tr>
<tr>
<td>Commodity supply</td>
<td>$\varepsilon_{p,t}^*$</td>
<td>MA(1)</td>
<td>(R)AS* Foreign commodity supply shock</td>
</tr>
<tr>
<td>Price indexation</td>
<td>$\varepsilon_{\pi,t}^*$</td>
<td>IID</td>
<td>(N)AS* Price-push shock in indexation process</td>
</tr>
<tr>
<td>Wage indexation</td>
<td>$\varepsilon_{w,t}^*$</td>
<td>IID</td>
<td>(N)AS* Wage-push shock in indexation process</td>
</tr>
<tr>
<td><strong>SOE shock</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country risk premium</td>
<td>$\tilde{\phi}_t$</td>
<td>AR(1)</td>
<td>SOE Affecting the UIP condition</td>
</tr>
<tr>
<td>Trade shock</td>
<td>$\varepsilon_{0,t}$</td>
<td>ARMA(1)</td>
<td>SOE Home bias in the domestic and foreign eco.</td>
</tr>
<tr>
<td><strong>Domestic shocks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wedge</td>
<td>$\varepsilon_{b,t}$</td>
<td>AR(1)</td>
<td>AD Wedge btw policy and private interest rates</td>
</tr>
<tr>
<td>Government demand</td>
<td>$\varepsilon_{g,t}$</td>
<td>AR(1)</td>
<td>AD Government consumption shock</td>
</tr>
<tr>
<td>Monetary policy</td>
<td>$\varepsilon_{R,t}$</td>
<td>IID</td>
<td>AD Deviation from Taylor Rule</td>
</tr>
<tr>
<td>Productivity</td>
<td>$\varepsilon_{k,t}$</td>
<td>AR(1)</td>
<td>(R)AS Capital specific productivity shock</td>
</tr>
<tr>
<td>Investment specific</td>
<td>$\dot{Y}_{t}$</td>
<td>AR(1)</td>
<td>(R)AS Investment efficiency shock</td>
</tr>
<tr>
<td>Commodity supply</td>
<td>$\varepsilon_{p,t}$</td>
<td>AR(1)</td>
<td>(R)AS Domestic commodity supply shock</td>
</tr>
<tr>
<td>Price indexation</td>
<td>$\varepsilon_{\pi,t}$</td>
<td>IID</td>
<td>(N)AS Price-push shock in indexation process</td>
</tr>
<tr>
<td>Wage indexation</td>
<td>$\varepsilon_{w,t}$</td>
<td>IID</td>
<td>(N)AS Wage-push shock in indexation process</td>
</tr>
</tbody>
</table>

Domestic and foreign shocks are classified in 2 sub-groups. On the one hand, aggregate demand shocks (AD) include wedge\(^{29}\), government consumption and monetary policy shocks. On the other hand, aggregate supply shocks (AS) consist of three real (R) technology shocks: capital productivity, commodity supply and investment specific shocks as well as two nominal (N) disturbances: price indexation and wage indexation shocks.

### 5.2 Calibration

Table 10 in the appendix shows the value of calibrated parameters. Most of them are set in order to fit the empirical mean observed in the data. The relative importance of labour in utility $A_h$ is calibrated such that agents devote 30% of their time to labour activities (which only represents a choice of units). The annual inflation rate is set to 6%. It corresponds to the upper band of the South African Reserve Bank inflation target and is close to its empirical mean. The discount factor

\(^{29}\)The wedge shock is usually considered as a financial shocks. Considering that its main impact is on consumption and investment demands, it qualifies as a demand shock.
$\beta$ is set to 0.99 in order to match the average real risk-free rate. The depreciation rate is set to 0.02 in order to match the investment to GDP ratio. The capital income share is set to 1/3 in both sectors. The land share $\beta_p$ is calibrated to 0.31 to ensure that the mining sector represents 10% of GDP while households devote 6% of their labour efforts to this sector on average. The share of imports in consumption $\omega_c$ and investment $\omega_i$ are set to 0.3 and 0.5, respectively. Those values imply an import to GDP ratio of about 28% as observed in the data. The net foreign asset position is set to 0 at steady-state for simplicity. The government consumption to GDP ratio is set to 19.5%.

Two parameters present in the EHL and GTT versions of the model deserve particular attention. First, the foreign interest rate elasticity to net foreign asset position $\phi_a$ captures the degree of integration of the emerging economy in global financial markets. As $\phi_a$ decreases, the costs of international risk sharing decreases and so does the welfare costs of business cycles. Adolfson et al. (2007) calibrate this parameter to 0.01. However, Brzoza-Brzezina and Kotlowski (2016) argue that this value depends on the initial debt level and could be as low as 0.0001. In the baseline model, $\phi_a$ is calibrated to 0.001. Second, the input demand elasticity $\varepsilon_d$ influences the output wastes presented in equations (4.40) and (4.41) generated by inflation volatility. This parameter is set to 11 in the baseline. It implies that distributors impose a 10% mark-up on their marginal costs. The net profit margin that fluctuated between 6 and 12% for the 2001-2015 period (Annual financial statistics 2015, Stat SA).

Some parameters are specific to the labour market and are crucial since they generate idiosyncratic risks. In the EHL framework, labour demand elasticity $\varepsilon_w$ influences hours and consumption dispersion in equations (4.46) and (4.50) with important welfare implications. This parameter is set to 11 and the implied labour income dispersion is confronted to the data. Considering that many factors beyond the mechanisms described in this paper could generate income inequality, it is important to check that this model does not generate more income dispersions than what is actually observed. The EHL version of the model generates an average within individual coefficient of variation of 0.15.\footnote{The within individual coefficient of variation takes, for each individual, the ratio of its standard deviation in income (over time) to its average income.} The South African National Income Dynamics Study (NIDS) database provides information on income at the household level. Ranchhod (2013) describes this database and computes the average within-individual coefficient of variation to argue that income is very volatile at the household level in South Africa. He reports a value of 0.64 using the first three waves of the NIDS. Restricting the analysis to households employed in the four waves of this study (there is no unemployment in the EHL version of the model), removing the growth trend in income (due to both inflation and real income growth) and excluding the first income percentile give an mean within individual coefficient of variation of 0.27, still above the value implied by the...
model. In the GTT framework, the equilibrium unemployment rate is calibrated to 10%. Although the unemployment rate in South Africa remained close to 25% over the estimation period, more than 60% of the unemployed are classified as long term unemployment (OECD data and Banerjee et al. (2008)). Calibrating the unemployment rate to 10% therefore offers a better description of the transitory unemployment dynamics generated by the model. The (quarterly) separation rate $\delta_n$ is calibrated to 0.07 based on the labour market transition probabilities in Anand et al. (2016). This assumption generates a job finding rate of 4% and 59% in the primary and secondary sectors (based on the Beveridge Curve). The scaling parameters $\sigma_{m,p}$ and $\sigma_{m,f}$ in the matching function are adjusted such that the probability to fill a vacancy equals 0.5 at steady-state and $\chi$ is set such that hiring cost represents 1% of GDP following Thomas (2008). The unemployment benefits $\sigma$ represent 42% of the steady-state wage and imply that the worker share of the employment surplus $\omega_w$ equals 60%. The GTT framework generates a within-individual coefficient of variation of 0.34 for labour incomes (assigning a zero wage to the unemployed).

5.3 Bayesian estimation

This subsection presents the dataset, the value of some key estimated parameters and their identification.

5.3.1 Data

The model is estimated with Bayesian methods using 11 domestic and 8 foreign variables. The data set includes domestic GDP; private consumption; investment; government consumption and commodity exports; employment; consumer price index; import price index; aggregate wage index; risk free rate; and nominal effective exchange rate. Commodity exports are proxied by sales in the mining sector (about 70% is exported). Foreign variables include GDP; private consumption; investment; government consumption, consumer price index; wages; risk free rate; hours worked and commodity price. US data are used to proxy the foreign economy. Commodity prices are measured as an average of world coal, platinum, silver, gold and aluminium prices. It includes important South African commodities. Since there are more observed variables than shocks, estimated measurement errors are introduced on the domestic price and wage indexes as well as on the domestic and foreign GDPs. Data range from 1994Q1 to 2016Q1 in order to exclude the apartheid period in South Africa (characterised by political and economic instability).\(^{32}\)

\(^{31}\)G7 data were use as a robustness check in Houssa et al (forthcoming).

\(^{32}\)Houssa et al (forthcoming) also experiment stopping in 2010Q1 in order to avoid most of the zero lower bound period in the US (which is difficult to capture with a simple Taylor rule) as well as starting in 2000Q1 which corresponds to the introduction of formal inflation targeting in South Africa.
5.3.2 Estimated parameters

Shocks processes, rigidities and policy rule interact to generate business cycles and further inter-play with the utility function to translate into welfare costs. This subsection describes the value of estimated parameters and discusses their identification. In particular, it focuses on the persistence and magnitude of estimated business cycles shocks, on the importance of nominal and real frictions and on the estimated monetary policy rule followed by the central bank. The priors and posteriors of some key estimated parameters with specific welfare implications are reported in Figure 3 and 4 in the appendix. The full set of estimated parameters is described in Tables 11 and 12 also in the appendix.

Identification The methodologies proposed by Andrle (2010) and Iskrev (2010) implemented in Dynare revealed some cases of weak identification. First, Iskrev (2010) collinearity analysis shows that elasticities of substitution $\eta_c$ in the consumption basket (4.2) and $\eta_i$ in the investment basket (4.7) suffer from perfect collinearity. Considering the fact that these two parameters are conceptually similar, they were constrained to take the same value in the estimation. Second, the labour supply elasticity $\sigma_l$ in (4.1) is weakly identified. It is due to its minor marginal effect on the likelihood function and to collinearity patterns with some parameters such as the elasticity of substitution between labour services $\eta_h$ in (4.24) in the EHL version of the model. Looking at the prior and posterior distributions of $\sigma_l$ it is clear that the impact of the prior is substantial for both versions of the model. Therefore, the prior (which is relatively wide) plays an important role. An alternative would be to calibrate this parameter and perform some robustness exercises. However, since this parameter is identical for each categories of households in the domestic and in the foreign economy, it should not cause difference among each groups. Third, Andrle (2010) singular value decomposition of the Fischer information matrix shows that the investment adjustment costs (both in the domestic and foreign block) are the weakest identified parameters in the final estimation. Although their marginal impact on the likelihood is high, these parameters suffer from collinearity with the investment shocks variance and persistence. The investment shock persistence is therefore calibrated to 0.5. It nevertheless means that a perfect identification of the welfare effects of this specific friction would be difficult. Nominal rigidities are on the other hand properly identified.

Shocks magnitude and persistence Large and persistent shocks are known to generate larger welfare effects. Table 11 shows the standard deviation and persistence of each shock and indicates that domestic disturbances tend to be larger but less persistent, on average. This is particularly true for the capital specific and commodity sector TFP shocks. Demand shocks do not display such a difference, although the wedge shock seems slightly more volatile and more persistent in the
emerging economy. Nominal cost-push shocks are similar in the domestic and foreign economies while wage-push shocks are slightly larger in the former.

**Nominal rigidities** Nominal price and wage rigidities are crucial since they reduce firms and households ability to adjust their prices and wages to business cycle fluctuations. They generate price and wage dispersions that are costly in term of welfare. Based on the EHL version of the model (which is the only assumption used to model the foreign economy block) domestic prices and wages seem to be less rigid in South Africa, when compared to the US. It is therefore unlikely that this amount of nominal rigidities could amplifies the cost of business cycle fluctuations when compared to advanced countries. However, incomplete exchange rate pass-through is important and implies potentially inefficient deviations from the low of one price. Compared to the EHL version of the model, the GTT staggered wage parameter is larger. The average contract lasts almost two years.

**Real rigidities** Real rigidities are also important since they can impair the reallocation of resources across time or sectors. Investment adjustment costs ($\tilde{S}'')$ are larger in the domestic economy. In addition, labour mobility across sectors is small ($\eta_h<1$) in the EHL version of the model. These relatively important real rigidities might exacerbate the costs of business cycle fluctuations by preventing (individually) optimal resources reallocations, but might also dampen the transmission of some exogenous disturbances and reduce the volatility in some aggregate variables (for given shocks processes).

**Utility parameters** In order to focus on the welfare effects of business cycles, independently from potential differences in preferences, the utility parameters ($\sigma_c, b$ and $\sigma_h$) are identical for each categories of households. Moreover, since ROTHs do not maximise their utility, it is not possible to infer their preferences from their decisions. The inverse of the labour supply elasticity ($\sigma_h$) is not well identified and its posterior distribution is close to its prior. Its distribution reflects relatively large uncertainty around the value of this parameter. The coefficient of relative risk aversion ($\sigma_c$) and external habits ($b$) are both relatively high and would therefore support high welfare costs of business cycles fluctuations for each types of agents in the domestic and foreign economies.

---

33 $\eta_h$ is calibrated to one in Horvath (2000) and Dagher et al. (2010). There is no equivalent in the GTT variant or in the foreign economy since commodity supply is assumed to be exogenous for simplicity.
Taylor Rule The coefficients of the estimated Taylor rule show that the SARB responded to inflation fluctuations ($\tau_\pi=1.69$ and $1.62$ in the EHL and GTT versions of the mode, respectively), which is consistent with its mandate and the introduction of inflation targeting. In addition, changes in interest rate were smooth ($\rho_r=0.86$ and $0.87$) and the SARB responded to output growth ($\tau_{\Delta y}=0.53$) and to the change in the nominal exchange rate ($\tau_{\Delta s}=0.12$ and $0.13$). These results are close to the prior. However, they are also relatively close to the literature (on which the prior are based) and will serve as a benchmark for comparing the costs of business cycles under different monetary policy rules. Note that the Taylor rule in the foreign economy is calibrated in order to avoid an estimation on the zero lower bound period.

5.4 Welfare measures

Welfare cost of business cycle This paper measures the welfare cost of business cycle fluctuations in the emerging economy using a second order approximation to the model (Schmitt-Grohe and Uribe (2004)). The welfare cost of business cycles is defined along the lines of Lucas (1987) as the share of consumption that an agent would be ready to give-up at every period to insulate the economy from all shocks and therefore eliminate aggregate fluctuations. This measure is provided for the two categories of domestic households and compared to the foreign economy serving as a benchmark. A second order approximation implies that the variance of shocks can have an impact on the mean of endogenous variables. This could make the volatile environment artificially attractive if, for example, precautionary motives would encourage capital accumulation. Conditional welfare measures are therefore computed. They solve this issue by imposing that all simulations (i.e. with or without shocks) start from the same initial point (including the same value of capital). In this paper, this common starting point is the deterministic steady-state. Unconditional welfare cost measures are also reported. They should be interpreted as the long-term cost of business cycles after agents are done accumulating precautionary assets.

Comparison of simple policy rules This paper also explores potential welfare gains from alternative monetary policy rules. It focuses on simple and implementable monetary rules (Schmitt-Grohe and Uribe (2007)). Those rules determine the response of policy variables as a function of a small number of easily observable macroeconomic indicators (such as inflation, output and exchange rate measures) and deliver uniqueness of the rational expectation equilibrium. As such, they include the rule advocated by Taylor (1993) as well as most modified versions proposed in

---

34The literature has also used the linear-quadratic approach of Benigno and Woodford (2005) and Benigno and Woodford (2012). Although this approach delivers a closed form (as a function of deep parameters) solution to the welfare loss function, the complexity of this model would make computation difficult.
the literature. A simple evaluation of conditional aggregate welfare measures would be enough in order to rank alternative policy rules. However, conditional compensation measures are also provided in order to assess the magnitude of the difference in welfare. It is defined as the fraction of consumption that an agent would be ready to abandon in order to be transferred from the benchmark economy to an alternative economy. The computations are provided in appendix D.

6 Empirical Results

This section presents the results. First, it computes the welfare cost of business cycle fluctuations. Second, describes the impact of alternative simple monetary policy rules on welfare and searches for an optimal simple rule.

6.1 Welfare costs of business cycles

This section has two sets of objectives. First, it shows that the costs of business cycles are relatively large in the emerging economy - especially for ROTHs - and it highlights the role of financial markets exclusion. Second, it evaluates the welfare effects of each type of shocks. It shows that each category of shocks is associated with substantial business cycle costs. Surprisingly, commodity price volatility could be welfare increasing for plausible sets of parameters.

6.1.1 Welfare costs of business cycles and the role of financial markets

This section evaluates the welfare costs of business cycle fluctuations for each type of agents in the EHL and GTT versions of the model. Moreover, it assesses the importance of insurance market exclusion for ROTHs by computing welfare costs in two environment. First, this paper reports a baseline measure that reflects complete asset markets exclusion as described in the model section. Second, it evaluates these costs assuming that these households are excluded from capital and bonds markets but are able to trade in state-contingent assets. In this case, ROTHs are capable to insure against labour market idiosyncratic risks and remain homogeneous regarding their consumption levels. In the EHL framework, there is only one type of labour market idiosyncratic risks which is the staggered wage setting mechanism generating labour income dispersion. ROTHs utility in equation (4.49) is recomputed assuming that \( \nu_c = 1 \) to shut-down this risk. In the GTT version of the model, there are three distinct layer of labour market idiosyncratic risks: households face staggered wage negotiations, sector specific average wage differentials and unemployment risks. The utility in equation (4.52) is therefore re-evaluated with \( C_t^{RP} = C_t^{RF} = C_t^{RU} \) and \( \nu_{cP}^{c} = \nu_{cF}^{c} = 1 \) to remove all of these risks. Moreover, the welfare costs of business cycles
are computed for some intermediate levels of risk sharing. It is assumed that households share
risks with their peers in their sectors ($v_{i}^{cp} = v_{i}^{cf} = 1$ and $C_{i}^{RP} \neq C_{i}^{RF} \neq C_{i}^{RU}$) or with all workers
($v_{i}^{cp} = v_{i}^{cf} = 1$ and $C_{i}^{RP} = C_{i}^{RF} \neq C_{i}^{RU}$) in order to assess the relative importance of each type of
risk.

Table 2: Welfare costs of business cycles

<table>
<thead>
<tr>
<th>Model</th>
<th>Cdt cost</th>
<th>Relative to OHs</th>
<th>Relative to ROTHs</th>
<th>Uncdt cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.547</td>
<td>1</td>
<td>0.217</td>
<td>-0.911</td>
</tr>
<tr>
<td></td>
<td>(0.268 ; 0.941)</td>
<td>(1 ; 1)</td>
<td>(0.124 ; 0.309)</td>
<td>(-1.686 ; -0.334)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>2.443</td>
<td>4.612</td>
<td>1</td>
<td>1.707</td>
</tr>
<tr>
<td></td>
<td>(1.994 ; 3.651)</td>
<td>(3.235 ; 8.095)</td>
<td>(1 ; 1)</td>
<td>(1.077 ; 2.945)</td>
</tr>
<tr>
<td>RoTHs: perfect RS</td>
<td>0.494</td>
<td>0.914</td>
<td>0.195</td>
<td>-0.433</td>
</tr>
<tr>
<td></td>
<td>(0.287 ; 0.771)</td>
<td>(0.76 ; 1.113)</td>
<td>(0.125 ; 0.276)</td>
<td>(-0.979 ; -0.033)</td>
</tr>
<tr>
<td>OHs*</td>
<td>0.371</td>
<td>0.7</td>
<td>0.147</td>
<td>0.445</td>
</tr>
<tr>
<td></td>
<td>(0.272 ; 0.545)</td>
<td>(0.4 ; 1.206)</td>
<td>(0.099 ; 0.216)</td>
<td>(0.326 ; 0.642)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GTT model</td>
<td>Cdt cost</td>
<td>Relative to OHs</td>
<td>Relative to ROTHs</td>
<td>Uncdt cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.743</td>
<td>1</td>
<td>0.568</td>
<td>-0.463</td>
</tr>
<tr>
<td></td>
<td>(0.473 ; 1.152)</td>
<td>(1 ; 1)</td>
<td>(0.454 ; 0.687)</td>
<td>(-1.086 ; 0.008)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>1.305</td>
<td>1.754</td>
<td>1</td>
<td>0.496</td>
</tr>
<tr>
<td></td>
<td>(0.862 ; 1.921)</td>
<td>(1.457 ; 2.205)</td>
<td>(1 ; 1)</td>
<td>(-0.095 ; 1.197)</td>
</tr>
<tr>
<td>RoTHs: sectoral RS</td>
<td>1.215</td>
<td>1.627</td>
<td>0.927</td>
<td>0.385</td>
</tr>
<tr>
<td></td>
<td>(0.805 ; 1.788)</td>
<td>(1.333 ; 2.041)</td>
<td>(0.907 ; 0.948)</td>
<td>(-0.187 ; 1.022)</td>
</tr>
<tr>
<td>ROTHs: workers RS</td>
<td>1.212</td>
<td>1.617</td>
<td>0.923</td>
<td>0.377</td>
</tr>
<tr>
<td></td>
<td>(0.801 ; 1.781)</td>
<td>(1.327 ; 2.033)</td>
<td>(0.899 ; 0.945)</td>
<td>(-0.193 ; 1.012)</td>
</tr>
<tr>
<td>RoTHs: perfect RS</td>
<td>0.545</td>
<td>0.724</td>
<td>0.411</td>
<td>-0.297</td>
</tr>
<tr>
<td></td>
<td>(0.378 ; 0.785)</td>
<td>(0.629 ; 0.823)</td>
<td>(0.34 ; 0.482)</td>
<td>(-0.65 ; 0.015)</td>
</tr>
</tbody>
</table>

Note: Welfare costs expressed a percentage point of (permanent) steady-state level of consumption. Conditional costs in the first column assume that the stochastic economy initially starts from its deterministic steady-state. Second and third columns report relative costs expressed as ratios of conditional costs for each agents compared to two different benchmarks: OHs and ROTHs respectively. Unconditional costs in the last column. Mode and 90% confidence bands reported in parenthesis.

The upper panel in Table 2 presents the welfare costs of business cycle fluctuations in the
EHL version of the model for OHs, ROTHs, insured ROTHs and foreign agents; respectively. It
shows that OHs would be ready to give-up 0.55% of their steady-state level of consumption in
order to avoid macroeconomic fluctuations while ROTHs would be ready to offer 2.44%. Those
costs are larger than in the advanced economy: foreign households would renounce to 0.37%.
Having access to state-contingent assets, these costs would drop from 2.44% to 0.49% for ROTHs.
The lower panel in Table 2 reports the welfare costs of business cycle fluctuations in the GTT
framework. In this case, the welfare costs of business cycles represent 0.74% and 1.31% of steady-
state consumption for OHs and ROTHs, respectively. In addition to the baseline - where ROTHs are excluded from all assets markers - three alternative assumptions regarding risk sharing are made. First, when ROTHs are able to share risks with their peers working in the same sector, the welfare cost of business cycles declines to 1.22%. Therefore, the inability to insure against staggered wage bargaining risks generating wage dispersion in each sector exacerbates the welfare costs of business cycles for about on tenth of a percentage point of steady-state consumption. This is much below the equivalent staggered wage setting risk in the EHL framework but economically meaningful. Second, when they are additionally able to share risk with all employed households, thereby cancelling sector specific wage differentials, the welfare cost of business cycles barely changes. Sectoral differences in average wages therefore seems to play a marginal role. In the GTT framework, wages in one sector influence wage bargaining in the other sector via its impact on employees outside option. Average wages in the primary and secondary sectors are therefore highly correlated. Moreover, only a small fraction of the workers are employed in the primary sector. This makes the effects of risk sharing between sector marginal. Third, when they are allowed to share risks all together, the welfare cost of business cycles drops to 0.55%. It indicates that unemployment risks are crucial.

In both versions of the model, the welfare costs of business cycles are particularly high, in relative term, for domestic financially excluded households. Indeed, they would be ready to abandon between 3.2 and 8.1 times as much, as a fraction of steady-state consumption, than OHs in order to avoid macroeconomic fluctuations in the EHL framework; and between 1.5 and 2.2 times as much in the GTT version of the model. Assuming that ROTHs could insure against idiosyncratic risks, their welfare costs of business cycles would likely be below those of their financially included counterparts. This result shows that exclusion from insurance markets is the key factor explaining the gap in the welfare costs of business cycles between financially included and excluded households.

Two mechanisms explain why financial markets exclusion exacerbates the welfare costs of business cycles in both versions of the model. First, lets consider wage rigidities. In the EHL context, a typical business cycle downturn encourages households to adjust their wage. Wages rigidities imply that a faction of agents cuts on their hourly wage rate while others simply index their wages to past inflation. Any household therefore faces the risk to end up with a relatively large wage - compared to other workers - and to suffer drastic drop in hours worked and income (the hours effect dominates because the labour demand elasticity of substitution is usually very large). Under the GTT assumption, a similar downturn decreases the firms employment surplus and the employees outside options. For the unlucky households facing wage renegotiation, wages are cut. In both versions of the model, financially included households can trade in state-contingent asset
markets to mute these risks. However, unlucky excluded households have no other choice than to adjust their consumption expenditures to their income with large detrimental welfare effects. Since households are risk averse, these unequal consumption levels has a detrimental effect on aggregate welfare. The magnitude of the implied consumption dispersion is however very different in both versions of the model. Under the EHL hypothesis, the high individual labour demand elasticity to wages generates larger labour income dispersion and therefore has very large welfare effects. Second, and specifically to the GTT variant, unemployment idiosyncratic risks exacerbate the welfare costs of business cycles for ROTHs. As already mention, unemployment benefits are tied to previous labour incomes. Consequently, it is worse to be laid-off during a recession because replacement wages are low. Business cycle fluctuations therefore generate income fluctuations when households are the most vulnerable. Since their consumption levels are very low when unemployed, they are ready to pay a large premium at every time and date to avoid further consumption volatility when unemployed. The welfare gains from eliminating aggregate fluctuations are important because households already face substantial amounts of uninsurable unemployment idiosyncratic risks.

Surprisingly, bonds and capital markets exclusion do not amplify the welfare costs of business cycle fluctuations. Actually, exclusion from bonds and capital markets does not increase consumption volatility and consequently does not raise the welfare costs of business cycles fluctuations. Two characteristics of the model provide the explanation. First, consumption is usually more volatile than output in emerging markets. However, ROTHs consumption follows income and therefore cannot be much more volatile than GDP. It implies that OHs consumption volatility need to adjust to match the aggregate consumption volatility. Second, there are important risks associated to holding any types of assets and to saving or borrowing in foreign bonds in particular. Following Schmitt-Grohe and Uribe (2003), the interest rate on foreign bonds depends on the net foreign assets position of the domestic economy (which captures the country risk premium and ensure stability of the model). By definition, the net foreign assets position depends on the cumulated trade balance surplus and deficits. Since a large share of exports are commodities whose prices are extremely volatile and persistent, it is subject to relatively large swings. This affects the country

\[35\text{In practice, unemployment benefits are linked to past individual wages in South Africa. However, for simplicity, it is assumed that they are based on aggregate wages.}\]

\[36\text{Other arguments have been developed in the literature to show that it is worse to be laid-off during recessions. Krebs (2007) considers that long term earning losses of displaced workers are larger during recessions due to lower entry wages or foregone wage rise. Krusell et al. (2009) recognize that prolonged periods of unemployment - which are more likely during recessions - exhaust poor households savings with large welfare effects. Specifically to the South African context, prolonged periods of unemployment end unemployment benefits.}\]

\[37\text{Santis (2007) show that idiosyncratic consumption risks can increase the gain of macroeconomic stability because the marginal gain from more stability is higher when the total amount of risk is large.}\]

\[38\text{Bhattacharya and Patnaik (2016) find a similar result.}\]
risk premium and OHs consumption/savings decisions. Moreover, holding primary sector capital is also very risky. These two specificities of the model explain why capital and bonds markets exclusion does not amplify the welfare costs of business cycles for households having access to the insurance markets. Some words of caution relate to the interpretation of this last result. This paper does not provide evidence on the effects of bonds and capital markets exclusion when households have no access to insurance. It would requires a third category of households - having access to bonds and capital but excluded from state contingent asset markets - that cannot be accommodated in a typical DSGE model. In this framework, one would expect bonds to play a crucial role as a self insurance tool. Moreover, this latter result does not mean that bonds and capital markets exclusion does not generate inequality. In this model, it actually does: bonds and capital increase the average level of consumption although they do not decrease its volatility.

6.1.2 Sources of the business cycle fluctuations and welfare costs

This section explores the relative importance of different types of shocks classified by nature (AD, NAS, RAS) and origin (domestic, foreign, SOE) in driving business cycles and generating welfare costs in the emerging economy. The sources of business cycle fluctuations and welfare costs have important implications for monetary policies. On the one hand, domestic monetary policies are especially well armed to deal with demand shocks. Therefore, an economy mainly driven by domestic demand factors would benefit the most from domestic demand management policies. On the other hand, supply disturbances entail a trade-off in term of inflation and output volatility. In addition, real supply shocks affect the natural level of output implying that, even if feasible, perfect output stabilisation would not be optimal. Similarly, foreign sources of disturbances can force a trade-off in term of inflation, output and exchange rate stabilisation to the domestic monetary policy.

The variance decomposition analysis reported in Table 13 in the appendix describes the sources of business cycle fluctuations at a five years horizon. Domestic real aggregate supply (RAS) shocks are the most important drivers of GDP fluctuations and also explain a large share of the fluctuations in hours worked. Domestic nominal aggregate supply (NAS) shocks are responsible for most of the fluctuations in domestic prices and wages. Together, domestic aggregate supply shocks contribute to a large fraction of the fluctuations in output and prices. However, these shocks do not trigger important monetary policy responses, probably because of the inflation/output trade-off they impose. Domestic aggregate demand (AD) shocks are the second driver of GDP and are the

39Idiosyncratic risks would make this type of agent heterogeneous with respect to capital and bonds holding and the representative agent framework would break. A way around would be to assume that this type of agents also applies simple rules of thumbs for their savings decisions.
Table 3: Welfare costs decomposition by disturbances

<table>
<thead>
<tr>
<th></th>
<th>EHL model</th>
<th></th>
<th>GTT model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cdt cost</td>
<td>Premium</td>
<td>Cdt cost</td>
<td>Premium</td>
</tr>
<tr>
<td><strong>NO AD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.341</td>
<td>0.168</td>
<td>0.408</td>
<td>0.316</td>
</tr>
<tr>
<td></td>
<td>(0.152 ; 0.569)</td>
<td>(0.077 ; 0.506)</td>
<td>(0.234 ; 0.651)</td>
<td>(0.174 ; 0.647)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>1.725</td>
<td>0.689</td>
<td>0.842</td>
<td>0.458</td>
</tr>
<tr>
<td></td>
<td>(1.495 ; 2.164)</td>
<td>(0.338 ; 1.852)</td>
<td>(0.52 ; 1.287)</td>
<td>(0.254 ; 0.877)</td>
</tr>
<tr>
<td><strong>NO RAS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.513</td>
<td>0.032</td>
<td>0.606</td>
<td>0.136</td>
</tr>
<tr>
<td></td>
<td>(0.244 ; 0.902)</td>
<td>(0.022 ; 0.045)</td>
<td>(0.351 ; 0.983)</td>
<td>(0.102 ; 0.181)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>2.346</td>
<td>0.092</td>
<td>1.281</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>(1.907 ; 3.569)</td>
<td>(0.075 ; 0.113)</td>
<td>(0.849 ; 1.906)</td>
<td>(0.002 ; 0.051)</td>
</tr>
<tr>
<td><strong>NO NAS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.381</td>
<td>0.168</td>
<td>0.62</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>(0.134 ; 0.749)</td>
<td>(0.135 ; 0.22)</td>
<td>(0.359 ; 0.988)</td>
<td>(0.106 ; 0.168)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>1.624</td>
<td>0.828</td>
<td>1.222</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>(1.154 ; 2.835)</td>
<td>(0.694 ; 1.051)</td>
<td>(0.797 ; 1.813)</td>
<td>(0.044 ; 0.151)</td>
</tr>
<tr>
<td><strong>NO SOE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.644</td>
<td>-0.099</td>
<td>0.851</td>
<td>-0.092</td>
</tr>
<tr>
<td></td>
<td>(0.407 ; 1.009)</td>
<td>(-0.174 ; -0.058)</td>
<td>(0.579 ; 1.238)</td>
<td>(-0.147 ; -0.053)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>2.364</td>
<td>0.074</td>
<td>1.327</td>
<td>-0.021</td>
</tr>
<tr>
<td></td>
<td>(1.908 ; 3.555)</td>
<td>(0.034 ; 0.132)</td>
<td>(0.902 ; 1.978)</td>
<td>(-0.071 ; 0.023)</td>
</tr>
<tr>
<td><strong>NO AD<em>AS</em></strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.269</td>
<td>0.241</td>
<td>0.497</td>
<td>0.234</td>
</tr>
<tr>
<td></td>
<td>(0.139 ; 0.634)</td>
<td>(0.117 ; 0.451)</td>
<td>(0.319 ; 0.83)</td>
<td>(0.093 ; 0.436)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>1.757</td>
<td>0.687</td>
<td>0.539</td>
<td>0.741</td>
</tr>
<tr>
<td></td>
<td>(1.314 ; 2.893)</td>
<td>(0.467 ; 1.027)</td>
<td>(0.31 ; 1.062)</td>
<td>(0.431 ; 1.174)</td>
</tr>
</tbody>
</table>

Note: The first column in each panels represents the welfare costs of business cycles in an economy sheltered from one particular group of shocks. See Table 1 for the definition of these groups of shocks. The second column shows the premium (as a fraction of consumption) that an agent would be ready to give to be transferred from the baseline to this particular economy. All numbers expressed in percentage points. Mode and 90% confidence bands reported in parenthesis.

primary focus of monetary policy. Excluding monetary policy shocks, they explain almost 50% of the variance in nominal interest rates. Foreign shocks also contribute to the fluctuations in domestic variables. Among foreign shocks, commodity supply shocks are the most important. These shocks generate important consumption fluctuations, especially for ROTHs. SOE shocks also weight on domestic variables via their effects on trade and the exchange rate.
The welfare cost analysis in Table 3 evaluates the fraction of consumption that each type of households would be ready to give-up in order to insulate the economy from one particular group of shocks (starting from the baseline economy whose business cycles are driven by all shocks). OHs are mainly affected by domestic aggregate demand, nominal aggregate supply and foreign shocks. Their effects are similar in term of magnitude in both versions of the model. For ROTHs, domestic aggregate demand and foreign shocks are important in both versions of the model. However, nominal aggregate supply shocks represent the largest source of welfare costs in the EHL version of the model while they only play a small role in the GTT framework. In the EHL framework, wage inflation generates more wage dispersion which translates into costly consumption dispersion. Since nominal supply shocks are responsible for the largest share of wage volatility, they are very important under the EHL hypothesis.

6.1.3 Commodity price fluctuations and option effects

Among foreign sources of business cycle fluctuations, commodity supply shocks would be a natural suspect to explain the large welfare costs of business cycles in the emerging economy. Foreign commodity supply shocks, through their impact on commodity prices, have large repercussions on the domestic economy and generate important consumption, investment and exchange rate fluctuations.

Figure 1 depicts the response of domestic and foreign variables to foreign commodity supply shock (in the EHL and GTT versions of the model). In the foreign economy, an exogenous increase in global commodity production generates a boom: it lowers commodity prices and acts as a positive supply shock by reducing firms marginal costs. In the domestic economy, this contraction in mining prices triggers a drop in mining production. Revenues from mining activities collapse damaging the trade balance (in nominal term) and leading to a build up of foreign debt. This increases the risk associated to the domestic currency. In addition, anticipations of lower output and inflation rates (from lower aggregate demand) resulting in lower domestic interest rates further play against the domestic currency. The exchange rate surges. Lower exports revenues and higher import prices depress imports, consumption and investments. In the EHL framework, the initial drop in consumption is larger for ROTHs who face lower labour earnings and cannot access financial markets to smooth consumption. In the GTT framework, search and matching frictions generate a delay between the shock and the peak in unemployment which causes an hump-shaped response in ROTHs consumption.

What are the effects of foreign commodity supply volatility - characterised by a succession of random foreign commodity supply shocks - on domestic households welfare? Surprisingly, they are welfare increasing for financially included households. Moreover, they could also raise
excluded households welfare depending on the version of the model (see Table 4). Actually, although the entailed volatility in aggregate variables such as consumption is unambiguously welfare decreasing, foreign commodity supply fluctuations could also have positive effects for at least two reasons. First, commodity supply volatility increases the average price of commodities relative to the final good in the foreign economy. The final good production function in the foreign economy (equation 4.11) implies that the price of commodities depends on their availability relative to other production factors (expressed as the capital and labour value added to commodity supply ratio). As commodity supply volatility increases, the average value of this ratio also increases and so does the average commodity price. This translates into better term of trade, on average, for commodity exporters such as the emerging economy considered in this paper. Households can therefore

\[ \text{See equation (B.23) in the appendix.} \]
sustain a higher average level of consumption for a given average level of commodity exports. Second, commodity price fluctuations offer option effects, which are the focus of the remainder of this subsection.

Table 4: Welfare cost of foreign commodity supply and commodity price shocks

<table>
<thead>
<tr>
<th></th>
<th>EHL model</th>
<th>GTT model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cdt cost</td>
<td>Uncdt cost</td>
</tr>
<tr>
<td><strong>Com supply shock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>-0.097</td>
<td>-0.215</td>
</tr>
<tr>
<td></td>
<td>(-0.139 ; -0.061)</td>
<td>(-0.349 ; -0.146)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.122</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td>(0.03 ; 0.253)</td>
<td>(-0.019 ; 0.174)</td>
</tr>
<tr>
<td><strong>Com price shock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.002</td>
<td>-0.167</td>
</tr>
<tr>
<td></td>
<td>(-0.024 ; 0.029)</td>
<td>(-0.239 ; -0.109)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.339</td>
<td>0.263</td>
</tr>
<tr>
<td></td>
<td>(0.275 ; 0.448)</td>
<td>(0.192 ; 0.376)</td>
</tr>
</tbody>
</table>

Note: Welfare costs of commodity supply fluctuations in the upper panel. Welfare costs of commodity price fluctuations in the lower panel. All numbers expressed in percentage points. Mode and 90% confidence bands reported in parenthesis.

How do option effects works for commodity prices? As an introduction, lets consider a simple example. Assume that a firm produce one unit of commodity at period one and period two. Imagine that there are no business cycle fluctuations and that commodity prices are fixed to one. The producer’s income amounts to one monetary unit at every period, hence two in total. Now imagine prices are subject to mean-preserving fluctuations. At period one, the price is equal to 1.5; at period two to 0.5. If the producer does not adjust, his income remains equal to two (1.5 plus 0.5). But imagine that the employer can convince his employees to work twice as hard on period one (to produce two units), and to have a break at period two (hence no production). By transferring production from period two to one, he could get an income of three (1.5 times 2). Could this strategy increase welfare? It could, depending on the ability to transfer resources from period one to period two and on employees preferences for smooth working hours and income streams. In the more realistic economy presented in section four, the same intuition is valid. Indeed, option effects could compensate or even dominate the adverse welfare effects of consumption and hours fluctuations as long as the elasticity of factor supply is large enough and if households have a mean to transfer wealth across periods in the form of capital or bonds. Having access to these tools, OHs have the opportunity to benefit from option effects. Financially excluded households could also indirectly benefit from these effects if they translate into more physical capital and therefore
increase the marginal productivity of labour and eventually wages.

In order to identify option effects, this paper evaluates the welfare effects of a pure commodity price shocks (see Table 4). It is modelled as random mean-preserving exogenous shocks to real commodity prices (expressed in foreign currency) leaving activity in the foreign economy unaffected. It allows to focus on the effect of commodity price volatility, independent from their effects on the average level of commodity prices or economic activity abroad. This shock also significantly increases welfare of financially included households in the GTT version of the model. The impact is uncertain under the EHL assumption. Nevertheless, it shows that mean-preserving commodity price fluctuations might be welfare enhancing for some households and plausible sets of parameters. Also note that in the GTT variant, there is a small chance that commodity price fluctuations also increase excluded households welfare.

To understand these option effects, one very intuitive methodology would be to compare the average value of commodity incomes, capital stocks, foreign assets and consumption in the domestic economy driven by commodity price shocks, compared to its steady-state. If option effects are playing any role, consumption levels should be higher on average in the stochastic economy. However, this strategy might confuse option effects with precautionary savings. Indeed, when anticipating shocks, agent could decide to accumulate more assets to hedge against aggregate fluctuations. This paper therefore compares two alternative economies which all start at their deterministic steady-state (DSS). In the first economy, commodity prices are subject to exogenous shocks which generate business cycle fluctuations. In the second economy, no shock ever actually hits the economy, although agents anticipate commodity prices to fluctuate following the same law of motion as in the first economy. In this second economy, precautionary savings motives operate (because agents anticipate shocks) while option effects do not (because no shock actually ever hits the economy). All variables therefore simply converge towards what is usually referred to as their stochastic steady-state (SSS). This experiment allows to distinguish the effects of precautionary savings from option effects by comparing this SSS with the expected value of key variables in the first economy. Figure 2 reports the expected evolution of domestic variables in the first economy over 80 quarters, compared to the second. In the long run, forecasts for the first economy converge to their unconditional means while the second economy simply transitions towards its SSS. Table 5 reports the DSS, SSS and the unconditional mean of simulated variables in the first economy.

Comparing the DSS and SSS, it is clear that precautionary motives encourage OHs to save in foreign assets and to accumulate secondary sector capital when anticipating commodity price fluctuations. However, OHs decide to hold less primary sector capital, probably for two reasons. On the one hand, holding primary sector capital is risky and it would therefore make sense to hold more foreign assets and domestic final good sector capital to hedge against commodity price
Figure 2: Short-run effects of foreign commodity price fluctuations

Note: Effects of mean-preserving foreign commodity price fluctuations on domestic variables. Commodity price and net foreign assets in domestic currency. First economy mean conditional forecasts in grey. Forecasts converges to the first economy unconditional mean in dashed grey in the long run. Second economy transition to the SSS in black. SSS in dashed black. Computations based on the mode of estimated parameters. Horizon in quarters. GTT version of the model (EHL results are similar and not reported).

fluctuation risks. On the other hand, accumulating foreign assets reduces the country risk premium, hence generating an appreciation of the domestic currency and a drop in commodity prices expressed in domestic currency units, thereby reducing the incentive to invest in the primary sector.41 Comparing the mean of simulated variables with their SSS gives a picture of option effects. The average value of OHs and ROTHs consumption in the first economy is larger than their SSS indicating that mean-preserving commodity price fluctuations enable households to increase their

41In addition to option effects, some specific shocks could increase welfare through the precautionary savings motive. Since individual households do not internalise the impact of their net foreign assets position on the country risk premium, at the aggregate level, households could hold too few foreign assets. When some business cycle fluctuations trigger precautionary savings in the form of foreign assets accumulation, the gains from a lower risk premium could dominate the costs of aggregate fluctuations.
Table 5: Long-run effects of foreign commodity price fluctuations

<table>
<thead>
<tr>
<th></th>
<th>EHL model</th>
<th>GTT model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DSS</td>
<td>SSS</td>
</tr>
<tr>
<td>Commodity Income</td>
<td>0.1236</td>
<td>0.1225</td>
</tr>
<tr>
<td>Commodity Price</td>
<td>1.0000</td>
<td>0.9955</td>
</tr>
<tr>
<td>Commodity Output</td>
<td>0.1236</td>
<td>0.1231</td>
</tr>
<tr>
<td>Commodity Capital</td>
<td>1.1041</td>
<td>1.0964</td>
</tr>
<tr>
<td>Commodity Hours</td>
<td>0.0402</td>
<td>0.0400</td>
</tr>
<tr>
<td>Sec. Output</td>
<td>1.0000</td>
<td>0.9986</td>
</tr>
<tr>
<td>Sec. Capita</td>
<td>8.1208</td>
<td>8.1303</td>
</tr>
<tr>
<td>Sec. Hours</td>
<td>0.5598</td>
<td>0.5583</td>
</tr>
<tr>
<td>Net foreign assets</td>
<td>0.0000</td>
<td>0.0230</td>
</tr>
<tr>
<td>OHs consumption</td>
<td>0.4568</td>
<td>0.4666</td>
</tr>
<tr>
<td>ROTHs consumption</td>
<td>0.2632</td>
<td>0.2629</td>
</tr>
</tbody>
</table>

Note: Effects of a mean-preserving foreign commodity price shock on domestic variables. Commodity price and net foreign assets in domestic currency. DSS = deterministic steady-state, SSS = stochastic steady-state, Mean = unconditional mean of simulated variables in the stochastic economy. Computations based on the mode of estimated parameters.

average level of consumption. The extra average income generated (in the short-run) by commodity price fluctuations are invested in foreign assets and in secondary capital goods allowing to sustain higher domestically produced and imported consumption. This, in turn, decreases the country risk premium, fuels an appreciation of the domestic currency and reduces the average value of commodity products. However, once OHs have accumulated foreign bonds and secondary sector capital, these extra assets are enough to sustain higher average consumption levels. ROTHs indirectly benefit from this strategy: the domestic currency appreciation reduces the real price of imported consumption goods, and the increase in physical capital raises labour productivity and therefore wages.

6.2 Welfare effects of monetary policy

This section has three objectives. First, it demonstrates that the benefits of monetary policy rules that respond aggressively to inflation are substantial and robust to parameter uncertainty for each type of agents. Responding to output growth has modest effects and is more likely to benefit financially excluded households. Second, it shows that pure inflation targeting with no interest rate smoothing is the optimal simple rule in the EHL framework. In the GTT version of the model, a combination of a strong anti inflation stance with moderate and strong response to output maximises the welfare of OHs and ROTHs, respectively. Third, it decomposes the source of the
welfare gains associated to the optimal simple rule conditional on the occurrence of some types of specific shocks. It shows that most of the welfare gains associated to pure inflation targeting comes from mitigating the effects of demand shocks while this type of policy could be welfare decreasing in an economy driven by supply shocks. The optimal simple rule delivers important welfare gains but the welfare costs of business cycles remain substantial, especially for financially excluded households.

6.2.1 Welfare effects of alternative monetary policy rules

This section compares the welfare effects of five alternative simple rules to the baseline case where the Taylor rule is calibrated at the mode of its estimated parameters. First, it simulates a pure CPI-inflation targeting rule where $\tau_{\pi} = 3$ and $\tau_{\Delta y}=\tau_{\Delta r}=0$ and the interest rate smoothing parameter $\rho_r$ is kept unchanged. Pure inflation targeting has been widely recommended and is therefore a natural policy candidate. Second, it evaluates a pure domestic-inflation targeting rule with the same parameters values. Those two pure inflation targeting rules allow to contrast the effects of two relevant price index targets. Third, it gauges the impact of a faster policy response by lowering the smoothing parameter to $\rho_r = 0.5$. Central banks usually move their interest rates gradually for precautionary motives (for e.g. if the state of the economy is uncertain) and to maintain financial stability. In a context where agents are forward looking, monetary policies guiding future interest rates are capable to stabilise the economy. In the present model, half of households are hand to month consumers and it is interesting to evaluate the efficiency of interest rate smoothing. Fourth, it considers a muted response to output by imposing that $\tau_{\Delta y}=0$. Finally, it examines a muted response to the exchange rate with $\tau_{\Delta r}=0$. Those last two rules are introduced in order to evaluate the desirability of interest rate responses to changes in real activity and to the exchange rate. Table 6 reports the premium (expressed as a fraction of steady-state consumption) that each domestic agents would be ready to give-up in order to be transferred from the baseline to one of the five alternative policy described above. Moreover, Tables 14 and 15 in the appendix show the impact of these policies on the simulated and theoretical variances of some key variables. In addition, Figures 5 and 6 depicts the welfare costs sensitivity to changes in each Taylor Rule coefficient.

Pure CPI-inflation targeting  Pure CPI-inflation targeting (with a much larger weight on CPI-inflation, no weight on output or the exchange rate and an unchanged smoothing parameter) could deliver substantial welfare gains for both types of households. These gains represents 0.1% and 0.26% of consumption for OHs in the EHL and GTT frameworks, respectively. ROTHs would be

\footnote{Schmitt-Grohe and Uribe (2007) argue that policy coefficients larger than 3 or negative would be difficult to communicate to policy-makers or the public.}
Table 6: Welfare effects of alternative MP rules

<table>
<thead>
<tr>
<th></th>
<th>EHL model</th>
<th></th>
<th>GTT model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cdt cost</td>
<td>Premium</td>
<td>Cdt cost</td>
<td>Premium</td>
</tr>
<tr>
<td>CPI targeting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.437</td>
<td>0.102</td>
<td>0.492</td>
<td>0.256</td>
</tr>
<tr>
<td>(0.196 ; 0.744)</td>
<td>(0.055 ; 0.251)</td>
<td>(0.276 ; 0.817)</td>
<td>(0.165 ; 0.44)</td>
<td></td>
</tr>
<tr>
<td>ROTHs</td>
<td>2.049</td>
<td>0.398</td>
<td>0.974</td>
<td>0.352</td>
</tr>
<tr>
<td>(1.711 ; 2.743)</td>
<td>(0.19 ; 0.964)</td>
<td>(0.602 ; 1.453)</td>
<td>(0.213 ; 0.63)</td>
<td></td>
</tr>
<tr>
<td>PPI targeting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.416</td>
<td>0.125</td>
<td>0.469</td>
<td>0.281</td>
</tr>
<tr>
<td>(0.191 ; 0.716)</td>
<td>(0.067 ; 0.276)</td>
<td>(0.263 ; 0.77)</td>
<td>(0.19 ; 0.485)</td>
<td></td>
</tr>
<tr>
<td>ROTHs</td>
<td>1.824</td>
<td>0.635</td>
<td>1.073</td>
<td>0.261</td>
</tr>
<tr>
<td>(1.521 ; 2.473)</td>
<td>(0.363 ; 1.268)</td>
<td>(0.719 ; 1.539)</td>
<td>(0.112 ; 0.524)</td>
<td></td>
</tr>
<tr>
<td>Low int. rate smoothing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.541</td>
<td>-0.018</td>
<td>0.714</td>
<td>0.032</td>
</tr>
<tr>
<td>(0.271 ; 0.924)</td>
<td>(-0.03 ; 0.061)</td>
<td>(0.445 ; 1.123)</td>
<td>(-0.054 ; 0.101)</td>
<td></td>
</tr>
<tr>
<td>ROTHs</td>
<td>2.278</td>
<td>0.163</td>
<td>1.229</td>
<td>0.08</td>
</tr>
<tr>
<td>(1.81 ; 3.446)</td>
<td>(-0.044 ; 0.383)</td>
<td>(0.792 ; 1.874)</td>
<td>(0.002 ; 0.17)</td>
<td></td>
</tr>
<tr>
<td>Muted resp. to GDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.543</td>
<td>-0.006</td>
<td>0.756</td>
<td>-0.01</td>
</tr>
<tr>
<td>(0.265 ; 0.938)</td>
<td>(-0.006 ; 0.01)</td>
<td>(0.481 ; 1.156)</td>
<td>(-0.032 ; 0.002)</td>
<td></td>
</tr>
<tr>
<td>ROTHs</td>
<td>2.456</td>
<td>-0.018</td>
<td>1.359</td>
<td>-0.048</td>
</tr>
<tr>
<td>(1.999 ; 3.714)</td>
<td>(-0.065 ; 0.009)</td>
<td>(0.899 ; 1.986)</td>
<td>(-0.092 ; -0.025)</td>
<td></td>
</tr>
<tr>
<td>Muted resp. to NEER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.557</td>
<td>-0.007</td>
<td>0.731</td>
<td>0.014</td>
</tr>
<tr>
<td>(0.277 ; 0.997)</td>
<td>(-0.06 ; 0.004)</td>
<td>(0.435 ; 1.168)</td>
<td>(-0.039 ; 0.061)</td>
<td></td>
</tr>
<tr>
<td>ROTHs</td>
<td>2.469</td>
<td>-0.026</td>
<td>1.247</td>
<td>0.055</td>
</tr>
<tr>
<td>(1.985 ; 3.825)</td>
<td>(-0.242 ; 0.03)</td>
<td>(0.788 ; 1.889)</td>
<td>(-0.039 ; 0.16)</td>
<td></td>
</tr>
</tbody>
</table>

Note: The first column in each panel represents the conditional welfare costs of business cycles under an alternative Taylor rule. The second column shows the premium (as a fraction of consumption) that an agent would be ready to give to be transferred from the baseline to the economy operating with the alternative Taylor rule. Positive numbers show the agent prefers the alternative rule. All numbers expressed in percentage points. Mode and 90% confidence bands reported in parenthesis.

ready to renounce to 0.4% or 0.35% of consumption. This indicates that there is room for policy improvement through perusing a more aggressive inflation targeting policy. Most of these gains come from stabilising nominal variables. The drop in domestic good price inflation volatility reduces price dispersion and the input loss in the domestic distribution process. The reduction in wages inflation variance reduces hours dispersion. The drop in wages dispersion also reduces in-
individual labour income volatility which benefits uninsured ROTHs. Moreover, this policy is likely to stabilise aggregate real wages which further mitigates ROTHs consumption fluctuations. In the GTT version of the model, pure inflation targeting also reduces unemployment volatility. In fact, unemployment fluctuations are mainly driven by demand factors (see the variance decomposition in Table 13). An aggressive interest rate response does a good job at mitigating demand shocks and therefore also reduces unemployment fluctuations. However, a more aggressive interest rate response could increase investment and OHs consumption volatility, as well as output. Overall, the welfare effects of pure CPI targeting are favourable for each type of agents. Figures 5 and 6 in the appendix show the welfare costs sensitivity to changes in the Taylor rule inflation coefficient for values between one and three. Increasing the inflation coefficient always raises welfare for each type of households over this interval but the gains slow as the value of this parameter increases.

**Pure domestic-inflation targeting**  Pure domestic inflation targeting also sharply reduces the welfare costs of business cycles. The gains are similar to those obtained with pure CPI targeting. The underlying mechanisms are akin to those described above and the results are therefore not discussed in details.

**Low interest rate smoothing**  Quick monetary policy response could bring welfare gains to financially excluded households. The effect amounts to 0.16% and 0.08% of consumption in the EHL and GTT versions of the model and is significant in the latter. The impact on included households welfare is not robust to parameter uncertainty in both models. Figures 5 and 6 show that an intermediate interest rate smoothing parameter (in the range of 0.75) would be optimal (fixing other Taylor Rule parameters at the mode). Faster monetary policy adjustments tend to reduce real variables volatility and to moderate the initial responses of inflation to a large range of shocks. However, this rule generates more persistence in inflation which eventually increases inflation volatility. With other Taylor rule parameters at their modes, reconciling these trade-offs requires an interest rate smoothing parameter of about 0.75, below its estimated value of 0.86. In particular, NAS and foreign shocks (including commodity price shocks) requires a faster monetary policy response while RAS and UIP shocks call for gradual interest rates movements.

**Muted response to output growth**  Had the central bank muted its response to output, the welfare costs of business cycles would have been slightly larger for hand-to-mouth consumer. They would be ready to give-up 0.02 and 0.05% of their consumption level to avoid this policy in the EHL and GTT frameworks, respectively. The effect is significant in the latter. Accommodating output fluctuations makes unemployment and aggregate consumption more volatile. The variances
of real labour income and wage inflation could also increase. Moreover, accommodating output fluctuations is unlikely to bring important gains in term of inflation stabilisation in a context where demand shocks are important drivers of business cycles. Figures 5 and 6 show conflicting preferences for OHs and ROTHs over the intensity of the monetary policy response to GDP growth deviation from its trend. ROTHs always favour the strongest response, while in the EHL framework, OHs fare better when monetary policy accommodates GDP fluctuations. In addition, although OHs prefer that the central bank accommodates GDP fluctuations caused by domestic supply shocks, ROTHs desire some intermediate level of output management. In fact, GDP growth stabilisation represents the main trade-off between OHs and ROTHs utility. From an utilitarian point of view, more emphasis on output stabilisation would be desirable since the gains for ROTHs outweighs OHs losses.

**Muted response to changes in the NEER** Had the central bank muted its response to the nominal exchange rate, the welfare costs of business cycles would have been slightly larger in the EHL version, but lower in the GTT context, for each types of households. However, none of these results are significant. One the one hand, Tables 14 and 15 show that a muted response to the NEER could increase the variance of nominal variables such as consumer prices, domestic prices, wages and the nominal exchange rate. On the other hand, this strategy could reduce ROTHs consumption volatility in the GTT framework. Engel (2011) argued that sticky prices in the importer currency (comparable to the model in this paper) generate inefficient deviations from the law of one price which justify some response to the import price index. However, it might not be necessary to respond to nominal exchange rate fluctuations beyond their impacts on the CPI. In particular, all external shocks (foreign shocks and SOE shocks) require a muted response to the exchange rate when the central banks already place a sufficient weight on the consumer price index.

### 6.2.2 Optimal simple rules

This subsection evaluates the optimal simple rule within the set of rules responding to CPI-inflation, output growth and the change in the NEER. The smoothing parameter $\rho_r$ is restricted to the $[0, 1]$ interval, the inflation and output parameters $\tau_\pi$ and $\tau_{\Delta y}$ are restricted to $[0, 3]$ and the NEER parameter $\tau_{\Delta s}$ to $[0, 1/2]$. Moreover, since monetary policy shocks decrease welfare, the optimal simple rule requires to set these shocks to zero.

Table 7 shows the optimal values of Taylor Rule coefficients in the EHL and GTT frameworks. In the EHL version, pure inflation targeting without interest rate smoothing is the optimal policy for each type of households. OHs would be ready to abandon 0.13% of their steady-state consumption level to implement the optimal simple rule. ROTHs would renounce to 0.62%. There is no trade-
off between financially included and excluded households welfare. In this version of the model, business cycles generate similar types of risks for both categories of agents. Indeed, price and wage fluctuations generate an input loss in the production process and hours dispersion for OHs. Wage fluctuations cause hours and income dispersion for ROTHs. Income dispersion generates additional welfare costs to ROTHs, but the underlying mechanism remains wage inflation. Since pure CIP targeting can mitigate both price and wage inflation volatility, this policy is effective for both OHs and ROTHs. However, the welfare costs of business cycle fluctuations remain relatively large, even when the central follows the optimal monetary policy rule. Indeed, OHs and ROTHs would still agree to give-up 0.38% and 1.72% to edge against business cycles fluctuations, respectively. In the GTT framework, the optimal policy requires an additional response to GDP fluctuations. OHs welfare is maximised with a moderate response to GDP growth while ROTHs favour a stronger response. Search and matching frictions generate unemployment risks disproportionately borne by ROTHs (the search friction also imposes some rigidities on the firms). In this context, mitigating output fluctuations is welfare increasing, especially for ROTHs. From an utilitarian perspective, the output coefficient should be set to 2 to maximise aggregate welfare. OHs and ROTHs would be willing to pay a 0.25% and 0.4% premium to introduce the utilitarian optimal simple rule, respectively. Again, the welfare costs of business cycles remain substantial: they amount to 0.45% of consumption for OHs and to 0.84% for ROTHs.

### 6.2.3 Sources of welfare gains

This section further explores the sources of the welfare gains attained from following the optimal simple rules described above. It evaluates the desirability of these policies (compared to the baseline Taylor rule) conditionally on the occurrence of particular types of shock in the EHL and GTT versions of the model.

Table 8 reports the welfare gains associated to pure consumer price targeting with no interest rate smoothing in the EHL and GTT frameworks. It explores different scenarios where the economy is only affected by domestic aggregate demand shocks (AD), domestic real and nomi-
Table 8: Welfare effects of the EHL optimal simple rule

<table>
<thead>
<tr>
<th></th>
<th>EHL model</th>
<th></th>
<th>GTT model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cdt cost</td>
<td>Premium</td>
<td>Cdt cost</td>
<td>Premium</td>
</tr>
<tr>
<td><strong>All shocks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.381</td>
<td>0.131</td>
<td>0.423</td>
<td>0.264</td>
</tr>
<tr>
<td></td>
<td>(0.155 ; 0.669)</td>
<td>(0.073 ; 0.299)</td>
<td>(0.222 ; 0.714)</td>
<td>(0.16 ; 0.473)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>1.72</td>
<td>0.621</td>
<td>0.935</td>
<td>0.303</td>
</tr>
<tr>
<td></td>
<td>(1.417 ; 2.297)</td>
<td>(0.372 ; 1.282)</td>
<td>(0.552 ; 1.391)</td>
<td>(0.163 ; 0.582)</td>
</tr>
<tr>
<td><strong>AD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.08</td>
<td>0.065</td>
<td>0.115</td>
<td>0.141</td>
</tr>
<tr>
<td></td>
<td>(0.034 ; 0.264)</td>
<td>(0.021 ; 0.224)</td>
<td>(0.05 ; 0.25)</td>
<td>(0.061 ; 0.358)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.243</td>
<td>0.348</td>
<td>0.132</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>(0.118 ; 0.681)</td>
<td>(0.118 ; 1.079)</td>
<td>(0.058 ; 0.318)</td>
<td>(0.108 ; 0.501)</td>
</tr>
<tr>
<td><strong>RAS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.026</td>
<td>0.006</td>
<td>0.092</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>(0.018 ; 0.037)</td>
<td>(-0.001 ; 0.013)</td>
<td>(0.068 ; 0.122)</td>
<td>(0.028 ; 0.067)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.112</td>
<td>-0.015</td>
<td>0.037</td>
<td>-0.013</td>
</tr>
<tr>
<td></td>
<td>(0.088 ; 0.156)</td>
<td>(-0.045 ; 0.006)</td>
<td>(0.017 ; 0.07)</td>
<td>(-0.039 ; 0.008)</td>
</tr>
<tr>
<td><strong>NAS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.144</td>
<td>0.026</td>
<td>0.092</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td>(0.112 ; 0.189)</td>
<td>(0.019 ; 0.037)</td>
<td>(0.071 ; 0.116)</td>
<td>(0.028 ; 0.058)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.756</td>
<td>0.113</td>
<td>0.089</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.616 ; 0.943)</td>
<td>(0.06 ; 0.182)</td>
<td>(0.037 ; 0.166)</td>
<td>(-0.015 ; 0.012)</td>
</tr>
<tr>
<td><strong>SOE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>-0.101</td>
<td>0.001</td>
<td>-0.077</td>
<td>-0.013</td>
</tr>
<tr>
<td></td>
<td>(-0.184 ; -0.058)</td>
<td>(-0.007 ; 0.014)</td>
<td>(-0.136 ; -0.041)</td>
<td>(-0.032 ; 0)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.078</td>
<td>0.001</td>
<td>-0.011</td>
<td>-0.007</td>
</tr>
<tr>
<td></td>
<td>(0.035 ; 0.134)</td>
<td>(-0.028 ; 0.047)</td>
<td>(-0.048 ; 0.03)</td>
<td>(-0.046 ; 0.015)</td>
</tr>
<tr>
<td><strong>AD*AS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.214</td>
<td>0.03</td>
<td>0.198</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td>(0.099 ; 0.394)</td>
<td>(0.017 ; 0.051)</td>
<td>(0.062 ; 0.37)</td>
<td>(0.027 ; 0.065)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.532</td>
<td>0.183</td>
<td>0.656</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td>(0.367 ; 0.801)</td>
<td>(0.122 ; 0.283)</td>
<td>(0.35 ; 1.049)</td>
<td>(0.069 ; 0.141)</td>
</tr>
</tbody>
</table>

Note: The first panel shows the results for the baseline economy driven by all categories of shocks. Panels 2 to 6 represents economies affected by one particular group of shocks only. The first column in each panels represents the conditional welfare costs of business cycles under the optimal simple rule. The second column shows the premium that an agent would be ready to pay to be transferred from the baseline to the economy operating with the optimal simple rule. All numbers expressed in percentage points. Mode and 90% confidence bands reported in parenthesis.
Table 9: Welfare effects of the GTT optimal simple rule

<table>
<thead>
<tr>
<th>All shocks</th>
<th>EHL model</th>
<th>GTT model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cdt cost</td>
<td>Premium</td>
</tr>
<tr>
<td>OHs</td>
<td>0.392</td>
<td>0.111</td>
</tr>
<tr>
<td></td>
<td>(0.169 ; 0.69)</td>
<td>(0.059 ; 0.294)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>1.734</td>
<td>0.592</td>
</tr>
<tr>
<td></td>
<td>(1.456 ; 2.262)</td>
<td>(0.334 ; 1.295)</td>
</tr>
<tr>
<td>AD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.08</td>
<td>0.063</td>
</tr>
<tr>
<td></td>
<td>(0.036 ; 0.252)</td>
<td>(0.019 ; 0.236)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.244</td>
<td>0.356</td>
</tr>
<tr>
<td></td>
<td>(0.125 ; 0.612)</td>
<td>(0.111 ; 1.132)</td>
</tr>
<tr>
<td>RAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.034</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.023 ; 0.048)</td>
<td>(-0.006 ; 0.002)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.12</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>(0.095 ; 0.158)</td>
<td>(-0.049 ; -0.005)</td>
</tr>
<tr>
<td>NAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.149</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.116 ; 0.199)</td>
<td>(0.015 ; 0.026)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.762</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td>(0.627 ; 0.968)</td>
<td>(0.063 ; 0.15)</td>
</tr>
<tr>
<td>SOE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>-0.099</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(-0.188 ; -0.057)</td>
<td>(-0.007 ; 0.01)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.08</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(0.044 ; 0.135)</td>
<td>(-0.029 ; 0.036)</td>
</tr>
<tr>
<td>AD<em>AS</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHs</td>
<td>0.216</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>(0.1 ; 0.395)</td>
<td>(0.017 ; 0.049)</td>
</tr>
<tr>
<td>ROTHs</td>
<td>0.542</td>
<td>0.166</td>
</tr>
<tr>
<td></td>
<td>(0.367 ; 0.81)</td>
<td>(0.115 ; 0.26)</td>
</tr>
</tbody>
</table>

Note: The first panel shows the results for the baseline economy driven by all categories of shocks. Panels 2 to 6 represents economies affected by one particular group of shocks only. The first column in each panels represents the conditional welfare costs of business cycles under the optimal simple rule. The second column shows the premium that an agent would be ready to pay to be transferred from the baseline to the economy operating with the optimal simple rule. All numbers expressed in percentage points. Mode and 90% confidence bands reported in parenthesis.
nal supply shocks (NAS and RAS), small open economy shocks (SOE) and foreign shocks (AD*, NAS* and RAS*); respectively. It shows that most of the gain associated to this policy comes from stabilising domestic demand shocks. This policy would also undoubtedly benefit economies driven by foreign shocks. However, there is a possibility that this policy decreases welfare in economies affected by real and nominal supply shocks (especially for ROTHs) or small open economy shocks. Although the potential welfare loss associated to pure inflation targeting in the event of domestic supply shocks or small open economy shocks highlights an important trade-off faced by the monetary policy, this effect is relatively small compared to the gains collected with this policy when the economy is affected by other types of shocks.

Table 9 shows the welfare gains associated to the GTT optimal simple rule. When the central bank places a high weight on inflation and output fluctuations, a similar conclusion applies. Indeed, most of the welfare gains come from mitigating the effects of aggregate demand shocks and this policy is also a better response to foreign shocks than the estimated Taylor Rule. However, there is no guarantee that this optimal simple rule would beat the baseline in economies driven by real supply shocks or small open economy shocks.

7 Conclusion

This paper measures the cost of business cycle fluctuations and the effects of alternative monetary policies in a small open emerging economy. South Africa is the country of choice. The model captures the key characteristics of a typical small open emerging economy: a large commodity sector exposed to developments in world commodity prices and imperfect capital and financial markets limiting the ability of some households to smooth consumption inter-temporally and to insure against idiosyncratic risks in the labour market.

In this context, the welfare costs of business cycles are substantial in the emerging economy and they are much larger for households excluded from financial markets. Most of this welfare gap is driven by the exclusion from the insurance market. Moreover, option effects allow financially included households to benefit from some business cycle fluctuations - such as foreign commodity supply shocks - while it is unlikely to be the case for the other type of agents. This study also decomposes the welfare costs of business cycles into different types of disturbances classified according to their nature (demand vs supply) and origin (domestic vs foreign). It reveals that both domestic demand and supply shocks have important welfare effects hinting that there could be scope and limitation for more aggressive demand management policies. Foreign shocks also have economically meaningful welfare effects.

This paper then explores potential welfare gains from simple monetary policy rules to draw
relevant policy recommendations. The welfare gains from a more aggressive anti-inflation policy are very important and robust to parameter uncertainty. Responding to output fluctuations is more likely to benefit excluded households. The optimal rule depends on the structure of the labour market. In the staggered monopolistic wage setting environment, the optimal policy consist in an immediate and strong response to inflation deviation from its target. In the search and matching friction with staggered wage bargaining framework, included households would benefit from a moderate response to output, while excluded households would prefer to place a large weight on output in addition to the strong anti-inflation stance. Financially excluded households gain more from appropriate monetary policies. Most of the welfare gains obtained with these optimal rules come from mitigating the effects of domestic demand shocks. While this strategy is also desirable in the event of foreign shocks, pure inflation targeting could be welfare decreasing in a small open emerging economy primarily driven by large domestic supply shocks. The welfare costs of business cycles remain substantial for each types of agents and particularly large for households excluded from the capital and financial markets.

This paper raises different questions. First, what would be the role of self insurance for financially excluded households? Access to a simple storage technology - such as money - could have important implications. It could reduce the welfare costs of business cycles. However, recessions could still provoke prolonged periods of unemployment which could exhaust their wealth. Second, considering the fact that large welfare costs of business cycles remain, it would be interesting to consider the relative efficiency of fiscal policies. In particular, the welfare effects of commodity income management inspired from Norway’s oil fund could be studied in this framework. Third, where does those large welfare gain come from? Are there any particular rigidities - real or nominal - that are responsible for those large estimates? In this context, it could be interesting to assess the impact of labour mobility.

References


A Additional figures and tables

Figure 3: Prior and posterior densities - shocks std and AR(1) coefficients

Note: Prior in grey, posterior for South Africa in the EHL version in solid black and in the GTT version in dotted black. Shocks standard deviation ($\varepsilon, \Upsilon$ and $\phi$) described in Table 1 and their persistence ($\rho$).
Figure 4: Prior and posterior densities - domestic parameters

Note: Prior in grey, posterior for South Africa in the EHL version in solid black and in the GTT version in dotted black.
Figure 5: Welfare Costs sensitivity to estimated Taylor Rule parameters: EHL model

Note: Welfare costs of business cycles for OHs (solid line, left axis) and ROTHs (dashed, right axis) as a function of univariate changes in inflation coefficient (top left), smoothing parameter (top right), output coefficient (bottom left) and exchange rate coefficient (bottom right). Other coefficients at their estimated mode.
Figure 6: Welfare Costs sensitivity to estimated Taylor Rule parameters: GTT model

Note: Welfare costs of business cycles for OHs (solid line, left axis) and ROTHs (dashed, right axis) as a function of univariate changes in inflation coefficient (top left), smoothing parameter (top right), output coefficient (bottom left) and exchange rate coefficient (bottom right). Other coefficients at their estimated mode.
Figure 7: Welfare Costs sensitivity to estimated Taylor Rule parameters: EHL model

(a) Real aggregate supply shocks

(b) Nominal aggregate supply shocks

(c) Small open economy shocks

(d) Foreign shocks

Note: Welfare costs of business cycles for OHs (solid line, left axis) and ROTHs (dashed, right axis) as a function of univariate changes in inflation coefficient (top left), smoothing parameter (top right), output coefficient (bottom left) and exchange rate coefficient (bottom right). Other coefficients at their optimal values. Economy exclusively driven by RAS shocks (a), NAS (b), SOE (c) and foreign shocks (d), respectively.
Figure 8: Welfare Costs sensitivity to estimated Taylor Rule parameters: GTT model

(a) Real aggregate supply shocks

(b) Nominal aggregate supply shocks

(c) Small open economy shocks

(d) Foreign shocks

Note: Welfare costs of business cycles for OHs (solid line, left axis) and ROTHs (dashed, right axis) as a function of univariate changes in inflation coefficient (top left), smoothing parameter (top right), output coefficient (bottom left) and exchange rate coefficient (bottom right). Other coefficients at their optimal values. Economy exclusively driven by RAS shocks (a), NAS (b), SOE (c) and foreign shocks (d), respectively.
Table 10: Calibrated parameters and targets

<table>
<thead>
<tr>
<th>Common para.</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h )</td>
<td>Hours devoted to work</td>
<td>0.3000</td>
</tr>
<tr>
<td>( \pi )</td>
<td>Mean inflation rate</td>
<td>1.0150</td>
</tr>
<tr>
<td>( R )</td>
<td>Mean risk-free rate</td>
<td>1.0250</td>
</tr>
<tr>
<td>( \tau_k )</td>
<td>Capital gain taxes</td>
<td>0.2000</td>
</tr>
<tr>
<td>( \tau_k )</td>
<td>Capital gain taxes on bonds</td>
<td>0.0000</td>
</tr>
<tr>
<td>( \tau_w )</td>
<td>Pay-roll tax</td>
<td>0.0500</td>
</tr>
<tr>
<td>( \tau_y )</td>
<td>Labour income taxes</td>
<td>0.0300</td>
</tr>
<tr>
<td>( \tau_c )</td>
<td>Value added tax</td>
<td>0.1400</td>
</tr>
<tr>
<td>( \delta )</td>
<td>Capital depreciation rate</td>
<td>0.0200</td>
</tr>
<tr>
<td>( \alpha_p )</td>
<td>Capital inc. share in prim. sector</td>
<td>0.3333</td>
</tr>
<tr>
<td>( \alpha_d )</td>
<td>Capital inc. share in sec. sector</td>
<td>0.3333</td>
</tr>
<tr>
<td>( \omega_p )</td>
<td>Mining sector share in GDP</td>
<td>0.1100</td>
</tr>
<tr>
<td>( \omega_c )</td>
<td>Imports share in consumption</td>
<td>0.3000</td>
</tr>
<tr>
<td>( \omega_i )</td>
<td>Imports share in investment</td>
<td>0.5000</td>
</tr>
<tr>
<td>( \frac{a}{y} )</td>
<td>Foreign Debt to GDP ratio</td>
<td>0.0000</td>
</tr>
<tr>
<td>( \frac{\chi}{y} )</td>
<td>Gov. consumption to GDP ratio</td>
<td>0.1950</td>
</tr>
<tr>
<td>( \phi_d )</td>
<td>Debt-elastic foreign interest rate</td>
<td>0.0010</td>
</tr>
<tr>
<td>( \kappa_d = \kappa_x = \kappa_m )</td>
<td>Price indexation</td>
<td>0.2000</td>
</tr>
<tr>
<td>( \epsilon_d )</td>
<td>Mark-up final good</td>
<td>11.0000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EHL para.</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \epsilon_w )</td>
<td>Mark-up labour market</td>
<td>11.0000</td>
</tr>
<tr>
<td>( \omega_h )</td>
<td>Mining sector share in empl.</td>
<td>0.0670</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GTT para.</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta_n )</td>
<td>Job separation rate</td>
<td>0.0700</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>Unempl. benefits ratio</td>
<td>0.4200</td>
</tr>
<tr>
<td>( \frac{U}{N} )</td>
<td>Unempl. Rate</td>
<td>0.1000</td>
</tr>
<tr>
<td>( \frac{N^p}{N^p + N^f} )</td>
<td>Mining sector share in empl.</td>
<td>0.0670</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foreign para.</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda )</td>
<td>Mark-up final good</td>
<td>11.0000</td>
</tr>
<tr>
<td>( \lambda_w )</td>
<td>Mark-up labour market</td>
<td>11.0000</td>
</tr>
<tr>
<td>( \alpha^* )</td>
<td>Capital income share</td>
<td>0.3000</td>
</tr>
<tr>
<td>( \beta^* )</td>
<td>Commodities income share</td>
<td>0.0500</td>
</tr>
<tr>
<td>( \rho_{rs} )</td>
<td>Foreign Monetary Policy</td>
<td>0.8500</td>
</tr>
<tr>
<td>( \tau^*_\pi )</td>
<td>CB inflation response</td>
<td>1.8500</td>
</tr>
<tr>
<td>( \tau^*_\Delta )</td>
<td>CB GDP growth response</td>
<td>0.2500</td>
</tr>
<tr>
<td>( \tau^*_y )</td>
<td>CB GDP gap response</td>
<td>0.0000</td>
</tr>
<tr>
<td>( \kappa^* )</td>
<td>Indexation final good</td>
<td>0.2000</td>
</tr>
</tbody>
</table>
Table 11: Estimated shocks standard deviations and persistences

<table>
<thead>
<tr>
<th>Std</th>
<th>Description</th>
<th>EHL Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>GTT Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>Pr Mean</th>
<th>Pr Std</th>
<th>Pr shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_b^*$</td>
<td>Wedge*</td>
<td>0.0222</td>
<td>0.0044</td>
<td>0.0017</td>
<td>0.0030</td>
<td>0.0021</td>
<td>0.0044</td>
<td>0.0017</td>
<td>0.0030</td>
<td>0.0020</td>
<td>0.0020</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Gov*</td>
<td>0.0047</td>
<td>0.0001</td>
<td>0.0026</td>
<td>0.0069</td>
<td>0.0041</td>
<td>0.0001</td>
<td>0.0021</td>
<td>0.0063</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Mon. Pol.*</td>
<td>0.0024</td>
<td>0.0001</td>
<td>0.0022</td>
<td>0.0027</td>
<td>0.0025</td>
<td>0.0001</td>
<td>0.0022</td>
<td>0.0027</td>
<td>0.0020</td>
<td>0.0020</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Prod.*</td>
<td>0.0035</td>
<td>0.0003</td>
<td>0.0031</td>
<td>0.0040</td>
<td>0.0034</td>
<td>0.0003</td>
<td>0.0031</td>
<td>0.0040</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Com. Sup.*</td>
<td>0.0113</td>
<td>0.0019</td>
<td>0.0092</td>
<td>0.0153</td>
<td>0.0120</td>
<td>0.0022</td>
<td>0.0097</td>
<td>0.0165</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\Sigma^*$</td>
<td>Inv.*</td>
<td>0.0364</td>
<td>0.0083</td>
<td>0.0251</td>
<td>0.0557</td>
<td>0.0357</td>
<td>0.0083</td>
<td>0.0251</td>
<td>0.0607</td>
<td>0.0100</td>
<td>0.0100</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Price*</td>
<td>0.0107</td>
<td>0.0007</td>
<td>0.0096</td>
<td>0.0119</td>
<td>0.0113</td>
<td>0.0008</td>
<td>0.0099</td>
<td>0.0124</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_w^*$</td>
<td>Wage*</td>
<td>0.0083</td>
<td>0.0004</td>
<td>0.0077</td>
<td>0.0090</td>
<td>0.0081</td>
<td>0.0004</td>
<td>0.0075</td>
<td>0.0089</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\hat{\phi}$</td>
<td>UIP</td>
<td>0.0088</td>
<td>0.0012</td>
<td>0.0072</td>
<td>0.0111</td>
<td>0.0095</td>
<td>0.0013</td>
<td>0.0077</td>
<td>0.0118</td>
<td>0.0020</td>
<td>0.0020</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_{\omega}$</td>
<td>Trade</td>
<td>0.0208</td>
<td>0.0026</td>
<td>0.0164</td>
<td>0.0251</td>
<td>0.0187</td>
<td>0.0031</td>
<td>0.0139</td>
<td>0.0238</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_b^*$</td>
<td>Wedge</td>
<td>0.0030</td>
<td>0.0009</td>
<td>0.0022</td>
<td>0.0051</td>
<td>0.0041</td>
<td>0.0013</td>
<td>0.0023</td>
<td>0.0068</td>
<td>0.0020</td>
<td>0.0020</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Gov</td>
<td>0.0056</td>
<td>0.0003</td>
<td>0.0051</td>
<td>0.0062</td>
<td>0.0056</td>
<td>0.0003</td>
<td>0.0051</td>
<td>0.0062</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Mon. Pol.</td>
<td>0.0021</td>
<td>0.0002</td>
<td>0.0019</td>
<td>0.0026</td>
<td>0.0021</td>
<td>0.0002</td>
<td>0.0018</td>
<td>0.0025</td>
<td>0.0020</td>
<td>0.0020</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_k^*$</td>
<td>Pro.</td>
<td>0.0080</td>
<td>0.0007</td>
<td>0.0070</td>
<td>0.0092</td>
<td>0.0132</td>
<td>0.0017</td>
<td>0.0103</td>
<td>0.0159</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\Sigma^*$</td>
<td>Inv.</td>
<td>0.1218</td>
<td>0.0137</td>
<td>0.1020</td>
<td>0.1470</td>
<td>0.1510</td>
<td>0.0144</td>
<td>0.1297</td>
<td>0.1767</td>
<td>0.0100</td>
<td>0.0100</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_w^*$</td>
<td>Price</td>
<td>0.0106</td>
<td>0.0009</td>
<td>0.0092</td>
<td>0.0122</td>
<td>0.0100</td>
<td>0.0008</td>
<td>0.0087</td>
<td>0.0113</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
<tr>
<td>$\varepsilon_w^*$</td>
<td>Wage</td>
<td>0.0125</td>
<td>0.0010</td>
<td>0.0108</td>
<td>0.0142</td>
<td>0.0113</td>
<td>0.0008</td>
<td>0.0099</td>
<td>0.0127</td>
<td>0.0050</td>
<td>0.0050</td>
<td>INV GAM.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AR(1)</th>
<th>Description</th>
<th>EHL Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>GTT Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>Pr Mean</th>
<th>Pr Std</th>
<th>Pr shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Wedge*</td>
<td>0.876</td>
<td>0.018</td>
<td>0.836</td>
<td>0.896</td>
<td>0.882</td>
<td>0.018</td>
<td>0.843</td>
<td>0.901</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Prod.*</td>
<td>0.970</td>
<td>0.011</td>
<td>0.949</td>
<td>0.984</td>
<td>0.980</td>
<td>0.013</td>
<td>0.952</td>
<td>0.993</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Com. Sup.*</td>
<td>0.939</td>
<td>0.011</td>
<td>0.918</td>
<td>0.953</td>
<td>0.934</td>
<td>0.011</td>
<td>0.913</td>
<td>0.948</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Inv.*</td>
<td>0.720</td>
<td>0.044</td>
<td>0.630</td>
<td>0.774</td>
<td>0.709</td>
<td>0.049</td>
<td>0.605</td>
<td>0.767</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>UIP</td>
<td>0.851</td>
<td>0.023</td>
<td>0.808</td>
<td>0.882</td>
<td>0.839</td>
<td>0.024</td>
<td>0.795</td>
<td>0.872</td>
<td>0.800</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Trade</td>
<td>0.808</td>
<td>0.069</td>
<td>0.682</td>
<td>0.905</td>
<td>0.836</td>
<td>0.066</td>
<td>0.713</td>
<td>0.927</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Wedge</td>
<td>0.916</td>
<td>0.030</td>
<td>0.846</td>
<td>0.941</td>
<td>0.902</td>
<td>0.028</td>
<td>0.840</td>
<td>0.932</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Pro.</td>
<td>0.917</td>
<td>0.027</td>
<td>0.865</td>
<td>0.954</td>
<td>0.877</td>
<td>0.026</td>
<td>0.834</td>
<td>0.919</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^*$</td>
<td>Com. Sup.</td>
<td>0.666</td>
<td>0.073</td>
<td>0.540</td>
<td>0.780</td>
<td>0.667</td>
<td>0.069</td>
<td>0.543</td>
<td>0.770</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MA(1)</th>
<th>Description</th>
<th>EHL Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>GTT Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>Pr Mean</th>
<th>Pr Std</th>
<th>Pr shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_{\omega}^{MA}$</td>
<td>Trade</td>
<td>0.885</td>
<td>0.080</td>
<td>0.723</td>
<td>0.968</td>
<td>0.857</td>
<td>0.100</td>
<td>0.660</td>
<td>0.963</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\rho_{\omega}^{MA}$</td>
<td>Com. Sup.</td>
<td>0.365</td>
<td>0.057</td>
<td>0.274</td>
<td>0.462</td>
<td>0.369</td>
<td>0.057</td>
<td>0.275</td>
<td>0.460</td>
<td>0.500</td>
<td>0.100</td>
<td>BETA</td>
</tr>
</tbody>
</table>
Table 12: Estimated parameters

<table>
<thead>
<tr>
<th>Domestic</th>
<th>Description</th>
<th>EHL Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>GTT Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>Pr Mean</th>
<th>Pr Std</th>
<th>Pr shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi_d$</td>
<td>Calvo final good</td>
<td>0.676</td>
<td>0.032</td>
<td>0.615</td>
<td>0.718</td>
<td>0.848</td>
<td>0.020</td>
<td>0.813</td>
<td>0.877</td>
<td>0.750</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\xi_m$</td>
<td>Calvo imports</td>
<td>0.790</td>
<td>0.020</td>
<td>0.752</td>
<td>0.817</td>
<td>0.796</td>
<td>0.020</td>
<td>0.759</td>
<td>0.824</td>
<td>0.750</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\xi_x$</td>
<td>Calvo exports</td>
<td>0.825</td>
<td>0.029</td>
<td>0.780</td>
<td>0.873</td>
<td>0.856</td>
<td>0.024</td>
<td>0.813</td>
<td>0.893</td>
<td>0.750</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\xi_w$</td>
<td>Calvo wages</td>
<td>0.606</td>
<td>0.031</td>
<td>0.553</td>
<td>0.655</td>
<td>0.873</td>
<td>0.016</td>
<td>0.852</td>
<td>0.905</td>
<td>0.750</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\kappa_w$</td>
<td>wage indexation</td>
<td>0.443</td>
<td>0.046</td>
<td>0.372</td>
<td>0.523</td>
<td>0.430</td>
<td>0.045</td>
<td>0.351</td>
<td>0.499</td>
<td>0.500</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$S''$</td>
<td>Invest. adj. cost</td>
<td>6.407</td>
<td>0.602</td>
<td>5.460</td>
<td>7.430</td>
<td>8.196</td>
<td>0.615</td>
<td>7.246</td>
<td>9.277</td>
<td>3.500</td>
<td>1.000</td>
<td>NORM</td>
</tr>
<tr>
<td>$\eta_f$</td>
<td>Exports price elast.</td>
<td>0.444</td>
<td>0.053</td>
<td>0.364</td>
<td>0.537</td>
<td>0.482</td>
<td>0.063</td>
<td>0.383</td>
<td>0.586</td>
<td>1.500</td>
<td>1.000</td>
<td>INV G.</td>
</tr>
<tr>
<td>$\eta_i = \eta_i$</td>
<td>Imports price elast.</td>
<td>0.497</td>
<td>0.057</td>
<td>0.401</td>
<td>0.585</td>
<td>0.547</td>
<td>0.070</td>
<td>0.422</td>
<td>0.649</td>
<td>1.500</td>
<td>1.000</td>
<td>INV G.</td>
</tr>
<tr>
<td>$\rho_f$</td>
<td>Int. rate smooth.</td>
<td>0.860</td>
<td>0.013</td>
<td>0.835</td>
<td>0.877</td>
<td>0.874</td>
<td>0.011</td>
<td>0.854</td>
<td>0.890</td>
<td>0.800</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\tau_g$</td>
<td>CB inflation resp.</td>
<td>1.690</td>
<td>0.082</td>
<td>1.560</td>
<td>1.829</td>
<td>1.620</td>
<td>0.086</td>
<td>1.482</td>
<td>1.765</td>
<td>1.600</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\tau_{hind}$</td>
<td>CB NEER resp.</td>
<td>0.116</td>
<td>0.020</td>
<td>0.083</td>
<td>0.148</td>
<td>0.126</td>
<td>0.020</td>
<td>0.093</td>
<td>0.160</td>
<td>0.125</td>
<td>0.025</td>
<td>NORM</td>
</tr>
<tr>
<td>$\tau_{by}$</td>
<td>CB GDP resp.</td>
<td>0.534</td>
<td>0.090</td>
<td>0.390</td>
<td>0.684</td>
<td>0.532</td>
<td>0.091</td>
<td>0.378</td>
<td>0.675</td>
<td>0.500</td>
<td>0.100</td>
<td>NORM</td>
</tr>
<tr>
<td>$\rho_g$</td>
<td>Gov. cons. smooth.</td>
<td>0.853</td>
<td>0.016</td>
<td>0.824</td>
<td>0.877</td>
<td>0.836</td>
<td>0.017</td>
<td>0.806</td>
<td>0.861</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\xi_e$</td>
<td>Labour hoarding</td>
<td>0.410</td>
<td>0.032</td>
<td>0.353</td>
<td>0.457</td>
<td>0.402</td>
<td>0.031</td>
<td>0.342</td>
<td>0.447</td>
<td>0.500</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\eta_b$</td>
<td>Labour mobility</td>
<td>0.650</td>
<td>0.207</td>
<td>0.323</td>
<td>1.005</td>
<td>0.768</td>
<td>0.143</td>
<td>0.546</td>
<td>1.012</td>
<td>1.000</td>
<td>1.000</td>
<td>GAM</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Vacancy costs elast.</td>
<td>0.393</td>
<td>0.066</td>
<td>0.280</td>
<td>0.500</td>
<td>0.393</td>
<td>0.066</td>
<td>0.280</td>
<td>0.500</td>
<td>0.500</td>
<td>0.100</td>
<td>BETA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utility</th>
<th>Description</th>
<th>EHL Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>GTT Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>Pr Mean</th>
<th>Pr Std</th>
<th>Pr shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b$</td>
<td>External habits</td>
<td>0.798</td>
<td>0.034</td>
<td>0.742</td>
<td>0.853</td>
<td>0.824</td>
<td>0.032</td>
<td>0.771</td>
<td>0.873</td>
<td>0.700</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\sigma_e$</td>
<td>Cons. subst. elast.</td>
<td>3.369</td>
<td>0.293</td>
<td>3.024</td>
<td>3.977</td>
<td>3.435</td>
<td>0.281</td>
<td>3.153</td>
<td>4.069</td>
<td>2.000</td>
<td>0.500</td>
<td>GAM</td>
</tr>
<tr>
<td>$\sigma_l$</td>
<td>Labour sup. elast.</td>
<td>1.601</td>
<td>0.418</td>
<td>1.010</td>
<td>2.344</td>
<td>1.779</td>
<td>0.392</td>
<td>1.231</td>
<td>2.485</td>
<td>2.000</td>
<td>0.500</td>
<td>GAM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foreign</th>
<th>Description</th>
<th>EHL Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>GTT Mode</th>
<th>Pst Std</th>
<th>Pst 5%</th>
<th>Pst 95%</th>
<th>Pr Mean</th>
<th>Pr Std</th>
<th>Pr shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma^*_{d}$</td>
<td>Commodity subst.</td>
<td>0.185</td>
<td>0.028</td>
<td>0.155</td>
<td>0.243</td>
<td>0.191</td>
<td>0.030</td>
<td>0.160</td>
<td>0.256</td>
<td>0.250</td>
<td>0.100</td>
<td>BETA</td>
</tr>
<tr>
<td>$\xi^*_{d}$</td>
<td>Calvo final good</td>
<td>0.749</td>
<td>0.025</td>
<td>0.704</td>
<td>0.786</td>
<td>0.738</td>
<td>0.026</td>
<td>0.697</td>
<td>0.781</td>
<td>0.750</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\xi^*_{w}$</td>
<td>Calvo wages</td>
<td>0.734</td>
<td>0.025</td>
<td>0.688</td>
<td>0.770</td>
<td>0.738</td>
<td>0.024</td>
<td>0.695</td>
<td>0.775</td>
<td>0.750</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$\kappa^*_w$</td>
<td>wage indexation</td>
<td>0.382</td>
<td>0.039</td>
<td>0.319</td>
<td>0.446</td>
<td>0.377</td>
<td>0.038</td>
<td>0.317</td>
<td>0.443</td>
<td>0.500</td>
<td>0.050</td>
<td>BETA</td>
</tr>
<tr>
<td>$S^*$</td>
<td>Invest. adj. cost</td>
<td>3.586</td>
<td>0.842</td>
<td>2.547</td>
<td>5.179</td>
<td>3.382</td>
<td>0.926</td>
<td>2.512</td>
<td>5.244</td>
<td>3.500</td>
<td>1.500</td>
<td>NORM</td>
</tr>
<tr>
<td>$\rho^*_g$</td>
<td>Gov. cons. Smooth.</td>
<td>0.861</td>
<td>0.048</td>
<td>0.777</td>
<td>0.938</td>
<td>0.889</td>
<td>0.047</td>
<td>0.807</td>
<td>0.957</td>
<td>0.800</td>
<td>0.100</td>
<td>BETA</td>
</tr>
</tbody>
</table>
### Table 13: Variance Decomposition

<table>
<thead>
<tr>
<th>EHL Variables</th>
<th>Symbols</th>
<th>AD*</th>
<th>RAS*</th>
<th>NAS*</th>
<th>AD</th>
<th>R-AS</th>
<th>N-AS</th>
<th>SOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>$Y_t$</td>
<td>3.16</td>
<td>13.54</td>
<td>2.08</td>
<td>24.11</td>
<td>41.62</td>
<td>7.29</td>
<td>8.19</td>
</tr>
<tr>
<td>Consumption</td>
<td>$C_t$</td>
<td>2.55</td>
<td>39.35</td>
<td>4.78</td>
<td>31.88</td>
<td>11.42</td>
<td>4.77</td>
<td>5.26</td>
</tr>
<tr>
<td>OHs cons.</td>
<td>$C_o^t$</td>
<td>0.99</td>
<td>22.95</td>
<td>2.46</td>
<td>40.10</td>
<td>20.37</td>
<td>4.47</td>
<td>8.65</td>
</tr>
<tr>
<td>ROTHs cons.</td>
<td>$C_r^t$</td>
<td>4.57</td>
<td>43.12</td>
<td>5.88</td>
<td>19.68</td>
<td>7.68</td>
<td>9.81</td>
<td>9.26</td>
</tr>
<tr>
<td>Hours</td>
<td>$H_t$</td>
<td>4.74</td>
<td>13.49</td>
<td>2.33</td>
<td>26.34</td>
<td>22.10</td>
<td>10.15</td>
<td>20.85</td>
</tr>
<tr>
<td>Labour income</td>
<td>$\bar{w}_t$</td>
<td>4.54</td>
<td>20.35</td>
<td>2.04</td>
<td>16.37</td>
<td>22.19</td>
<td>21.92</td>
<td>12.58</td>
</tr>
<tr>
<td>Wage inflation</td>
<td>$\pi^w_t$</td>
<td>1.18</td>
<td>4.04</td>
<td>0.88</td>
<td>16.92</td>
<td>1.90</td>
<td>72.03</td>
<td>3.06</td>
</tr>
<tr>
<td>CPI inflation</td>
<td>$\pi^c_t$</td>
<td>1.45</td>
<td>0.96</td>
<td>9.39</td>
<td>23.93</td>
<td>13.16</td>
<td>37.97</td>
<td>13.14</td>
</tr>
<tr>
<td>Domestic inflation</td>
<td>$\pi_t$</td>
<td>1.32</td>
<td>3.49</td>
<td>0.28</td>
<td>22.69</td>
<td>18.21</td>
<td>48.20</td>
<td>5.78</td>
</tr>
<tr>
<td>NEER (diff)</td>
<td>$dS_t$</td>
<td>6.07</td>
<td>5.01</td>
<td>1.08</td>
<td>5.73</td>
<td>0.89</td>
<td>0.32</td>
<td>80.90</td>
</tr>
<tr>
<td>Interest rate</td>
<td>$R_t$</td>
<td>2.53</td>
<td>1.44</td>
<td>1.71</td>
<td>57.41</td>
<td>8.64</td>
<td>6.20</td>
<td>22.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GTT Variables</th>
<th>Symbols</th>
<th>AD*</th>
<th>RAS*</th>
<th>NAS*</th>
<th>AD</th>
<th>R-AS</th>
<th>N-AS</th>
<th>SOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>$Y_t$</td>
<td>3.13</td>
<td>13.82</td>
<td>1.54</td>
<td>21.23</td>
<td>44.66</td>
<td>5.85</td>
<td>9.78</td>
</tr>
<tr>
<td>Consumption</td>
<td>$C_t$</td>
<td>1.88</td>
<td>33.84</td>
<td>3.53</td>
<td>39.89</td>
<td>11.23</td>
<td>5.27</td>
<td>4.37</td>
</tr>
<tr>
<td>OHs cons.</td>
<td>$C_o^t$</td>
<td>0.95</td>
<td>19.27</td>
<td>1.63</td>
<td>51.77</td>
<td>16.72</td>
<td>4.23</td>
<td>5.44</td>
</tr>
<tr>
<td>ROTHs cons.</td>
<td>$C_r^t$</td>
<td>2.88</td>
<td>40.94</td>
<td>5.36</td>
<td>11.27</td>
<td>2.23</td>
<td>32.26</td>
<td>5.07</td>
</tr>
<tr>
<td>Unemployment</td>
<td>$U_t$</td>
<td>4.31</td>
<td>19.78</td>
<td>1.65</td>
<td>41.55</td>
<td>22.73</td>
<td>5.32</td>
<td>5.24</td>
</tr>
<tr>
<td>Hours in prim. sect.</td>
<td>$H_t^p$</td>
<td>7.83</td>
<td>39.23</td>
<td>3.07</td>
<td>16.54</td>
<td>9.87</td>
<td>1.64</td>
<td>21.83</td>
</tr>
<tr>
<td>Hours in sec. sect.</td>
<td>$H_t^f$</td>
<td>0.52</td>
<td>0.47</td>
<td>0.16</td>
<td>6.95</td>
<td>60.52</td>
<td>18.85</td>
<td>12.53</td>
</tr>
<tr>
<td>Prim. sect. lab. inc.</td>
<td>$\bar{w}_t^p$</td>
<td>3.95</td>
<td>25.81</td>
<td>1.04</td>
<td>11.75</td>
<td>23.05</td>
<td>28.23</td>
<td>6.18</td>
</tr>
<tr>
<td>Sec. sect. lab. inc.</td>
<td>$\bar{w}_t^f$</td>
<td>0.32</td>
<td>1.02</td>
<td>0.41</td>
<td>3.34</td>
<td>13.62</td>
<td>78.11</td>
<td>3.19</td>
</tr>
<tr>
<td>Prim. sect. wage infl.</td>
<td>$\pi_t^{p,p}$</td>
<td>3.88</td>
<td>14.58</td>
<td>1.05</td>
<td>7.94</td>
<td>2.30</td>
<td>63.28</td>
<td>6.97</td>
</tr>
<tr>
<td>Final sect. wage infl.</td>
<td>$\pi_t^{w,f}$</td>
<td>0.96</td>
<td>2.21</td>
<td>0.87</td>
<td>14.93</td>
<td>4.49</td>
<td>74.08</td>
<td>2.45</td>
</tr>
<tr>
<td>CPI inflation</td>
<td>$\pi_t^c$</td>
<td>1.87</td>
<td>0.51</td>
<td>9.48</td>
<td>25.83</td>
<td>10.35</td>
<td>39.32</td>
<td>12.65</td>
</tr>
<tr>
<td>Final good infl.</td>
<td>$\pi_t$</td>
<td>1.46</td>
<td>3.26</td>
<td>0.16</td>
<td>25.81</td>
<td>14.54</td>
<td>51.32</td>
<td>3.43</td>
</tr>
<tr>
<td>NEER (diff)</td>
<td>$dS_t$</td>
<td>5.77</td>
<td>4.49</td>
<td>1.00</td>
<td>5.41</td>
<td>0.45</td>
<td>0.20</td>
<td>82.68</td>
</tr>
<tr>
<td>Interest rate</td>
<td>$R_t$</td>
<td>3.48</td>
<td>1.05</td>
<td>1.58</td>
<td>56.41</td>
<td>7.61</td>
<td>5.44</td>
<td>24.45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foreign Variables</th>
<th>Symbols</th>
<th>AD*</th>
<th>RAS*</th>
<th>NAS*</th>
<th>AD</th>
<th>R-AS</th>
<th>N-AS</th>
<th>SOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>US GDP</td>
<td>$Y_t^*$</td>
<td>27.06</td>
<td>54.27</td>
<td>18.67</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>US inflation</td>
<td>$\pi_t^*$</td>
<td>12.82</td>
<td>3.36</td>
<td>83.82</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>US interest rate</td>
<td>$R_t^*$</td>
<td>59.60</td>
<td>7.79</td>
<td>32.62</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Commodity price</td>
<td>$\gamma_t^{<em>,</em>}$</td>
<td>10.24</td>
<td>82.28</td>
<td>7.50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Variables in percentage deviation from steady-state. Stars stand for foreign shocks. See Table 1 for a description of the shocks classification. South African variable in the EHL version the first panel. GTT in the second and foreign variable in the third. Variance decomposition for the 5 years horizon.
Table 14: Standard deviation of simulated variables in alternative monetary policy rules

<table>
<thead>
<tr>
<th>EHL Variables</th>
<th>Baseline</th>
<th>Pure CPI targeting</th>
<th>Low int. rate smoothing</th>
<th>Muted resp. to output</th>
<th>Muted resp. to NEER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100sd</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
</tr>
<tr>
<td>GDP</td>
<td>2.41</td>
<td>4.99 1.21 7.05</td>
<td>-6.68 -9.28 -4.92</td>
<td>2.34 1.55 3.17</td>
<td>1.29 0.60 2.59</td>
</tr>
<tr>
<td>Consumptio</td>
<td>3.04</td>
<td>1.49 -4.67 6.01</td>
<td>-9.90 -13.34 -6.62</td>
<td>1.83 1.09 2.56</td>
<td>1.35 0.66 2.41</td>
</tr>
<tr>
<td>OHs cons.</td>
<td>3.13</td>
<td>5.59 -0.75 10.03</td>
<td>-5.27 -9.68 -2.18</td>
<td>1.93 1.15 2.63</td>
<td>1.04 0.47 2.01</td>
</tr>
<tr>
<td>ROTHs cons.</td>
<td>4.33</td>
<td>-3.29 -6.60 -0.58</td>
<td>-8.45 -11.10 -6.09</td>
<td>0.85 0.47 1.42</td>
<td>1.06 0.42 2.03</td>
</tr>
<tr>
<td>Hours</td>
<td>3.31</td>
<td>-8.75 -12.35 -5.71</td>
<td>-9.91 -14.37 -6.91</td>
<td>0.32 -0.51 1.34</td>
<td>1.21 0.42 2.16</td>
</tr>
<tr>
<td>Labour income</td>
<td>3.66</td>
<td>-1.41 -4.14 0.54</td>
<td>-8.89 -10.50 -7.19</td>
<td>0.90 0.37 1.52</td>
<td>1.59 0.83 2.67</td>
</tr>
<tr>
<td>Wage inflation</td>
<td>1.31</td>
<td>-6.45 -9.76 -4.20</td>
<td>2.91 0.72 4.92</td>
<td>0.25 -0.05 0.96</td>
<td>0.98 0.38 2.38</td>
</tr>
<tr>
<td>CPI inflation</td>
<td>0.85</td>
<td>-15.79 -21.13 -11.95</td>
<td>9.96 6.25 13.83</td>
<td>-1.07 -2.24 0.27</td>
<td>2.18 1.11 4.92</td>
</tr>
<tr>
<td>Domestic inflation</td>
<td>1.07</td>
<td>-9.93 -13.70 -6.94</td>
<td>5.34 1.91 8.46</td>
<td>-0.24 -1.10 0.93</td>
<td>1.15 0.38 3.07</td>
</tr>
<tr>
<td>NEER (diff)</td>
<td>5.19</td>
<td>-1.68 -3.81 0.62</td>
<td>-8.34 -11.24 -4.21</td>
<td>-0.45 -0.92 -0.09</td>
<td>3.77 2.60 5.00</td>
</tr>
<tr>
<td>Interest rate</td>
<td>0.71</td>
<td>9.99 1.86 18.39</td>
<td>80.97 60.07 102.71</td>
<td>2.87 1.36 4.47</td>
<td>-0.98 -5.53 4.11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GTT Variables</th>
<th>Baseline</th>
<th>Pure CPI targeting</th>
<th>Low int. rate smoothing</th>
<th>Muted resp. to output</th>
<th>Muted resp. to NEER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100sd</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
</tr>
<tr>
<td>GDP</td>
<td>2.43</td>
<td>5.20 1.16 8.47</td>
<td>-4.37 -7.48 1.94</td>
<td>1.42 0.84 2.23</td>
<td>1.27 0.43 3.43</td>
</tr>
<tr>
<td>Consumptio</td>
<td>3.03</td>
<td>2.37 -3.59 7.81</td>
<td>-7.70 -10.05 -5.12</td>
<td>1.25 0.75 1.96</td>
<td>1.06 0.52 2.09</td>
</tr>
<tr>
<td>OHs cons.</td>
<td>3.37</td>
<td>3.25 -4.74 11.95</td>
<td>-8.02 -10.42 -5.42</td>
<td>1.34 0.60 2.27</td>
<td>1.80 0.95 3.28</td>
</tr>
<tr>
<td>ROTHs cons.</td>
<td>3.36</td>
<td>-0.09 -2.26 1.04</td>
<td>-0.11 -5.98 7.85</td>
<td>0.69 0.20 1.24</td>
<td>-0.81 -1.30 -0.31</td>
</tr>
<tr>
<td>Unemployment</td>
<td>20.92</td>
<td>-17.28 -23.26 -10.89</td>
<td>17.97 5.46 35.13</td>
<td>2.95 1.62 4.77</td>
<td>3.82 1.76 6.55</td>
</tr>
<tr>
<td>Hours in prim. sect.</td>
<td>5.74</td>
<td>0.44 -0.57 1.04</td>
<td>0.56 -0.08 1.70</td>
<td>0.05 -0.06 0.17</td>
<td>0.06 -0.13 0.40</td>
</tr>
<tr>
<td>Hours in sec. sect.</td>
<td>2.44</td>
<td>-1.09 -2.84 0.70</td>
<td>-0.85 -3.37 6.04</td>
<td>-0.30 -0.59 0.02</td>
<td>-0.16 -0.59 0.69</td>
</tr>
<tr>
<td>Prim. sect. lab. inc.</td>
<td>4.69</td>
<td>0.27 -3.15 1.94</td>
<td>4.16 0.91 9.31</td>
<td>1.44 0.90 2.15</td>
<td>0.90 0.37 1.84</td>
</tr>
<tr>
<td>Sec. sect. lab. inc.</td>
<td>3.54</td>
<td>-1.10 -5.63 2.45</td>
<td>6.73 0.49 14.48</td>
<td>2.05 1.26 3.21</td>
<td>0.91 -0.04 1.73</td>
</tr>
<tr>
<td>Prim. sect. wage infl.</td>
<td>1.38</td>
<td>-3.67 -5.85 -2.30</td>
<td>2.43 1.15 4.46</td>
<td>0.45 0.22 0.86</td>
<td>0.56 0.15 1.36</td>
</tr>
<tr>
<td>Final sect. wage infl.</td>
<td>1.27</td>
<td>-4.84 -7.99 -3.01</td>
<td>2.29 0.38 4.21</td>
<td>0.35 0.04 0.94</td>
<td>0.73 0.31 1.67</td>
</tr>
<tr>
<td>CPI inflation</td>
<td>0.86</td>
<td>-15.09 -19.93 -11.83</td>
<td>10.90 6.77 16.36</td>
<td>-0.20 -0.97 0.79</td>
<td>1.85 0.78 4.09</td>
</tr>
<tr>
<td>Final good infl.</td>
<td>1.07</td>
<td>-9.93 -13.94 -7.02</td>
<td>5.52 2.32 9.52</td>
<td>0.07 -0.62 0.86</td>
<td>0.98 0.29 2.52</td>
</tr>
<tr>
<td>NEER (diff)</td>
<td>5.33</td>
<td>-2.22 -4.55 0.33</td>
<td>-9.18 -11.84 -5.45</td>
<td>-0.13 -0.48 0.09</td>
<td>3.61 2.62 4.51</td>
</tr>
<tr>
<td>Interest rate</td>
<td>0.65</td>
<td>17.13 8.54 25.76</td>
<td>104.47 84.36 126.11</td>
<td>3.64 1.44 6.56</td>
<td>-1.84 -6.61 2.74</td>
</tr>
</tbody>
</table>

Note: 100sd = 100 times the standard deviation of variables expressed in deviation from steady-state. Diff = percentage change in variables standard deviation with alternative policy rules compared to the baseline. Simulated variables over 92 periods.
Table 15: Theoretical standard deviation in alternative monetary policy rules

<table>
<thead>
<tr>
<th>EHL Variables</th>
<th>Baseline</th>
<th>Pure CPI targeting</th>
<th>Low int. rate smoothing</th>
<th>Muted resp. to output</th>
<th>Muted resp. to NEER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100sd</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
<td>Diff 5% 95%</td>
</tr>
<tr>
<td>GDP</td>
<td>Y_t</td>
<td>3.36 -2.20 3.26</td>
<td>-4.59 -6.29 -3.33</td>
<td>1.80 1.19 2.33</td>
<td>0.20 -0.22 1.05</td>
</tr>
<tr>
<td>Consumptio</td>
<td>C_t</td>
<td>6.91 -1.66 0.89</td>
<td>-2.12 -4.01 -1.23</td>
<td>0.75 1.14 1.14</td>
<td>-0.13 -0.29 0.21</td>
</tr>
<tr>
<td>OHs cons.</td>
<td>C^o_t</td>
<td>7.59 -0.42 1.87</td>
<td>-0.96 -2.38 -0.32</td>
<td>0.76 1.18 1.14</td>
<td>-0.14 -0.26 0.13</td>
</tr>
<tr>
<td>ROTHs cons.</td>
<td>C^r_t</td>
<td>7.11 -3.79 -1.12</td>
<td>-3.42 -5.38 -2.36</td>
<td>0.42 0.23 0.71</td>
<td>-0.03 -0.24 0.44</td>
</tr>
<tr>
<td>Hours</td>
<td>H_t</td>
<td>4.30 -8.84 -3.91</td>
<td>-7.15 -10.50 -5.00</td>
<td>0.29 -0.26 1.01</td>
<td>0.08 -0.31 0.68</td>
</tr>
<tr>
<td>Labour income</td>
<td>w_t</td>
<td>4.55 -6.05 -1.60</td>
<td>-7.26 -9.05 -5.63</td>
<td>0.83 1.36 1.36</td>
<td>0.11 -0.36 0.86</td>
</tr>
<tr>
<td>Wage inflation</td>
<td>pi^c_t</td>
<td>1.31 -11.60 -5.76</td>
<td>-1.97 -3.54 1.33</td>
<td>-0.26 -0.54 0.18</td>
<td>0.62 0.06 2.27</td>
</tr>
<tr>
<td>CPI inflation</td>
<td>pi^t_t</td>
<td>0.91 -11.40 -4.04</td>
<td>7.61 3.65 10.91</td>
<td>-1.72 -2.56 -0.75</td>
<td>1.71 0.69 4.42</td>
</tr>
<tr>
<td>Domestic inflation</td>
<td>pi_t</td>
<td>1.17 -15.64 -9.12</td>
<td>2.79 -0.42 5.55</td>
<td>-0.90 -1.52 -0.13</td>
<td>0.76 0.06 2.76</td>
</tr>
<tr>
<td>NEER (diff)</td>
<td>dS_t</td>
<td>5.35 -3.10 1.22</td>
<td>-7.56 -10.55 -5.19</td>
<td>-0.45 -0.91 -0.13</td>
<td>3.60 2.49 4.80</td>
</tr>
<tr>
<td>Interest rate</td>
<td>R_t</td>
<td>0.72 12.18 21.23</td>
<td>84.91 61.50 104.58</td>
<td>1.84 -0.55 4.45</td>
<td>-0.26 -4.82 4.93</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GTT Variables</th>
<th>100sd</th>
<th>Diff 5% 95%</th>
<th>Diff 5% 95%</th>
<th>Diff 5% 95%</th>
<th>Diff 5% 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>Y_t</td>
<td>3.33 -3.33 2.69</td>
<td>0.36 -1.70 3.61</td>
<td>-0.08 -0.55 0.40</td>
<td>0.44 -0.24 1.88</td>
</tr>
<tr>
<td>Consumptio</td>
<td>C_t</td>
<td>6.50 -1.64 1.23</td>
<td>-0.91 -2.59 -0.06</td>
<td>0.22 0.02 0.61</td>
<td>-0.04 -0.31 0.39</td>
</tr>
<tr>
<td>OHs cons.</td>
<td>C^o_t</td>
<td>7.36 -1.21 3.25</td>
<td>-0.18 -1.80 1.33</td>
<td>-0.01 -0.46 0.50</td>
<td>-0.02 -0.56 0.79</td>
</tr>
<tr>
<td>ROTHs cons.</td>
<td>C^r_t</td>
<td>6.38 -2.37 -0.76</td>
<td>-1.14 -3.01 0.58</td>
<td>0.73 0.44 1.26</td>
<td>-0.48 -0.73 -0.30</td>
</tr>
<tr>
<td>Unemployment</td>
<td>U_t</td>
<td>28.16 -17.48 -8.43</td>
<td>6.77 -0.44 17.04</td>
<td>1.02 0.23 1.91</td>
<td>0.15 -1.59 3.17</td>
</tr>
<tr>
<td>Hours in prim. sect.</td>
<td>H^p_t</td>
<td>6.28 -0.03 1.89</td>
<td>0.16 -0.24 0.91</td>
<td>-0.03 -0.16 0.08</td>
<td>0.14 -0.05 0.48</td>
</tr>
<tr>
<td>Hours in sec. sect.</td>
<td>H^f_t</td>
<td>3.48 0.23 3.40</td>
<td>0.71 -1.03 5.50</td>
<td>-0.87 -1.56 -0.50</td>
<td>-0.73 -1.56 -0.21</td>
</tr>
<tr>
<td>Prim. sect. lab. inc.</td>
<td>p^t_t</td>
<td>5.68 -2.33 0.74</td>
<td>0.36 -0.79 2.47</td>
<td>1.60 0.94 2.58</td>
<td>0.41 0.08 1.09</td>
</tr>
<tr>
<td>Sec. sect. lab. inc.</td>
<td>p^f_t</td>
<td>4.43 -4.61 -0.39</td>
<td>1.33 -2.16 6.30</td>
<td>2.03 1.25 3.31</td>
<td>-0.18 -0.76 0.29</td>
</tr>
<tr>
<td>Prim. sect. wage infl.</td>
<td>p^o_t</td>
<td>1.35 -7.32 -3.11</td>
<td>1.95 4.59</td>
<td>0.26 0.06 0.56</td>
<td>0.21 -0.17 1.27</td>
</tr>
<tr>
<td>Final sect. wage infl.</td>
<td>p^o_t</td>
<td>1.29 -9.33 -4.03</td>
<td>1.15 -0.74 3.52</td>
<td>-0.08 -0.33 0.24</td>
<td>0.51 0.07 1.46</td>
</tr>
<tr>
<td>CPI inflation</td>
<td>pi^t_t</td>
<td>0.91 -22.03 -13.96</td>
<td>7.59 12.54</td>
<td>-0.65 -1.27 -0.06</td>
<td>1.66 0.59 4.01</td>
</tr>
<tr>
<td>Final good infl.</td>
<td>pi_t</td>
<td>1.14 -15.81 -9.17</td>
<td>2.32 -1.09 6.25</td>
<td>-0.31 -0.86 0.22</td>
<td>0.90 0.10 2.50</td>
</tr>
<tr>
<td>NEER (diff)</td>
<td>dS_t</td>
<td>5.47 -4.04 0.89</td>
<td>-8.49 -11.26 -4.62</td>
<td>-0.14 -0.54 0.12</td>
<td>3.38 2.45 4.31</td>
</tr>
<tr>
<td>Interest rate</td>
<td>R_t</td>
<td>0.66 3.29 21.06</td>
<td>105.71 83.65 126.40</td>
<td>1.11 -1.58 4.20</td>
<td>-0.12 -6.65 3.43</td>
</tr>
</tbody>
</table>

Note: 100sd = 100 times the standard deviation of variables expressed in deviation from steady-state. Diff = percentage change in variables standard deviation with alternative policy rules compared to the baseline. Unconditional standard deviations.
B Complete set of equilibrium conditions

This appendix provides the reader with the details on how to derive the complete set of equilibrium conditions for households, firms and the labour market (for both EHL and GTT versions). In addition, for some equations, it shows how they are implemented in Dynare. Those equations have been expressed following the convention that lower case variables denote the stationarized equivalent of their upper case counterparts. In particular, some variables have a nominal trend because of the positive inflation rate target.

B.1 Households

The consumption demand functions for the domestic and the imported goods are given by maximizing the consumption basket under a fixed consumption spendings:

\[ C_d^t = (1 - \omega_c) \left[ \frac{P_t}{P_c^t} \right]^{-\eta_c} C_t, \]  

\[ C_m^t = \omega_c \left[ \frac{P_m^t}{P_c^t} \right]^{-\eta_c} C_t, \]  

where \( P_t \) is the domestic good price, \( P_m^t \) the imported good price and \( P_c^t \) represents the Consumer price index (CPI) and is given by:

\[ P_c^t = \left[ (1 - \omega_c)(P_t)^{1-\eta_c} + \omega_c(P_m^t)^{1-\eta_c} \right]^{1/(1-\eta_c)}. \]

which is made stationary as follows:

\[ (\pi_c^t)^{1-\eta_c} = (1 - \omega_c) \left( \frac{\pi_{t-1}}{\pi_{c}^{t-1}} \right)^{1-\eta_c} + \omega_c \left( \frac{\pi_{m}^{t-1}}{\pi_{c}^{t-1}} \right)^{1-\eta_c} \]  

(B.3)

where gross inflation rates are defined as: \( \pi_c^t = \frac{P_c^t}{P_{c}^{t-1}} \); \( \pi_t = \frac{P_t}{P_{t-1}} \) and \( \pi_m^t = \frac{P_m^t}{P_{c}^{t-1}} \). Note that some price ratios are explicitly defined in order to save on notations. In Dynare, it requires to define a variable for each price ratio.

B.1.1 Financially included and optimising Households

OHs maximise their utility with respect to domestic and foreign bonds holding and consumption. The first order conditions associated to OHs with shadow value \( \psi_t \) on their budget constraint (4.3) are given by:
\[ \text{w.r.t. } C_t^0 : \quad (C_t^0)^{-\sigma_c} (C_{t-1}^0)^{-b(1-\sigma_c)} = \psi_t \frac{P_t^c}{P_t} (1 + \tau) \quad (B.4) \]

\[ \text{w.r.t. } B_{t+1} : \quad \psi_t = \beta E_t \frac{\psi_{t+1}}{\pi_{t+1}} \epsilon_{b,t} R_t \quad (B.5) \]

\[ \text{w.r.t. } B^*_t : \quad \psi_t = \beta E_t \frac{\psi_{t+1} S_t^1}{\pi_{t+1} S_t} \epsilon_{b,t} R^*_t \Phi(A_t, \tilde{\phi}_t) \quad (B.6) \]

where these variables are stationarized following Altig et al. (2003) such that \( x_t = \frac{X_t}{P_t} \) for nominal variables while the Lagrange multiplier is redefined as \( \psi_t = \nu_t P_t \).

OHs also maximise their utility with respect to the capital stock and investment in each sector \( q \in (p, f) \) subject to their budget constraint (4.3) and capital accumulation rule (4.4):

\[ \text{w.r.t. } K^q_{t+1} : \quad \psi_t \frac{P_t^{k,q}}{P_t} = \beta \psi_{t+1} \left( (1 - \tau^k) r^k_{t+1} + (1 - \delta) \frac{P_t^{k,q}}{P_{t+1}} \right) \quad (B.7) \]

\[ \text{w.r.t. } I^q_t : \quad -\psi_t \frac{P_t^i}{P_t} + \psi_t \frac{P_t^{k,q}}{P_t} Y_t \left( 1 - \tilde{S} \left( \frac{I^q_t}{I^q_{t-1}} \right) - \tilde{S}' \left( \frac{I^q_t}{I^q_{t-1}} \right) \left( \frac{I^q_{t+1}}{I^q_t} \right) \right) \]

\[ + \beta E_t \left( \psi_{t+1} Y_{t+1} \tilde{S} \left( \frac{I^q_{t+1}}{I^q_t} \right) \left( \frac{I^q_{t+1}}{I^q_t} \right)^2 \right) = 0 \quad (B.8) \]

where \( r^k_t = \frac{P_t^k}{P_t} \) is the rental rate of capital corresponding to marginal productivity of capital and \( \frac{P_t^{k,q}}{P_t} \) is the real price of the capital good (introduced for convenience).

**Country risk premium** Combining the First Order Conditions (FOCs) with respect to domestic and foreign bonds gives the uncovered interest rate parity (UIP) condition:

\[ R_t = R^*_t \Phi(A_t, \tilde{\phi}_t) E_t \frac{S_{t+1}}{S_t} \]

This last equality shows that the spread between domestic and foreign nominal risk free rates depends on the anticipated domestic currency depreciation, the country-wide foreign debt and an UIP shock.

**Capital Accumulation** The capital accumulation rule reads:

\[ K^q_{t+1} = (1 - \delta) K^q_t + Y_t (1 - \tilde{S}(I_t/I_{t-1})) I_t \quad (B.9) \]
Investment Basket  The two investment demand functions are given by maximising the investment basket under a fixed investment spending:

\[ I_d^q = (1 - \omega_i) \left[ \frac{P_t}{P_i^d} \right]^{-\eta_i} I_t^q, \]  
(B.10)

\[ I_m^q = \omega_i \left[ \frac{P_m^m}{P_i^m} \right]^{-\eta_i} I_t^q, \]  
(B.11)

where \( P_i^d \) is the aggregate investment price given by:

\[ P_i^d = \left[ (1 - \omega_i)(P_t)^{1-\eta_i} + \omega_i(P_m^m)^{1-\eta_i} \right]^{1/(1-\eta_i)} \]

which is made stationary as follows:

\[ (\pi_i^t)^{1-\eta_i} = (1 - \omega_i) \left( \frac{\pi_{t-1}^t P_{t-1}^d}{P_t^d} \right)^{1-\eta_i} + \omega_i \left( \frac{\pi_{t-1}^t P_{t-1}^m}{P_t^d} \right)^{1-\eta_i} \]  
(B.12)

where \( \pi_i^t = \frac{P_i^d}{P_t^d} \).

B.1.2 Rule-of-thumb households

ROTHs aggregate stationary budget constraint is given by

\[ \int_0^1 (1 + \tau^c) P_t^c C_{t,d} dl = \int_0^1 \left( \frac{1 - \tau^v}{1 + \tau^w} \bar{W}_{t,d} N_{t,d} + (1 - N_{t,d}) \bar{\sigma} \right) dl, \]

In the EHL version of the model, using labour demand (4.21), the definition of aggregate consumption and \( \bar{W}_{t,d} N_{t,d} = W_{t,d} H_{t,d} \) imply that

\[ (1 + \tau^c) P_t^c C_t^R = \left( \frac{1 - \tau^v}{1 + \tau^w} \right) W_t^{\epsilon_w} H_t^R \int_0^1 (W_{t,d})^{1-\epsilon_w} dl, \]

and using the wage index (4.22) yields

\[ (1 + \tau^c) \frac{P_t^c}{P_t^d} C_t^r = \frac{1 - \tau^v}{1 + \tau^w} W_t^r H_t^R \]  
(B.13)

where \( w_t = \frac{W_t}{P_t} \).

In the GTT version of the model, ROTHs can be employed in the primary sector, employed in
the secondary sector or unemployed. Therefore,

\[ (1 + \tau^c) \frac{P^c_t}{P_t} C^{RP}_t = \frac{1 - \tau^y}{1 + \tau^w} w^p_t \]  
(B.14)

\[ (1 + \tau^c) \frac{P^c_t}{P_t} C^{RF}_t = \frac{1 - \tau^y}{1 + \tau^w} w^f_t \]  
(B.15)

\[ (1 + \tau^c) \frac{P^c_t}{P_t} C^{RP}_t = \phi_t \]  
(B.16)

and aggregate ROTHs consumption is

\[ C^R_t = \frac{1}{2} (N^p_t C^{RP}_t + N^f_t C^{RF}_t + U^t C^{RU}_t) \]  
(B.17)

### B.2 Firms

Here is the profit maximisation problem of the firms in the commodity and manufacturing sectors.

#### B.2.1 Commodity sector

**Domestic commodity producers** Commodity producers combine capital \( K^p_t \), labour \( L^p_t = N^p_t H^p_t \) and land (fixed to 1) to produce a commodity input. In the EHL version of the model \( L^p_t = H^p_t \). Cost minimisation gives the capital to hours ratio:

\[ \frac{K^p_t}{H^p_t} = \left( \frac{\alpha_p}{1 - \alpha_p - \beta_p} \right) \frac{w^p_t}{r^k_p} \]  
(B.18)

Since commodity producers operate in a perfectly competitive environment, the marginal (hourly) cost of labour must equalise its productivity:

\[ w^p_t = (1 - \alpha_p - \beta_p) \frac{Y^p_t S^p_t P^p t^p}{H^p_t P_t} \]  
(B.19)

In the GTT bargaining framework, hours are set optimally to maximise the global surplus such that the marginal utility of hours worked (the production value in term of consumption utility) must equalise its dis-utility (from labour efforts):

\[ (1 - \alpha_p - \beta_p) \frac{Y^p_t S^p_t P^p t^p U'(C^*)}{H^p_t P_t} \frac{P^p_t}{P_t} = U'(H^p_t) \]  
(B.20)
And the FOC for capital is simply:

$$i_t^{k,p} = \alpha_p \frac{Y_t^p S_t P_t^p}{K_t^p P_t}$$

(B.21)

**Foreign commodity market**  Foreign demand for commodities comes from their use as inputs in the foreign production process (while supply is exogenous and therefore do not require to compute any FOCs). For simplicity, let us define a labour-capital aggregate:

$$LK_t^* = LK_0^* \left( \frac{\varepsilon_{k,t} K_t^*}{K_t^*} \right)^{\alpha^*} \left( \frac{L_t^*}{L_0^*} \right)^{(1-\alpha^*)}$$

(B.22)

In particular, foreign firms combine a labour-capital aggregate to the commodity input in a CES function. The FOCs for this cost minimisation problem give:

$$P_{pt} = \beta^* \frac{\lambda_t^* P_t^* Y_0^*}{(1 - \beta^*)} \left[ \left( \frac{Y_t^{p*}}{Y_0^{p*}} \right)^{\frac{\sigma_{p-1}}{\sigma_p}} + (1 - \beta^*) \left( \frac{LK_t^*}{LK_0^*} \right)^{\frac{\sigma_{p-1}}{\sigma_p}} \right]^{1 - \frac{\sigma_{p-1}}{\sigma_p}} \left( \frac{Y_t^{p*}}{Y_0^{p*}} \right)^{1 - \frac{\sigma_{p-1}}{\sigma_p}}$$

$$\bar{MC}_t^* = (1 - \beta^*) \lambda_t^* P_t^* Y_0^* \left[ \beta^* \left( \frac{Y_t^{p*}}{Y_0^{p*}} \right)^{\frac{\sigma_{p-1}}{\sigma_p}} + (1 - \beta^*) \left( \frac{LK_t^*}{LK_0^*} \right)^{\frac{\sigma_{p-1}}{\sigma_p}} \right]^{1 - \frac{\sigma_{p-1}}{\sigma_p}} \left( \frac{LK_t^*}{LK_0^*} \right)^{1 - \frac{\sigma_{p-1}}{\sigma_p}}$$

where $P_t^{p*}$ is the commodity price in foreign currency, $\bar{MC}_t^*$ is the unit marginal cost of the labour-capital aggregate $LK_t^*$ and $\lambda_t^* P_t$ is the nominal unit production cost of the final good $Y_t^*$. These FOCs give the commodity ratio:

$$\frac{Y_t^{p*}}{LK_t^*} = \left( \frac{\bar{MC}_t^*}{P_t^{p*} \frac{1}{1 - \beta^*}} \right)^{\frac{\sigma_{p}}{\frac{1}{\sigma_{p}} - 1}} \left( \frac{LK_t^*}{Y_0^{p*}} \right)^{\frac{1}{\sigma_{p}} - 1}$$

(B.23)

where we can see that commodity demand depends on its price relative to the labour-capital input (where $\sigma_p$ is the elasticity of substitution of commodities) and to the intensity of labour and capital used in the foreign economy. It also gives the final good marginal cost:

$$\lambda_t^* = \frac{1}{P_t Y_0} \left[ (\beta^*)^{\frac{\sigma_p}{\sigma_{p}}} \left( P_t^{p*} Y_0^{p*} \right)^{1 - \frac{\sigma_{p}}{\sigma_{p}}} + (1 - \beta^*)^{\frac{\sigma_p}{\sigma_{p}}} \left( \bar{MC}_t^* LK_0^* \right)^{1 - \frac{\sigma_{p}}{\sigma_{p}}} \right]^{\frac{1}{1 - \frac{\sigma_{p}}{\sigma_{p}}}}$$

(B.24)
B.2.2 Secondary sector

Secondary good producers In the EHL framework, cost minimization problem for the intermediate firm \( i \) in period \( t \) is given by

\[
\min_{K^f_i,t,H^f_i,t} W^f_t H^f_{i,t} + R^k_{i,t} K^f_{i,t} + \lambda_t P_t Y^f_{i,t}
\]

where the Lagrange multiplier \( \lambda_t P_t \) represents the nominal cost of producing one additional unit of the domestic good and \( \lambda_t \) is the real marginal cost.

The FOCs, with respect to \( H^f_{i,t} \) and \( K^f_{i,t} \), for firm’s \( i \) cost minimization problem are given by:

\[
W^f_t = (1 - \alpha_f) \lambda_t P^f_0 \left( \frac{e_{k,t} K^f_t}{K^f_0} \right)^{\alpha_f} \left( \frac{H^f_t}{H^f_0} \right)^{(1 - \alpha_f)} \frac{1}{H^f_t}
\]

\[
R^k_{i,t} = \alpha_f \lambda_t P^f_0 \left( \frac{e_{k,t} K^f_t}{K^f_0} \right)^{\alpha_f} \left( \frac{H^f_t}{H^f_0} \right)^{(1 - \alpha_f)} \frac{1}{K^f_t}
\]

From those equations we can find the capital to labour ratio:

\[
\frac{K^f_t}{H^f_t} = \left( \frac{\alpha_f}{1 - \alpha_f} \right) \frac{w^f_t}{r^k_{i,t}} \quad \text{(B.25)}
\]

As well as the equilibrium real marginal cost of the domestic input \( mc_t \):

\[
mc_t \equiv \lambda_t = \frac{1}{Y^f_0} \left( \frac{H^f_0}{1 - \alpha_f} \right)^{1 - \alpha_f} \left( \frac{K^f_0}{\alpha_f} \right)^{\alpha_f} \left( \frac{r^k_{i,t}}{e_{k,t}} \right)^{\alpha_f} \left( \frac{w^f_t}{r^k_{i,t}} \right)^{1 - \alpha_f} \quad \text{(B.26)}
\]

In the GTT bargaining framework, hours are set optimally to maximise the global surplus such that the marginal utility of hours worked (the production value in term of consumption utility) must equalise its dis-utility (from labour efforts):

\[
(1 - \alpha_f) Y^f_t H^f_t mc_t \frac{U'(C'_t)}{P'_t / P_t} = U'(H^f_t) \quad \text{(B.27)}
\]

And the FOC for capital is simply:

\[
r^k_{i,t} = \alpha_f \frac{Y^f_t}{K^f_t} mc_t \quad \text{(B.28)}
\]
**Domestic Distributors** The optimization problem faced by the intermediate distributor \( i \) when setting its price at time \( t \) taking aggregator’s demand as given reads:

\[
\max_{p_t^{\text{new}}} E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s u_{t+s} (P_{t,t+s} - MC_{t,s}) Y_{t}^{d}
\]

where

\[
P_{t,t+s} = \left( \pi_t \ldots \pi_{t+s-1} \right) \frac{k_d(\pi)(1-k_d)^s p_t^{\text{new}}}{P_t}
\]

\[
Y_{t,s}^d = \left( \frac{\left( \pi_t \ldots \pi_{t+s-1} \right) k_d(\pi)(1-k_d)^s p_t^{\text{new}}}{P_t} \right)^{-\varepsilon_d} Y_{t+s}^d
\]

\[
Y_{t,s}^d = C_{t,s}^d + I_{t,s}^d
\]

These expressions can be used to rewrite the maximisation problem as:

\[
E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s \psi_{t+s} \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s p_t^{\text{new}}}{\Pi_{t+1,t+s}} - mc_{t+s} \right) \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s p_t^{\text{new}}}{\Pi_{t+1,t+s}} \right)^{-\varepsilon_d} Y_{t+s}^d
\]

where \( p_t^{\text{new}} = \frac{p_t^{\text{new}}}{P_t} \). Distributing for convenience gives:

\[
E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s \psi_{t+s} \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s p_t^{\text{new}}}{\Pi_{t+1,t+s}} \right)^{1-\varepsilon_d} \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s p_t^{\text{new}}}{\Pi_{t+1,t+s}} \right)^{-\varepsilon_d} Y_{t+s}^d
\]

The FOC with respect to \( p_t^{\text{new}} \) reads:

\[
(\varepsilon_d - 1) (p_t^{\text{new}})^{-\varepsilon_d} E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s \psi_{t+s} \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s p_t^{\text{new}}}{\Pi_{t+1,t+s}} \right)^{1-\varepsilon_d} Y_{t+s}^d
\]

\[
= \varepsilon_d (p_t^{\text{new}})^{-\varepsilon_d - 1} E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s \psi_{t+s} \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s}{\Pi_{t+1,t+s}} \right)^{-\varepsilon_d} Y_{t+s}^d
\]

and can be rewritten as:

\[
p_t^{\text{new}} = \frac{\varepsilon_d}{\varepsilon_d - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s \psi_{t+s} \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s}{\Pi_{t+1,t+s}} \right)^{-\varepsilon_d} m_{t+s} Y_{t+s}^d}{E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s \psi_{t+s} \left( \frac{\left( \pi_{t,t+s-1} \right) k_d(\pi)(1-k_d)^s}{\Pi_{t+1,t+s}} \right)^{1-\varepsilon_d} Y_{t+s}^d}
\]
which can also be rewritten as a set of three equations:

\[
p_t^{new} = \frac{\varepsilon_d}{\varepsilon_d - 1} X_{1,t}^D
\]

\[
X_{1,t}^D = \psi_t m_{c1}(C_{t}^d + I_{t}^d) + \beta \xi_d \left( \frac{\pi_t^{K^d} \bar{\pi}^{1-K^d}}{\pi_{t+1}} \right) E_t X_{1,t+1}^D
\]

\[
X_{2,t}^D = \psi_t (C_{t}^d + I_{t}^d) + \beta \xi_d \left( \frac{\pi_t^{K^d} \bar{\pi}^{1-K^d}}{\pi_{t+1}} \right) E_t X_{2,t+1}^D
\]

In addition, the domestic price index evolves according to:

\[
1 = \xi_d \left( \frac{\pi_t^{K^d} \bar{\pi}^{1-K^d}}{\pi_t} \right)^{1-\varepsilon_d} + (1 - \xi_d) (p_t^{new})^{1-\varepsilon_d}
\]

Finally, the price dispersion measure

\[
\psi_t^d = \int_0^1 \left( \frac{P_{t,i}}{P_t} \right)^{-\varepsilon_d} \, di
\]

can be written as:

\[
\psi_t^d = (1 - \xi_d) \left( \frac{p_t^{new}}{P_t} \right)^{-\varepsilon_d} + \int_{1-\xi_d}^1 \left( \frac{(\pi_{t-1})^{K_d} (\bar{\pi})^{1-K_d} P_{t,i-1}}{\pi_t} \right)^{-\varepsilon_d} \, di
\]

which simplifies to:

\[
\psi_t^d = (1 - \xi_d) (p_t^{new})^{-\varepsilon_d} + \int_{1-\xi_d}^1 \left( \frac{(\pi_{t-1})^{K_d} (\bar{\pi})^{1-K_d} P_{t,i-1}}{\pi_t} \right)^{-\varepsilon_d} \, di
\]

then to:

\[
\psi_t^d = (1 - \xi_d) (p_t^{new})^{-\varepsilon_d} + \xi_d \left( \frac{(\pi_{t-1})^{K_d} (\bar{\pi})^{1-K_d}}{\pi_t} \right)^{-\varepsilon_d} \psi_{t-1}^d
\]

which is a function of aggregate variables only.

**Importing and exporting distributors**  Optimisation in the importing and exporting distributors price setting problem is similar to the domestic good price setting problem presented above. The difference is that importing and exporting firms face the following marginal cost to sale price ratio: \( \frac{S_{mc_t}}{P_t^{new}} \) and \( \frac{MC_t}{P_t} \), respectively. The difference with Adolfson et al. (2007) is that the importing firm
consider $MC_t^*$ instead of $P_t^*$ for its nominal marginal cost, and that exporting firms consider $MC_t$ instead of $P_t$.

B.3 Labour market

This subsection describes the FOC for the labour market in the EHL and GTT frameworks.

B.3.1 Monopolistic competition and staggered wage contracts

Wage setting Each household has a probability $(1 - \xi_w)$ to be allowed to optimally reset the nominal wage. Otherwise, wage is indexed on previous period consumer price inflation $\pi_{t-1}^c$ and the Central Bank inflation target $\bar{\pi}$. Households that can re optimize their wage maximize

$$\sum_{s=0}^{\infty} (\beta \xi_w)^s \left( \nu_{t+s} \frac{1 - \tau^y}{1 + \tau^w} W_{j,t+s} h_{j,t+s} - A_h \frac{(h_{j,t+s})^{1+\sigma_h}}{1 + \sigma_h} \right)$$

where

$$W_{j,t+s} = W_{j,t}^{new} \left( \pi_{t}^c \ldots \pi_{t+s-1}^c \right)^{K_w} \frac{\bar{\pi}^{(1-K_w)s}}{\nu_{t+s}}$$

$$h_{j,t+s} = \left( \frac{W_{j,t+s}}{W_{t+s}} \right)^{-\epsilon_w} H_{t+s}$$

$$= \left( \frac{W_{j,t}^{new} \left( \pi_{t}^c \ldots \pi_{t+s-1}^c \right)^{K_w} \frac{\bar{\pi}^{(1-K_w)s}}{1 + \sigma_h}}{W_{t+s}} \right)^{-\epsilon_w} H_{t+s}$$

with respect to the new wage $W_{t}^{new}$. Note that $\nu_{t+s}$ is the Lagrange multiplier in the household optimisation problem and that it is also useful to define

$$\Pi_{t,t+s-1}^c = (\pi_{t}^c \ldots \pi_{t+s-1}^c)$$

$$\Pi_{t+1,t+s} = (\pi_{t+1} \ldots \pi_{t+s})$$
Rearranging using the above equations gives:

\[
\sum_{s=0}^{\infty} (\beta \xi_w)^s \left( \psi_{t+s} \frac{1 - \tau^\psi}{1 + \tau^\psi} \right) W_{t+s} \left( \Pi_{t+s}^t \right) \frac{\kappa_w}{\bar{\pi} (1 - \kappa_w)_s} \left( \frac{W_{t+s}^{new} \left( \Pi_{t+s}^t \right)^\kappa_w \bar{\pi} (1 - \kappa_w)_s}{W_{t+s}} \right)^{-\varepsilon_w} H^{o}_{t+s} - \frac{A_h}{1 + \sigma_h} \left( \frac{W_{t+s}^{new} \left( \Pi_{t+s}^t \right)^\kappa_w \bar{\pi} (1 - \kappa_w)_s}{W_{t+s}^{new} \Pi_{t+s}^t \Pi_{t+s}^{new}} \right)^{(1 + \sigma_h) \varepsilon_w} \left( H^{o}_{t+s} \right)^{1 + \sigma_h}
\]

Expressing it in term of real wage and simplifying gives:

\[
\sum_{s=0}^{\infty} (\beta \xi_w)^s \left( \psi_{t+s} \frac{1 - \tau^\psi}{1 + \tau^\psi} \right) W_{t+s} \left( \Pi_{t+s}^t \right) \frac{\kappa_w}{\bar{\pi} (1 - \kappa_w)_s} \left( \frac{W_{t+s}^{new} \left( \Pi_{t+s}^t \right)^\kappa_w \bar{\pi} (1 - \kappa_w)_s}{W_{t+s}^{new} \Pi_{t+s}^t \Pi_{t+s}^{new}} \right)^{(1 + \sigma_h) \varepsilon_w} \left( H^{o}_{t+s} \right)^{1 + \sigma_h}
\]

The FOC is now easy to derive and reads:

\[
(\varepsilon_w - 1) \left( W_{t,s}^{new} \right)^{-\varepsilon_w} \sum_{s=0}^{\infty} (\beta \xi_w)^s \psi_{t+s} \frac{1 - \tau^\psi}{1 + \tau^\psi} \left( \frac{\left( \Pi_{t+s}^t \right)^\kappa_w \bar{\pi} (1 - \kappa_w)_s}{\Pi_{t+s}^t \Pi_{t+s}^{new}} \right)^{(1 + \sigma_h) \varepsilon_w} \left( H^{o}_{t+s} \right)^{1 + \sigma_h}
\]

which simplifies to:

\[
\left( W_{t,s}^{new} \right)^{(1 + \sigma_h) \varepsilon_w} = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{\sum_{s=0}^{\infty} (\beta \xi_w)^s \psi_{t+s} \frac{1 - \tau^\psi}{1 + \tau^\psi} \left( \frac{\left( \Pi_{t+s}^t \right)^\kappa_w \bar{\pi} (1 - \kappa_w)_s}{\Pi_{t+s}^t \Pi_{t+s}^{new}} \right)^{(1 + \sigma_h) \varepsilon_w} \left( H^{o}_{t+s} \right)^{1 + \sigma_h}}{\sum_{s=0}^{\infty} (\beta \xi_w)^s \psi_{t+s} \frac{1 - \tau^\psi}{1 + \tau^\psi} \left( \frac{\left( \Pi_{t+s}^t \right)^\kappa_w \bar{\pi} (1 - \kappa_w)_s}{\Pi_{t+s}^t \Pi_{t+s}^{new}} \right)^{(1 + \sigma_h) \varepsilon_w} \left( H^{o}_{t+s} \right)^{1 + \sigma_h}}
\]

since all re-optimising households set the same wage. This last equation is the wage-Phillips curve.
with partial indexation. In Dynare, the infinite sum can be rewritten as a set of three equations:

\[
(w_{t}^{new})^{1+\sigma_{h}e_{w}} = \left(\frac{e_{w}}{e_{w} - 1}\right) \frac{X_{1,t}^{H}}{X_{2,t}^{H}} \tag{B.34}
\]

\[
X_{1,t}^{H} = A_{h}w_{t}^{(1+\sigma_{h})e_{w}}(H_{t}^{\rho})^{1+\sigma_{h}} + \beta \xi_{w} \left(\frac{(\pi_{t}^{c})^{k_{w}}}{\pi_{t+1}}\right)^{-1+\sigma_{h}e_{w}} E_{t}X_{1,t+1}^{H} \tag{B.35}
\]

\[
X_{2,t}^{H} = \frac{1-\tau_{y}}{1+\tau_{w}} w_{t}^{e_{w}}H_{t}^{\rho} + \beta \xi_{w} \left(\frac{(\pi_{t}^{c})^{k_{w}}}{\pi_{t+1}}\right)^{-1+\sigma_{h}e_{w}} E_{t}X_{2,t+1}^{H} \tag{B.36}
\]

**Labour packer**  The real wage index evolves according to

\[
w_{t}^{1-e_{w}} = (1-\xi_{w}) (w_{t}^{new})^{1-e_{w}} + \xi_{w} \left(\frac{(\pi_{t-1}^{c})^{k_{w}}}{\pi_{t}}\right)^{1-e_{w}} \tag{B.37}
\]

**Labour dispatcher**  The labour allocation problem gives primary and secondary sectors wages function of the relative demand for labour in each sectors:

\[
w_{t}^{f} = \left[\frac{H_{t}^{f}}{(1-\omega_{h})H_{t}}\right]^{1/\eta_{h}} w_{t}, \tag{B.38}
\]

\[
w_{t}^{p} = \left[\frac{H_{t}^{p}}{\omega_{h}H_{t}}\right]^{1/\eta_{h}} w_{t}, \tag{B.39}
\]

where \(w_{t}^{p} = \frac{w_{t}^{p}}{\bar{w}_{t}}\) and \(w_{t}^{f} = \frac{w_{t}^{f}}{\bar{w}_{t}}\)

**B.3.2 Search and matching with staggered wage bargaining**

This subsection presents the FOCs for the primary sector. The final good sector is similar.

**Households employment surplus**  In stationary form, the aggregate employees surplus reads:

\[
S_{t}^{w,p} = \bar{w}_{t}^{p} - \sigma - \left[\frac{U(H_{t}^{p})}{\psi_{t}} + \beta \frac{\psi_{t+1}}{\psi_{t}} \left(p_{t}^{p}S_{t+1}^{w,p} + p_{t}^{f}S_{t+1}^{w,f}\right)\right] + (1-\delta_{n})\beta \frac{\psi_{t+1}}{\psi_{t}}S_{t+1}^{w,p} \tag{B.40}
\]

Let us define the minimum wage level acceptable in the flexible wage environment as:

\[
\bar{w}_{t}^{min,p} = \sigma_{t} + \left[\frac{U(H_{t}^{p})}{\psi_{t}} + \beta \frac{\psi_{t+1}}{\psi_{t}} \left(p_{t}^{p}S_{t+1}^{w,p} + p_{t}^{f}S_{t+1}^{w,f}\right)\right] \tag{B.41}
\]

91
**Firms employment surplus** In stationary form, the aggregate employers surplus is:

\[
S_{f,p}^t = \frac{P_p}{P_t} (1 - \alpha_p - \beta_p) \frac{Y_t}{N_t^p} - \bar{w}_1^p + \frac{\chi \theta}{1 + \theta} \left( \frac{V_p}{N_t^p} \right)^{1+\theta} + (1 - \delta_n) \beta \frac{w_{t+1}}{\bar{w}_1^p} S_{f,p}^{t+1} \tag{B.42}
\]

Let us define the maximum wage level acceptable in the flexible wage environment as:

\[
\bar{w}_{max,p}^t = \frac{P_p}{P_t} (1 - \alpha_p - \beta_p) \frac{Y_t}{N_t^p} + \frac{\chi \theta}{1 + \theta} \left( \frac{V_p}{N_t^p} \right)^{1+\theta} \tag{B.43}
\]

**Wage bargaining** Bargaining is modelled following Thomas (2008). Unions and firms agree to share the surplus. They set the wage such that workers receive an expected share \(\omega\) of the total surplus \(S_{w,p}^t + S_{f,p}^t\) over the contract duration. At every period, there is a targeted wage \(\bar{w}_{t,ar,p}\) that would satisfy the surplus sharing rule:

\[
\bar{w}_{t,ar,p} = \omega w_{t,ar,p} + (1 - \omega) \bar{w}_{t,min,p} \tag{B.44}
\]

Since each contract has a probability \(\delta_n\) to stop at every period, and since each worker has a probability \(1 - \xi_w\) to renegotiate, the optimal wage has to satisfy

\[
E_0 \sum_{s=0}^{\infty} (\beta \xi_w)^s (1 - \delta_n)^s \frac{\Psi_{t+s}}{\psi_t} \left( \frac{w_{new}}{\bar{w}_{t,ar,p}} \left( \frac{\left( \pi_{t+s} \cdots \pi_{t+s-1} \right)^{\kappa_w} \pi_{t+s}}{\left( \pi_{t+1} \cdots \pi_{t+s} \right)} \right) - \bar{w}_{t+s} \right).
\]

This equation can be written as a set of three equations to avoid the infinite sum:

\[
\frac{W_{t,new,p}}{Z_{1,t}} = \frac{Z_{1,t}}{Z_{2,t}} \tag{B.45}
\]

\[
Z_{1,t} = \psi_t \bar{w}_{t,ar,p} + \beta \xi_w (1 - \delta_n) Z_{1,t+1} \tag{B.46}
\]

\[
Z_{2,t} = \psi_t + \beta \xi_w (1 - \delta_n) \left( \frac{\left( \pi_{t+1} \cdots \pi_{t+s} \right)^{\kappa_w} \pi_{t+s}}{\pi_{t+1}} \right) Z_{2,t+1} \tag{B.47}
\]

**Hours decision** Hours decisions are reported in the firms section.
Employment decision  Firms in the primary sector maximise their profits w.r.t. vacancies. The FOC is:

\[
\frac{\chi \left( \frac{V^p_{it}}{N^p_{it}} \right)^\theta}{q^p_{it}} = \beta \psi_{t+1} \psi_t \left[ \frac{P^p_{it+1}}{P_{t+1}} \left( 1 - \alpha_p - \beta_p \right) \frac{V^p_{it+1}}{N^p_{it+1}} - \bar{w}^p_{t+1} + \chi \theta \left( \frac{V^p_{jt}}{N^p_{jt}} \right)^{1+\theta} \right] + (1 - \delta_n) \frac{\chi \left( \frac{V^p_{jt+1}}{N^p_{jt+1}} \right)^\theta}{q^p_{jt+1}}
\]

B.4 Aggregate Welfare

OHs aggregate utility  In the EHL version of the model, recall that the aggregate utility level for OHs is given by

\[
U^S_t = \left( \frac{C^o_t}{(C^o_{t-1})^{\delta}} \right)^{1-\sigma_c} - \frac{A^o_h(H^o_{t-1})^{1+\sigma_h}}{1-\sigma_c} \nu^h_t
\]

where

\[
\nu^h_t = \int_0^1 \left( \frac{W_{j,t}}{W_t} \right)^{-\varepsilon_w(1+\sigma_l)} d j
\]

The latter term can be re-expressed as a function of aggregate variables only. By the Calvo assumption, it implies that

\[
\nu^h_t = (1 - \xi_w) \left( \frac{W^new_t}{W_t} \right)^{-\varepsilon_w(1+\sigma_l)} + \int_1^{1-\xi_w} \left( \frac{(\pi^c_{t-1})^{\kappa_w}(\bar{\pi})^{1-\kappa_u} W_{j,t-1}}{W_t} \right)^{-\varepsilon_w(1+\sigma_l)} d j
\]

Rewriting this expression gives:

\[
\nu^h_t = (1 - \xi_w) \left( \frac{W^new_t}{W_t} \right)^{-\varepsilon_w(1+\sigma_l)} + \int_1^{1-\xi_w} \left( \frac{W_{t-1}(\pi^c_{t-1})^{\kappa_w}(\bar{\pi})^{1-\kappa_u} W_{j,t-1}}{w_t \pi_t W_{t-1}} \right)^{-\varepsilon_w(1+\sigma_l)} d j
\]

which simplifies to:

\[
\nu^h_t = (1 - \xi_w) \left( \frac{W^new_t}{W_t} \right)^{-\varepsilon_w(1+\sigma_l)} + \left( \frac{w_{t-1}(\pi^c_{t-1})^{\kappa_w}(\bar{\pi})^{1-\kappa_u}}{w_t \pi_t} \right)^{-\varepsilon_w(1+\sigma_l)} \int_1^{1-\xi_w} \left( \frac{W_{j,t-1}}{W_{t-1}} \right)^{-\varepsilon_w(1+\sigma_l)} d j
\]
and then to:

\[ u^h_t = (1 - \xi_w) \left( \frac{w_{t+1}^{new}}{w_t} \right)^{-\epsilon_w(1+\sigma_t)} + \xi_w \left( \frac{w_{t+1}^c \pi_{t-1}^c \kappa_w (\bar{\pi})^{1-\kappa_w}}{w_t \pi_t} \right)^{1-\epsilon_w(1+\sigma_t)} u^h_{t-1} \]  \hspace{1cm} (B.49)

which is indeed a function of aggregate variables only and can be introduced in the model. In the GTT version of the model, no extra computations are needed.

**Rule of thumb’s aggregate utility**  In the EHL model, recall that their aggregate level of utility is given by

\[ U^R_t = \frac{\left( C_t^R / (C_{t-1}^R)^b \right)^{1-\sigma_c} u^c_t - 1}{1 - \sigma_c} - \frac{A_{h,r} (H_t^R)^{1+\sigma_h}}{1 + \sigma_h} u^h_t \]  \hspace{1cm} (B.50)

where

\[ u^c_t = \int_0^1 \left( \frac{w_{t+1}^c}{w_t} \right)^{(1-\epsilon_w)(1-\sigma_c)} \]  \hspace{1cm} (B.51)

This latter term can also be written as a function of aggregate variables only using a similar procedure as above:

\[ u^c_t = (1 - \xi_w) \left( \frac{w_{t+1}^c}{w_t} \right)^{(1-\epsilon_w)(1-\sigma_c)} + \xi_w \left( \frac{w_{t+1}^c \pi_{t-1}^c \kappa_w (\bar{\pi})^{1-\kappa_w}}{w_t \pi_t} \right)^{(1-\epsilon_w)(1-\sigma_c)} u^c_{t-1} \]  \hspace{1cm} (B.51)

In the GTT framework, recall that

\[ U^R_t = \frac{1}{2} \left( N_t^p \left( C_t^R / (C_{t-1}^R)^b \right)^{1-\sigma_c} u^c_{t+1} - 1 \right) + \frac{1}{2} \left( \left( C_t^R / (C_{t-1}^R)^b \right)^{1-\sigma_c} - 1 \right) \]  \hspace{1cm} (B.52)

where, using again the same procedure:

\[ u^c_{t+1} = (1 - \xi_w) \left( \frac{w_{t+1}^c p^c}{w_t^c} \right)^{(1-\epsilon_w)(1-\sigma_c)} + \xi_w \left( \frac{w_{t+1}^c p^c \pi_{t-1}^c \kappa_w (\bar{\pi})^{1-\kappa_w}}{w_t^c \pi_t^c} \right)^{(1-\epsilon_w)(1-\sigma_c)} u^c_{t-1} \]  \hspace{1cm} (B.53)

\[ u^c_{t+1} = (1 - \xi_w) \left( \frac{w_{t+1}^f p^f}{w_t^f} \right)^{(1-\epsilon_w)(1-\sigma_c)} + \xi_w \left( \frac{w_{t+1}^f p^f \pi_{t-1}^f \kappa_w (\bar{\pi})^{1-\kappa_w}}{w_t^f \pi_t^f} \right)^{(1-\epsilon_w)(1-\sigma_c)} u^c_{t-1} \]  \hspace{1cm} (B.54)
C  Steady state

Here are the details on the computation of steady-state for the domestic economy.

**Calibration and choice of units**  First some variables are calibrated to some values reflecting some freedom in the choice of units:

\[
\begin{align*}
Y^f &= Y^f_0 = 1 \\
P_0 &= P^*_0 = 1 \\
h^f &= h^o = 1/3
\end{align*}
\]

where \(Y^f_0\) and \(P_0\) are free choice of units and \(h_j = 1/3\) ensures that agents devote on average \(1/3\) of their time to labour activities and just imposes to calibrate \(A_h\) accordingly.

In the EHL version of the model, it implies that total hours worked by OHs and ROTHs is given by \(H^r = H^o = 1/3\); that \(H = H^r + H^o\) and that the time they spend working in each sectors is given by \(H^p = \omega_h H\) and \(H^f = (1 - \omega_h)H\).

In the GTT version, there is a fraction \(U = U^*\) of agents that are unemployed. Others work in the primary sector: \(N^p = \omega_h (2 - U)\) or in the secondary sector: \(N^f = (1 - \omega_h)(2 - U)\). At steady-state, \(H^p = H^f = 1/3\) and \(L^p = N^p H^p\) and \(L^f = N^f H^f\).

The primary commodity sector’s share in GDP is calibrated to \(\omega_p\) to match its empirical counterpart. it implies that

\[
\begin{align*}
Y &= \frac{Y^f}{1 - \omega_p} \\
Y^p &= Y^p_0 = \omega_p Y
\end{align*}
\]

Assuming that inflation and and the risk-free rates are the same in the domestic and foreign economies:

\[
\begin{align*}
\pi &= \pi^* \\
R &= R^*
\end{align*}
\]

where \(\pi\) and \(R\) are calibrated to match the empirical mean of domestic variables. It implies that \(dS = 1\) (through the UIP condition). Therefore, all inflations rates are equal to \(\pi\). By carefully calibrating mark-ups\(^{43}\) for each distributors, all relative prices \(\gamma\) equalise to one at steady-state.

\(^{43}\)by assuming that mark-ups in the import and foreign distribution sectors are identical; and that mark-ups in the
**Households**  Turning to patient households FOCs, the assumptions presented above imply that:

\[ \beta = \frac{\pi}{R} \]

and pin down the real price of capital and its rental rate to

\[ p^k = \frac{p^k}{P} = \frac{p^i}{P} = 1 \]

\[ r^k = \frac{p^k (1 - (1 - \delta)\beta)}{(1 - \tau^k)\beta} \]

where the real price of capital and its rental rate are the same in both sectors at steady-state.

**Final good sector**  Turning to final good distributors, the marginal costs are given by:

\[ mc = mc^x = \frac{\varepsilon_d - 1}{\varepsilon_d} \]

\[ mc^m = mc^* = \frac{\varepsilon_* - 1}{\varepsilon_*} \]

In addition, the use of a normalised production function in the final good sector allows to write

\[ MC_t Y_t^f = R_t^{k,f} K_t^f + W_t^f N_t^f \]

where the capital income share at steady-state is given (in their stationary form) by

\[ r^{k,f} K^f = \alpha mc Y^f \]

which implies that

\[ K^f = \frac{\alpha Y^f mc}{r^k} \]

It also implies that the value of investment is:

\[ I^f = \delta K^f \]

export and domestic distribution sectors are identical
Primary good sector  Using once again a Normalised production function implies that

\[ S_t P_t^p Y_t^p = R_t^k K_t^p + \bar{W}_t N_t^p + \text{landshare}, \]

where \( R_t^L \) is the rental rate of the land input. It implies that

\[ r^k K^p = \alpha_p Y^p \]

which implies

\[ K^p = \frac{\alpha_p Y^p}{r^k} \]

Therefore,

\[ I^p = \delta K^p \]

Aggregate resource constraints  Total, imported and domestic investments are given by

\[ I = I^f + I^p \]
\[ I^m = \omega_i I \]
\[ I^d = (1 - \omega_i) I \]

The aggregate resource constraint evaluated at steady state reads

\[ Y^f - G = C^d + I^d + X^f \]

Plugging steady state domestic consumption values from households yields

\[ Y^f - G = (1 - \omega_c) C + I^d + X^f \]

The net foreign assets accumulation rule gives

\[ C^m + I^m = Y^p + X^f + \left( \frac{R}{\pi} - 1 \right) A \]

Plugging steady state value of imported consumption we have,

\[ \omega_c C + I^m = Y^p + X^f + \left( \frac{R}{\pi} - 1 \right) A \]
Assuming the net foreign asset position$^{44}$ is calibrated, there are two equations with only $x^f$ and $c$ unknown. Solving yields

\[
\begin{align*}
C &= Y^f - (I^m + I^d + G) + Y^p + \left(\frac{R}{\pi} - 1\right)A \\
X^f &= Y^f - G - C^d - I^d
\end{align*}
\]

It implies that $C^m = \omega_c C$ and $C^d = (1 - \omega_c)C$.

**Wages in EHL version**  Using once again a Normalised production function and remembering that $W^f H^f = W^f H^f$ imply that

\[
w^f H^f = (1 - \alpha)mcY^f
\]

which implies that

\[
w^f = \frac{(1 - \alpha)Y^f mc}{H^f}
\]

Since wages are equal in both sectors at steady-state, $w = w^p = w^f$. In addition, using once again a Normalised production function and remembering that $W^p H^p = W^p H^p$ imply that

\[
w^p H^p = (1 - \alpha_p - \beta_p)Y^p
\]

which, since $H^p$ is calibrated and $w^p = w^f$, imposes to set

\[
\beta_p = 1 - \alpha_p - \frac{w^p H^p}{Y^p}
\]

where $\frac{w^p H^p}{Y^p}$ is the labour income share in the primary sector.

**Beveridge curve in GTT version**  The law of motion of employment implies that

\[
\begin{align*}
\delta_n N^p &= q^p V^p \\
\delta_n N^p &= p^p U
\end{align*}
\]

$^{44}$Any net foreign asset position can be made consistent with steady state by setting the parameter $\bar{A} = A$ in $\Phi(\cdot)$. 


Since employment in each sectors $N^p, N^f$, the unemployment rate $U$ and the vacancy rate $V^p / N^p$ are set to attain steady-state targets

\[ q^p = \frac{\delta_n N^p}{V^p} \]
\[ p^p = \frac{\delta_n N^p}{U} \]

**Wages in GTT version** In the GTT version, it is a bit more complicated to pin down wages (note that the value for capital is the same than in the EHL version since the marginal productivity of capital is equal to its rental rate). The maximum wage value are given by

\[
\bar{w}^{\text{max}, f} = mc(1 - \alpha_f) \frac{Y_f}{N_f} + \chi \theta \left( \frac{V_f}{N_f} \right)^{1+\theta}
\]
\[
\bar{w}^{\text{max}, p} = (1 - \alpha_p - \beta_p) \frac{Y_p}{N_p} + \chi \theta \left( \frac{V_p}{N_p} \right)^{1+\theta}
\]

where $\beta_p = 1 - \alpha_p - \frac{mc(1 - \alpha_f)Y_f}{Y_p} L_p / L_f$ such that $\bar{w}^{\text{max}, f} = \bar{w}^{\text{max}, p}$. It is then possible to use the firm employment decision to get:

\[ \bar{w}^f = \bar{w}^{\text{max}, f} - \left( \frac{1}{\beta} - (1 - \delta_n) \right) \frac{\chi}{\delta_n} \left( \frac{V_p}{N_p} \right)^{1+\theta} \]

and therefore $\bar{w}^{\text{tar}, f} = \text{new}, \bar{w}^f = \bar{w}^f$.

**Disaggregated consumption** The consumption of rule of thumbs households is given by $C^r = \frac{1 - \tau_0}{(1 + \tau_0)(1 + \tau_1)} wH^r$ in the EHL model and $C^r = \frac{1 - \tau_0}{2(1 + \tau_0)(1 + \tau_1)} \left( \bar{w}^p N^p + \bar{w}^f N^f + U \sigma \right)$ in the GTT model. The consumption level of OHs is then simply given by $C^o = C - C^r$.

**Back to wages in GTT version** With $C^o$, it is possible to compute $\nu$ and then the minimum wage value (as a function of $\sigma$) and the employment surplus with:

\[
\bar{w}^{\text{min}, f} = \sigma + \left[ \frac{U(H^f)}{\nu} + \beta \left( p^p S^{w,p} + p^f S^{w,f} \right) \right]
\]
\[
S^{w,p} = \frac{\bar{w}^f - \bar{w}^{\text{min}, f}}{1 - (1 - \delta_n) \beta}
\]

where $S^{w,p} = S^{w,f}$. It implies that the employees surplus share is $\omega_w = \frac{\bar{w}^{\text{max}, f} - \bar{w}^f}{\bar{w}^{\text{max}, f} - \bar{w}^{\text{min}, f}}$ and can be adjusted by calibrating $\sigma$ or $\chi$. 

99
D Welfare cost measures

Conditional compensation measures are defined as the fraction of consumption that an agent $j$ would be ready to give up in the economy $l$ in order to be equally well off in that economy than in an alternative economy $v$, when both economies state variables are initially identical. This appendix shows how to compute conditional compensation for a domestic rule of thumbs household in the EHL environment. The method to derive this measure for OHs, ROTHs and foreign households in the EHL and GTT frameworks is similar.

In order to clarify notations, let $W\left((1-\lambda)C_{R,j}^{l}, h_{R,j}^{l}\right)$ denote welfare of a rule-of-thumb household $j$ in economy $l$ where this household renounces to a fraction $\lambda$ of its consumption flow $C_{R,j}^{l}$ at every period. Similarly, let $W\left(C_{R,v}^{j}, h_{R,v}^{j}\right)$ be its welfare in economy $v$.

The maximum fraction $\lambda_{R}^{j}$ of consumption that household $j$ would be ready to give up in economy $l$ in order to be as well off as under economy $v$ should satisfy

$$E_{0}W\left((1-\lambda_{R}^{j})C_{R,j}^{l}, h_{R,j}^{l}\right) = E_{0}W\left(C_{R,v}^{j}, h_{R,v}^{j}\right)$$

(D.1)

In order to make this household indifferent between the two environments. In this expression, the conditional expectation operator $E_{0}$ conditions on the initial state of the economy (assumed to be its steady-state) and integrates over the probability density of aggregate disturbances (business cycle shocks presented in Table 1) and idiosyncratic shocks (Calvo price and wage stickiness affecting each households differently). It is therefore convenient to rewrite this expression as

$$E_{0}\int_{0}^{1} W\left((1-\lambda_{R}^{j})C_{R,j}^{l}, h_{R,j}^{l}\right) d\lambda = E_{0}\int_{0}^{1} W\left(C_{R,v}^{j}, h_{R,v}^{j}\right) d\lambda$$

(D.2)

where the conditional expectation operator $E_{0}$ still conditions on the initial state of the economy but now only integrates over the probability density of aggregate disturbances while the integral explicitly integrates over households idiosyncratic shocks.

Expanding on the left-hand side of the above equation yields

$$E_{0}\int_{0}^{1} \sum_{t=0}^{\infty} \beta^{t} \left\{ \frac{(1-\lambda_{R}^{j})C_{R,j}^{l} / \left(C_{t-1}^{l}\right)^{b}}{1-\sigma_{c}} - \frac{A_{h}(h_{R,j}^{l})^{1+\sigma_{h}}}{1+\sigma_{h}} \right\} d\lambda = E_{0}\int_{0}^{1} W\left(C_{R,v}^{j}, h_{R,v}^{j}\right) d\lambda$$

(D.3)
Solving for the integrals in the left and right-hand sides gives

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1 - \lambda_u^R}{\sigma_c} \left[ \frac{C_{t-1}^R}{C_t^R} \right]^{1-\sigma_c} v_t^c - 1 - \frac{A_h(h_t^{R,l})^{1+\sigma_h}}{1+\sigma_h} v_t^w \right\} = E_0 W(C_t^R, h_t^{R,l})
\]

This expression can be solve for \( \lambda_u^R \). Indeed, rearranging the terms gives

\[
\lambda_u^R = 1 - \left( \frac{E_0 W(C_t^R, h_t^{R,l}) - E_0 W(h_t^{R,l}) + \frac{1}{(1-\beta)(1-\sigma_c)}}{E_0 W(C_t^R) + \frac{1}{(1-\beta)(1-\sigma_c)}} \right)^{1-\sigma_c}
\]

which can be used in order to measure welfare costs. This expression for \( \lambda_u^R \) can be evaluated provided that we can evaluate the functions \( E_0 W(.) \). These functions are given by

\[
E_0 W(C_t^{R,v}, h_t^{R,v}) = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{R,v}/(C_{t-1}^{R,v})^{1-\sigma_c}}{1-\sigma_c} v_t^c - 1 - \frac{A_h(h_t^{R,v})^{1+\sigma_h}}{1+\sigma_h} v_t^w \right\}
\]

\[
E_0 W(h_t^{R,l}) = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ -\frac{A_h(h_t^{R,l})^{1+\sigma_h}}{1+\sigma_h} v_t^w \right\}
\]

\[
E_0 W(C_t^{R,l}) = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{R,l}/(C_{t-1}^{R,l})^{1-\sigma_c}}{1-\sigma_c} v_t^c - 1 \right\}
\]

and can be evaluated by simulations. It requires to condition the initial state of the economy to be its steady-state, to generate shocks from their probability density and to simulate the model.

In Dynare, the trick is simply to rewrite these sums as

\[
W_{t=0}(.) = U_{t=0}(.) + \beta E_{t=0} W_{t=1}(.)
\]

where \( E_{t=0} \) is the expectation operator conditional on information available at time \( t = 0 \); and to simulate the model in order to recover the values of \( W_{t=0}(.) \). By averaging over enough simulations (and therefore averaging over different realisations of the shocks) the law of large number ensures convergence to \( E_0 W_{t=0}(.) \).