Essays in International Macroeconomics

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I confirm that chapter 1 was jointly co-authored with Mr Kirill Shakhnov and I contributed 50% of the work.

I confirm that chapter 3 was jointly co-authored with Mr Piotr Denderski and I contributed 50% of the work.

Wojciech Paczos

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Acknowledgments

Contents

Abstract

This thesis studies how frictions shape macroeconomic outcomes and affect policies. The thesis consists of three chapters.

The first chapter studies how distortionary taxation and volatile output together with government discretion shape sovereign debt issuance and sovereign defaults. It is a novel theory to explain why sovereigns borrow on both domestic and international markets and why defaults are mostly selective (on either domestic or foreign investors). The model matches business cycle moments and frequencies of different types of defaults in emerging economies. It is also shown, that secondary markets are not a sufficient condition to avoid sovereign defaults. The outcome of the trade in bonds on secondary markets depends on how well each group of investors can coordinate their actions

The second chapter studies how the price stickiness friction affects the optimal rate of inflation and gains from a monetary integration. Inflation constitutes a tax on consumption so the local monetary authority finds it optimal to inflate. But also the average markup constitutes a cost of holding money so the monetary authority finds it optimal to deflate. The findings are: i) in the local currencies the first motive dominates and the optimal inflation is positive. ii) In a monetary union the first motive is absent and the optimal inflation is negative. iii) A monetary union improves global welfare. However, when the difference in price stickiness between two countries is large, only one country benefits.

The third chapter studies how the intermediation friction affects a transmission of monetary policy. It provides new evidence on the bank lending channel using bank-level data from Central and Eastern Europe economies. The findings are: i) banks adjust their loans to changes in host country's monetary policy, ii) foreign-owned banks are less responsive to monetary policy of a host country than domestic-owned banks, iii) contrary to previous studies, the effects i) and ii) are present not only in the times of a crisis, but also in normal times. Second part of this chapter presents two mechanisms that can explain the second effect. First, foreign banks may have access to funds from parent banks. Second, foreign banks may serve more profitable borrowers. The first mechanism renders monetary policy less effective in the level of foreign banks penetration, while the second one does not. However, data do not unambiguously favor one explanation over the other.

Chapter 1

Sovereign Debt Issuance and Selective Default

Joint with Kirill Shakhnov (EIEF Rome, formerly EUI Florence)

Abstract

We propose a novel theory to explain why sovereigns borrow on both domestic and international markets and why defaults are mostly selective (on either domestic or foreign investors). Domestic debt issuance can only smooth tax distortion shocks, whereas foreign debt can also smooth productivity shocks. If the correlation of these shocks is sufficiently low, the sovereign borrows on both markets to avoid excess consumption volatility. Defaults on both types of investors arise in equilibrium due to market incompleteness and the government's limited commitment. The model matches business cycle moments and frequencies of different types of defaults in emerging economies and we show our hypothesis is confirmed by the data. We also find, that secondary markets are not a sufficient condition to avoid sovereign defaults. The outcome of the trade in bonds on secondary markets depends on how well each group of investors can coordinate their actions.[1]

Keywords: sovereign debt, selective default, debt composition, secondary markets
JEL Classification: E43, F34, G15, H63

1.1   Introduction

Humanity has witnessed sovereign debt crises for hundreds of years. The first recorded instance of sovereign default dates back to 377 B.C. in ancient Greece. Sovereign default has been studied extensively in the literature. However, the focus has mainly been on default on external debt, while the study of domestic defaults has been neglected. Reinhart and Rogoff (2011b) have documented and categorized all default events in the last 210 years. Based on their observations, there have been at least 58 *de jure* defaults on domestic public debt. This is certainly an underestimate, due to the difficulty of detecting *pure* domestic defaults.[2] Also, out of 267 defaults in this period, only 17 times did the government default simultaneously on both domestic and foreign debt.

In this paper, we address the open question of why governments usually default *selectively* on either foreign or domestic debt. We do so by providing a novel theory of domestic debt and default, where domestic debt is issued to smooth tax distortions, and combining it with the well established literature on foreign debt and default. We present a two-period model to deliver the economic intuition, and a calibrated quantitative model to replicate data moments. We show that our theory is empirically plausible, as it is able to match frequencies of different types of default and debt compositions. To the best of our knowledge, this is the first contribution that is able to replicate two stylized facts: that defaults happen mostly in a selective fashion, and that the composition of bondholders matters for interest rates and the volume of total public debt. The two-period version of the model is the starting point for an additional discussion of the role of secondary markets in solving sovereign default problems. Our analysis questions the efficiency role associated with secondary markets.

We build an incomplete markets model in which the government has limited commitment. The government has to cover its expenditures and has three means of financing them: it issues one-period defaultable bonds on an international and a domestic market, and it collects taxes. Tax collection is costly because taxes are distortionary. The economy is subject to two shocks: an output shock and a tax distortion shock. While the output shock provides incentives for the government to borrow on international markets, the tax distortion shock creates a wedge between domestic borrowing and taxation. This breaks Ricardian equivalence in our endowment economy, and draws a distinction between tax-financed and debt-financed expenditure policies. In this we provide a simple theory of domestic debt issuance.

Foreign debt can be used to smooth out both shocks, which makes it a more valuable instrument. However, if the correlation of the two processes is sufficiently low, then using only one instrument to smooth two shocks would result in households' consumption being too volatile. Therefore, the government engages in borrowing on both markets. When the government has outstanding debts

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[2]For example, the large-scale 1989 *pure* domestic default is relatively unknown outside Argentina. The most well know domestic default happened in Russia 1998, which was one of the largest local currency debt defaults (US $39 billion). This number does not include *de facto* default through inflation, the nationalization of pensions and other forms.

on both markets it faces two trade-offs: one between foreign repayment and default, and another between domestic repayment and default.

The mechanism of foreign default is similar to that in Eaton and Gersovitz (1981) and Arellano (2008). A benevolent government accumulates defaultable foreign debt in order to smooth residents' consumption over the business cycle. Interest rates reflect default probabilities, which are endogenous to the borrower's incentives to default. The government decides each period whether to transfer resources away from the economy as a repayment of debt to foreign investors or to keep resources at home and suffer default penalties. When output is low, *ceteris paribus*, it is more costly for a risk averse borrower to respect the contract. Default occurs along the equilibrium path after a long enough sequence of negative output shocks. These contributions gave rise to a large literature, which has nonetheless not yet considered domestic debt and default in an open economy setting.

While the mechanisms and trade-offs behind foreign default are clear, the domestic default literature is still at an early stage. There are two recent contributions that adhere to the benevolent government assumption and study domestic default in a Ramsey setting. D'Erasmo and Mendoza (2013) propose a heterogeneous agent model in which a utilitarian government relies on lump-sum taxes and defaultable bonds to finance stochastic governments expenditures. Default has a redistributive aspect, because it hurts mostly the rich, while repayment by taxation hurts mostly the poor. Pouzo and Presno (2014), on the other hand, consider a model in which the government relies on distortionary labor income taxes and defaultable bonds to finance its stochastic expenditures. The government might default to mitigate these distortions. The second crucial trade-off in our model, the one behind domestic debt and default, is similar to their mechanism. Both contributions, however, are closed-economy models that do not consider borrowing on international markets.

Both repayment and default on domestic debt are transfers of resources within the economy. In a case of default on domestic debt, the government suffers default penalties similar to the penalties imposed after foreign default. When the government decides to repay, it needs to finance this repayment by collecting taxes. When distortions from taxation are high, the government prefers to issue debt rather than collect taxes, hoping that in the future tax collection will be less distortionary, giving it the ability to repay the debt at a lower cost. The government thus issues domestic debt up to an endogenous debt limit, and if the possibility of repayment through non-distortionary taxes does not arrive it has no other choice than to default.

Vasishtha (2010) and Erce (2012) study the selective nature of sovereign default with foreign and domestic investors. The former generates domestic debt issuance through disutility of taxation, but in equilibrium foreign default never happens. In the latter, both domestic and foreign debt levels are exogenously predetermined. Our analysis shows that incorporating two shocks, to output and to taxation, is crucial to generating equilibria with both types of selective default, and that the feedback loop from selective default to debt issuance should not be neglected. In our paper, both

domestic and foreign debt issuance and selective default are optimal decisions of the government. In addition, Cooper et al. (2008) study how the distribution of debt among domestic and foreign investors influences the government's incentives to default. They find conditions (government expenditure and the fraction of debt held by foreign investors being high enough) under which the government has incentives to default, but the underlying composition of debt is given exogenously. In this paper, we derive endogenous fractions of public debt held by domestic and foreign investors.

The main contributions of this paper are the new theory of selective sovereign defaults and a quantitative framework to study sovereign debt issuance and debt composition. But our analysis also has also some other, quite novel implications. After the Great Recession, secondary sovereign debt markets attracted increasing interest among economists. Based on the two-period version of our model, we analyze the role of secondary markets in solving the problem of sovereign risk. Broner et al. (2010) show that, even in the absence of default penalties, sovereign risk does not prevent governments from borrowing on international markets if foreign creditors can resell their assets to domestic investors on secondary markets under the assumption that tax collection is costless. Instead, we assume that taxation is costly, and show that the result of the trade depends on how well each group of investors can coordinate their actions. In particular, without any coordination, trade on secondary markets generates a possible welfare loss, as it incentivizes the government to default on all its debt, instead of only foreign debt. We also prove that whenever secondary markets fail to reduce the default problem, debt haircuts can play a useful role, and *vice versa*.

The remainder of the paper is organized as follows. In the next section we summarize empirical facts on domestic and foreign public debt holdings and selective defaults. Section 3 studies equilibrium in a two-period model and shows intuitively the main trade-offs. Section 4 presents an infinite-horizon version of the model and the results of a calibration exercise. Section 5 analyzes the role of secondary markets and haircuts. The last section concludes.

1.2   Facts

The goal of this section is to establish three stylized facts that motivate our analysis. First, that sovereign defaults happen mostly in a selective fashion; second, that governments have a number of tools to discriminate among different types of bondholders; and third, that the composition of bondholders matters. In this section we review some empirical studies of selective sovereign defaults and the composition of bondholders, and augment them with our findings.

Before we begin our discussion, we set the scene with some definitions. There are three different ways to draw the distinction between domestic and foreign debt. According to the *legal* definition, domestic debt is any debt issued according to domestic law, regardless of its currency, and regardless of who holds it. According to the *economic* definition, domestic debt is held by residents, regardless of the currency and the law under which it was issued. Finally, according to the *currency* definition, domestic debt is the debt denominated in home currency, regardless of law and the residency of

bond holders. The second definition creates clear differential incentives for the sovereign to default. For this reason, throughout the model, we adopt the *economic* definition.

An important point to raise is that these three definitions do not necessarily overlap. However, Reinhart and Rogoff (2011a) claim that: *"The overwhelming majority of external public debt, debt under the legal jurisdiction of foreign governments, has been denominated in foreign currency and held by foreign residents"*. This was certainly true before the wave of capital flow liberalizations starting in the 1980s. After this, the mapping between the *legal* and the *economic* definitions is less ideal.[3] Still, we observe selective sovereign defaults both before and after the wave of capital flow liberalizations.

For our stylized facts and in our calibration we rely on three sources of data. Merler and Pisani-Ferry (2012) provide the breakdown of the public debt by the residence of holders for ten industrialized economies between 1990 and 2012. For the developing economies we rely on the dataset compiled by Panizza (2008), which covers the data of up to 130 countries between 1990 and 2007. Data for developing economies is however obtained using the *legal* definition. Our third source is the dataset on crises and defaults provided by Reinhart and Rogoff (2011b), which covers up to 70 countries between 1800 and 2010. The *legal* definition of debt is also used for the default data. In what follows we present three empirical facts that motivate and guide our theoretical analysis.

1. Sovereign defaults usually happen in a selective fashion. The database collected by Reinhart and Rogoff (2011b) reveals interesting features of sovereign default episodes between 1800 and 2010. First, domestic debt, usually neglected in the theoretical literature on sovereign risk, plays an important role in the build-up, during and after sovereign defaults on foreign holdings. This argument is extensively developed in Reinhart and Rogoff (2011a). Second, sovereign defaults happen on both domestic and foreign debt holdings, usually in a selective fashion. Whereas foreign defaults are common, domestic defaults are hardly rare. Out of 267 episodes of sovereign debt crisis identified across 70 countries in the last 210 years, 205 were *pure foreign*, 26 were *pure domestic*, and 36 featured government default on *both domestic and foreign* debt. Only 17 times did the default on home and foreign debt happen within the same year. In Figure 1.1 we plot the fraction of sovereign borrowers that were in foreign, domestic or total default in a given year between 1800 and 2010. These findings suggest that the assumption that sovereigns can default selectively fits reality better than the two alternative assumptions commonly used in the literature: that domestic debt is always senior and so only foreign debt is defaulted on, or that defaults can only be non-discriminatory.

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[3]A notable example here is the Mexican crisis of 1994. Short-term securities called *tesobonos* were dollar-denominated (foreign debt according to the *currency* definition), issued according to Mexican law (domestic debt according to the *legal* definition) and held by investors both in the US and Mexico (partly domestic and partly foreign debt according to the *economic* definition). Also, at that time, there were no means of tracing the final creditor either by nationality or by residence. Therefore, a default on *tesobonos* obligations could not have been classified either as domestic or as foreign selective default. Luckily, Mexico did not default in 1994.

Figure 1.1: Fraction of countries in different types of default
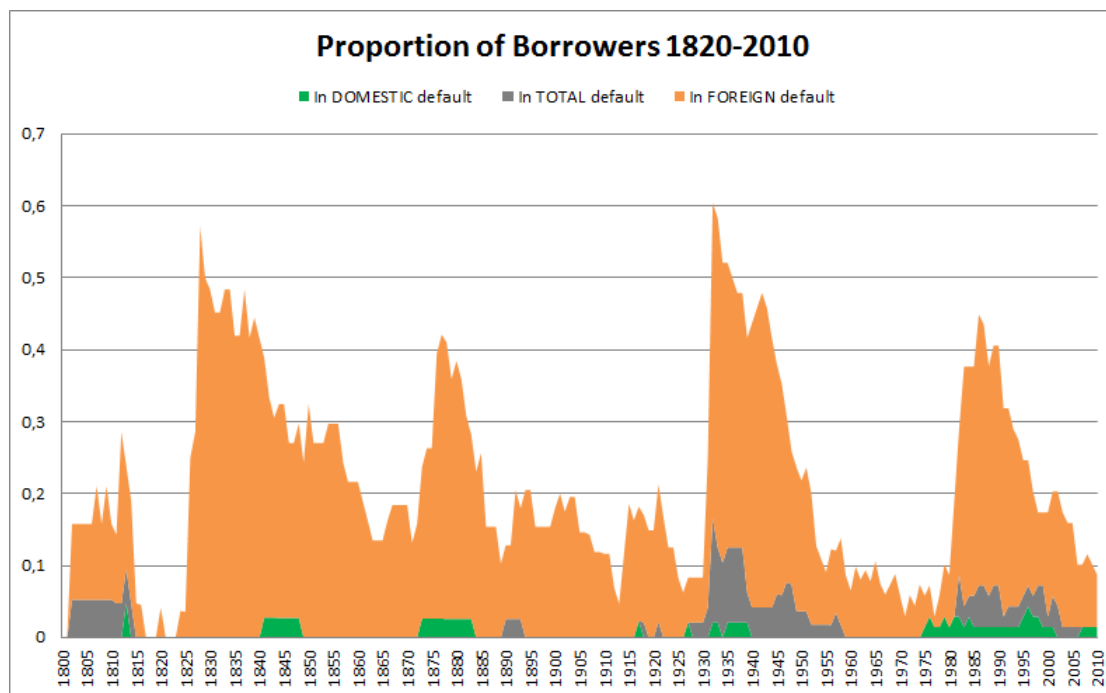
Source: Own calculations based on Reinhart and Rogoff (2011b)

2. Governments have a number of tools to discriminate among types of bondholders. How can the government default on foreign investors while repaying domestic investors or *vice versa*? The assumption that the two types of bondholders are indistinguishable, and therefore sovereigns can only default on total debt outstanding, underestimates the creativity of governments.

Among the tools that governments use to discriminate against particular types of bondholders, the most popular are capital controls, exchange controls and freezes on deposits. In 1990 Brazil defaulted on its domestic debt but kept servicing its foreign debt. All foreign exchange transactions were directed through the central bank and a multiple exchange rate regime was introduced as well as a freeze on local currency deposits.

In 1998 Russia defaulted on both foreign and local currency debt, imposing capital and exchange rate controls. However, in subsequent years Russia "undefaulted" on its foreign obligations and kept servicing debts to foreign investors. Moreover, bonds held by domestic companies were also repaid, so Russia effectively defaulted only on domestic households' holdings of public debt. Default was accompanied by both foreign and local currency deposit freezes.

Argentina's 2001 default is often considered as a model case of foreign default.[4] In fact, this

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[4]Many sovereign default models are calibrated to mimic salient features of this default (e.g. Arellano (2008)).

episode is cataloged as a total default. First, all resident-held bonds, both domestic and foreign currency denominated, were converted to government-guaranteed loans, which were all later converted to pesos at a much lower rate than the market exchange rate. Also, 60% of the debt defaulted on in December 2001 was held by Argentines.

Recent examples of what could be considered pure foreign default (in peaceful times) include: Bolivia in 1989 (most domestic debt was repurchased a year before default), Pakistan in 1999 (which stopped payments on outstanding obligations to creditors in the UK, Europe and the US and put a freeze on foreign currency deposits mostly owned by non-residents) and most probably Cyprus in 2013 (freeze and partial expropriation of deposits exceeding €100,000, which were mostly owned by non-residents).

3. The composition of bondholders matters. Empirical work on the composition of bondholders is growing. We draw on this literature, particularly on Andritzky (2012) and Dell'Erba et al. (2013), to show that the composition of investors is correlated with interest rates and the total level of debt to GDP. Dell'Erba et al. (2013) find that there is a significant correlation between spreads and debt levels when the majority of the debt is denominated in foreign currency (in both emerging economies and Eurozone countries). They also document that financial crises have more profound effects on economies that rely more on foreign borrowing. Andritzky (2012) finds a strong positive correlation between the fraction of domestic debt in total debt and the total debt-to-GDP ratio, and a negative correlation between the fraction of foreign debt and spreads in advanced economies. The present paper contributes to this literature by providing a framework to study the driving forces behind debt composition and its consequences for spreads, total debt and default incentives.

1.3   Two Period Model

We begin by introducing the model in a simplified and tractable two-period version. We study an endowment economy that consists of three types of actors: domestic households, foreign investors and a benevolent government. The government can raise resources in three different ways: by issuing bonds to domestic households, by issuing bonds to foreign investors and by collecting taxes. Taxes are lump sum, but collecting taxes comes at a cost to the economy. We assume raising an amount T of taxes by the government induces a loss of $T(1 + \tau)$ resources to agents. This is a key element that will break Ricardian equivalence in this endowment economy and create a trade-off between taxes and domestic debt.

Domestic households are identical and risk averse. The representative household decides on her

bond holdings to maximize lifetime utility subject to two intra-period budget constraints:

$$\max_{b^h} \left(u\left(c_1 \right) + \beta \mathbb{E} \left[u \left(c_2 \right) \right] \right) \tag{1.3.1}$$

subject to:

$$y_1 = c_1 + T_1(1 + \tau_1) + q_h b_h, \tag{1.3.2}$$

$$y_2 + (1 - d_h)b_h = c_2 + T_2(1 + \tau_2), \tag{1.3.3}$$

where y is the exogenous output, c is consumption, T is taxes, τ is the distortion imposed by taxes, b_h is domestic bond holdings, q^h is the discount price of domestic bonds and d_h is the government's decision to repay $(d_h = 0)$ or default on $(d_h = 1)$ domestic debt.

Foreign investors are risk neutral and have deep pockets. They borrow on international markets at risk-free rate r and lend funds to the government at discount q_f to break even in expectation:

$$q_f = \frac{\mathbb{E}\left[1 - d_f\right]}{1 + r} \tag{1.3.4}$$

The government has to cover expenditures only in the first period $g_1 > 0$. Government expenditures in the second period are $g_2 = 0$. This creates an incentive to borrow due to the consumption smoothing motive. In the first period, the government decides on debt issuances in the domestic and foreign markets b_h and b_f. In the second period, the government takes repayment decisions d_h and d_f. The government maximizes the lifetime utility of domestic households subject to two intra-period government budget constraints:

$$g_1 = q_h b_h + q_f b_f + T_1, \tag{1.3.5}$$

$$(1 - d_h)b_h + (1 - d_f)q_f = T_2. \tag{1.3.6}$$

If the government decides to default, the economy will suffer proportional output penalties. After domestic default, output in the second period is reduced to

$$y_{hd} = y_2(1 - \delta_h), \tag{1.3.7}$$

and after foreign default, output in the second period is reduced to

$$y_{fd} = y_2(1 - \delta_f). \tag{1.3.8}$$

If the government decides to default on both markets, the economy will suffer from both output penalties.

Finally, in the second period the economy is subject to two shocks: an output shock and a tax

distortion shock. Both processes are stochastic Markovian and assume two outcomes:

$$
y_2 = \begin{cases} y_H & \text{with prob. } \Pi_y \\ y_L & \text{with prob. } 1 - \Pi_y, \end{cases} \tag{1.3.9}
$$

$$
\tau_2 = \begin{cases} \tau_L & \text{with prob. } \Pi_\tau \\ \tau_H & \text{with prob. } 1 - \Pi_\tau, \end{cases} \tag{1.3.10}
$$

where subscript H stands for high and L for low.

If the debts are repaid with taxes, the government imposes distortions on the economy. If they are repaid with new debt, the government might go into default. The main driving forces of the government's optimal policies are two trade-offs. The first is the trade-off between a transfer of resources away from the economy as foreign debt repayment versus a loss of resources due to foreign default penalties. The second is between imposing distortions on the economy from tax collection versus imposing a loss of resources from domestic default penalties. Unlike in cases where Ricardian equivalence holds, the timing of taxes matters here.

1.3.1   Default schedule

We solve the model by backward induction starting in the second period. Given debt issuance decisions from the first period b_h and b_f, in the second period the government takes default decision that maximize domestic households' utility from consumption. As it is the terminal period there is no demand for government bonds in the second period, so the only source of income for the government is taxation. In the second period, four scenarios may arise: repayment, foreign default, domestic default and total default. Substituting the government's repayment decisions $(d_h \in \{0,1\}, d_f \in \{0,1\})$ and default penalties (1.3.7), (1.3.8) into households' second-period budget constraint (1.3.3) and the government's second-period budget constraint (1.3.6), household consumption levels in each of the four scenarios are given by the following equations: (Notice that, in order to repay an amount b_h of domestic bonds to households, the government needs to raise $b_h(1 + \tau)$ taxes, which yields a net loss of τb_h resources to the economy.)

$$
\begin{align}
c^r &= y_2 - b_f(1 + \tau_2) - b_h \tau_2, \tag{1.3.11} \\
c^{fd} &= y_2(1 - \delta_f) - b_h \tau_2, \tag{1.3.12} \\
c^{hd} &= y_2(1 - \delta_h) - b_f(1 + \tau_2), \tag{1.3.13} \\
c^{td} &= y_2(1 - \delta_h)(1 - \delta_f), \tag{1.3.14}
\end{align}
$$

where consumption superscripts stand for *repayment, foreign default, home default* and *total default* respectively.

A. Foreign default schedule

When deciding whether to default on foreign investors, the government compares household consumption under repayment and under foreign default. It is immediate to see that foreign debt will be repaid whenever:

$$\frac{b_f}{y_2} \leq \frac{\delta_f}{1 + \tau_2}, \tag{1.3.15}$$

where the left-hand side is the foreign debt-to-GDP ratio and the right-hand side is a number defined by parameters of the model. Whenever the inequality has the opposite sign, the government defaults on foreign debt.

Proposition 1. *If taxation is costly then the government's optimal policy on the international market is characterized by the foreign default threshold (1.3.15). Whenever the debt is below this threshold, it is riskless and is always repaid. Whenever it is above the threshold, it will always be defaulted on and therefore can never be issued. If either output or tax distortions are stochastic, the default threshold is also stochastic, debt can be risky and default can arise in equilibrium.*

Proof. The first part follows directly from comparing (1.3.11) and (1.3.12). For the second part, suppose that future output y_2 and tax distortions τ_2 are known in period one. Any debt b_f exceeding $\frac{y_2 \delta_f}{1+\tau_2}$ will be defaulted on with certainty in period two, therefore its discount price in period one is zero. The government is only able to take out loans $b_f \leq \frac{y_2 \delta_f}{1+\tau_2}$ which are repaid with certainty. Foreign default cannot arise in equilibrium. For b_f to be in the default area with positive probability, we need at least one parameter to be stochastic. $\qquad\square$

B. Domestic default schedule

Similarly, we can define the domestic debt limit. Domestic debt will be repaid whenever:

$$\frac{b_h}{y_2} \leq \frac{\delta^h}{\tau_2}, \tag{1.3.16}$$

where the left-hand side is the domestic debt-to-GDP ratio and the right-hand side is a number defined by parameters of the model. Whenever the inequality has the opposite sign, the government defaults on domestic debt. Most importantly, the denominator on the right-hand side of inequality (1.3.16) is of a different magnitude than that in (1.3.15). This is because repayment of foreign debt is a transfer of resources out from the economy, while repayment of domestic debt is only a redistribution of resources within the economy. This redistribution is costly, and these costs are captured by the parameter τ_2. Inequality (1.3.16) allows us to prove two interesting propositions.

Proposition 2. *If taxation is costless and home default induces small positive costs to the economy, then any level of domestic debt is repaid.*

This is the result of Broner et al. (2010), where taxes are assumed to be lump sum and default on domestic agents induces redistribution costs, which are endogenously derived (here captured

by the parameter δ_h). This result has powerful consequences. For example, if any level of debt is sustainable on the domestic market, then if secondary debt markets are efficient, any level of foreign debt is also sustainable in repayment equilibrium. Foreign debt can always be repaid even without exogenous default penalties, and a sufficient solution to the default problem is to improve the efficiency of secondary debt markets.

Proposition 2 shows that the assumption of lump-sum taxes is the key to deriving the Broner et al. (2010) result. Without this assumption, there is finite limit to the amount of domestic debt that can be sustained in repayment equilibrium.

Proposition 3. *If taxation is costly then the government's optimal policy on the domestic market is characterized by the domestic default threshold (1.3.16). Whenever the debt is below this threshold, it is riskless and is always repaid. Whenever it is above the threshold, it will always be defaulted on and therefore can never be issued. If either output or tax distortions are stochastic, the default threshold is also stochastic, debt can be risky and default can arise in equilibrium.*

Proof. The first part follows directly from comparing (1.3.11) and (1.3.13). The proof of the second part is analogous to the proof of Proposition 1. $\qquad\square$

Inequalities (1.3.15) and (1.3.16) completely characterize government policy in the second period. Notice that whenever both inequalities are reversed, it is also the case that $c^{td} > c^r$, which is consistent with the definition of total default being simultaneous default on both domestic and foreign debts outstanding.

C. Default policies in the second period

Having established default thresholds in the second period, we posit an equilibrium in which, depending on the realizations of stochastic shocks, all four outcomes (repayment, foreign default, domestic default and total default) arise in the second period. The purpose of this part is to find a set of parameters that can sustain this equilibrium and, in the next subsection, to check that this set of parameters delivers debt issuances that are consistent with the posited equilibrium. By doing this we want to understand the mechanics and interactions between debt issuances and selective default, and prove that the set of parameters that is able to deliver the four outcomes is non-empty. Both of the stochastic processes in this economy have two outcomes. Therefore, we impose equilibrium conditions that would map the four possible realizations of joint (y, τ) stochastic processes into four equilibrium outcomes. These conditions are:

1. After a bad output shock $y_2 = y_L$, the government defaults on foreign debt regardless of the realization of the tax distortion shock.

2. After a good output shock $y_2 = y_H$, the government repays foreign debt regardless of the realization of the tax distortion shock.

3. After a bad tax distortion shock $\tau_2 = \tau_H$, the government defaults on domestic debt regardless of the realization of the output shock.

4. After a good tax distortion shock $\tau_2 = \tau_L$, the government repays domestic debt regardless of the realization of the output shock.

Mathematically these conditions can be summarized by four inequalities that follow from substituting realizations of y and τ into (1.3.15) and (1.3.16):

$$\frac{y_L \delta_f}{1 + \tau_L} < b_f \leq \frac{y_H \delta_f}{1 + \tau_H}, \tag{1.3.17}$$

$$\frac{y_H \delta_h}{\tau_H} < b_h \leq \frac{y_L \delta_h}{\tau_L}, \tag{1.3.18}$$

where the inequalities in (1.3.17) correspond to conditions 1) and 2) respectively, and the inequalities in (1.3.18) correspond to conditions 3) and 4) respectively. How these conditions translate into a mapping between (y, τ) outcomes and repayment-default decisions can be easily understood by looking at Figure 1.2. The red (dotted) line represents the domestic default threshold, while the blue (solid) line represents the foreign default threshold. In the second period, four situations may occur. Circles show allocations for which debt is repaid, while crosses show defaults. Colors represent respective debt types (red for home, blue for foreign). A negative shock to output is shown as an increase in the debt-to-GDP ratio.

Figure 1.2 shows four possible outcomes denoted by letters A to D. Tax distortions τ are on the horizontal axis, while the vertical axis represents domestic and foreign debt-to-GDP ratios in the second period $\frac{b_h}{y_2}$ and $\frac{b_f}{y_2}$. A negative output shock is shown as a move up, and a negative taxation shock is shown as a move to the right. A) After a good output shock and a good tax distortion shock, both debts fall below the default thresholds and therefore both are repaid. B) After a bad output shock and a good tax distortion shock, foreign debt (blue cross) is above its threshold and is therefore defaulted on. However, domestic debt (red circle) is still repaid, as it falls below its threshold. C) After a good output shock but bad a tax distortion shock, the situation is the reverse of B. D) After a bad output shock and a bad tax distortion shock, both debts are above default their thresholds and are therefore defaulted on.

1.3.2 Debt policies in the first period

In this section we solve for first-period debt issuance decisions that are consistent with the second-period default decisions described by (1.3.17) and (1.3.18) (or equivalently by Figure 1.2). In the remainder of this paper we assume a constant relative risk aversion (CRRA) instantaneous utility function for domestic agents:

$$u(c) = \frac{c^{1-\sigma}}{1 - \sigma}.$$

Figure 1.2: Default thresholds and selective defaults
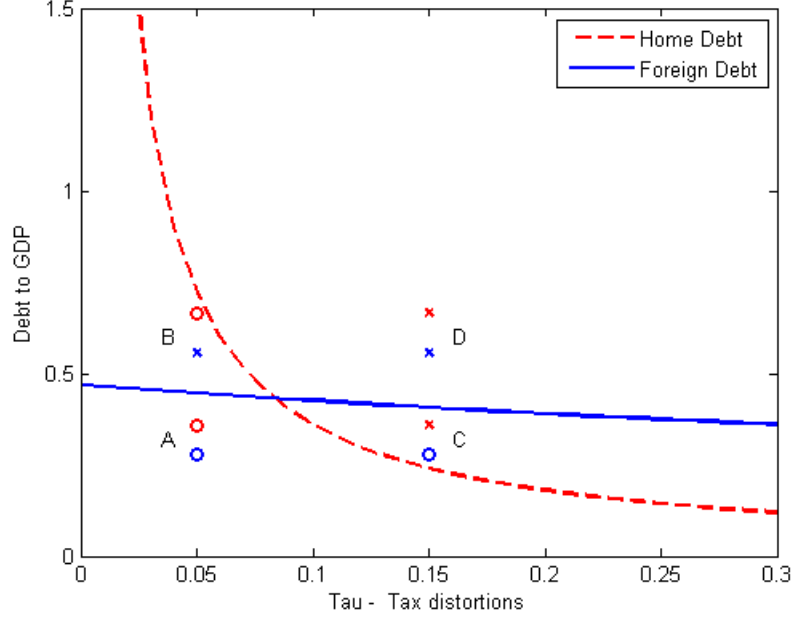
The aim of this section is to first find a set of parameters for which foreign default is driven by the output shock and domestic default is driven by the tax distortion shock. The solution algorithm is provided in Solution Algorithm. We show that this set is non-empty (see Two Period Model). Second, we examine the comparative statics of an equilibrium solution.

The government chooses debt issuances b_h and b_f to maximize the lifetime utility of domestic agents:

$$\max_{\{b_h, b_f\}} u(c_1) + \beta \mathbb{E}\left[u(c_2)\right], \tag{1.3.19}$$

where

$$c_1 = y_1 + \tau_1 q_h b_h - (1 + \tau_1)(g - q_f b_f),$$

$$c_2 = \begin{cases} (1.3.11) \text{ with prob. } \Pi_y \Pi_\tau \\ (1.3.12) \text{ with prob. } (1 - \Pi_y)\Pi_\tau \\ (1.3.13) \text{ with prob. } \Pi_y(1 - \Pi_\tau) \\ (1.3.14) \text{ with prob. } (1 - \Pi_y)(1 - \Pi_\tau), \end{cases}$$

subject to price schedules derived from foreign investors' zero-profit condition and domestic

households' first-order condition:

$$q_f = \frac{\Pi_y}{1+r}, \tag{1.3.20}$$

$$q_h = \beta \frac{\Pi_y \Pi_\tau u'(c^r) + (1 - \Pi_y)\Pi_\tau u'(c^{fd})}{u'(c_1)}. \tag{1.3.21}$$

Debt issuances must obey first-order conditions given by:

$$(b_h :) \qquad\qquad (\tau_L - \tau_1)q_h = \tau_1 b_h \frac{\partial q_h}{\partial b_h}, \tag{1.3.22}$$

$$(b_f :) \qquad u'(c)\left((1+\tau_1)\, q_f + \tau_1 b_h \frac{\partial q_h}{\partial b_h}\right) = \beta\,(1+\tau_L)\left(\Pi_y \Pi_\tau u'\,(c^r) + \Pi_y\,(1 - \Pi_\tau)\, u'\left(c^{hd}\right)\right). \tag{1.3.23}$$

Comparative statics reveal that this two-period environment can account for two empirically observed facts. First, that the share of foreign investors is negatively correlated with interest rates; and second, that the share of domestic investors is positively correlated with the total public debt of the economy (see for example Andritzky (2012)). We document these findings graphically in Two Period Model. Graphical Solutions.

Now that the trade-offs behind our model have been described in detail, we can turn to quantitative analysis of an infinite-horizon version of the model.

1.4   Quantitative Analysis

We build an incomplete-markets model in which the government has limited commitment. Let time be indexed by $t = 0, 1, 2, \ldots$ The economy has an exogenous stochastic stream of income $y_t \in \mathbb{Y}$, which is a Markov process. At each time t the government has to cover a fixed exogenous stream of government expenditure g_t.

In each period t the government decides either to repay or default on outstanding foreign and domestic debt. When the government chooses to default, the economy suffers from output penalties and is excluded from borrowing on the market where default happened for a random number of periods. We allow the expected exclusion durations and output costs to differ between types of default.

1.4.1   Households

Households are identical and risk averse. Their utility is given by:

$$\sum_{t=0}^{\infty} \beta^t \mathbb{E}_0 \left[u(c_t) \right],$$

where β is the discount factor, c is consumption and $u(c)$ is increasing and strictly concave. House-holds are allowed to save using domestically issued government bonds b_h. They take bond discount prices and taxes as given. They face an intra-temporal budget constraint, which differs depending on the government's decision to default on either of the two bonds.

If the government repays both domestic and foreign debt, households' budget constraint is the following:

$$c^r = y - T(1 + \tau) + b_h - q_h b'_h, \tag{1.4.1}$$

where b_h is the amount of domestic debt owed and repaid by the government to households, b'_h is the new issuance of government domestic debt (household savings), q_h is the domestic bond's discount price, T is the amount of lump-sum taxes and τ is the distortion imposed by taxation.[5]

If the government defaults on foreign debt, households are still allowed to save in the domestic market. However, foreign default induces output costs and affects the endogenous price of domestic bonds:

$$c^{fd} = y(1 - \delta_f) - T(1 + \tau) + b_h - q_h^{fd} b'_h. \tag{1.4.2}$$

In the case of domestic default, the government maintains foreign borrowing, but the domestic debt market is closed:

$$c^{hd} = y(1 - \delta_h) - T(1 + \tau). \tag{1.4.3}$$

Similarly, in the case of simultaneous domestic and foreign default, which we will refer to as total default:

$$c^{td} = y(1 - \delta_f)(1 - \delta_h) - T(1 + \tau). \tag{1.4.4}$$

1.4.2 Foreign investors

Foreigners are risk neutral investors with deep pockets and access to international credit markets, where they can save and borrow at a constant interest rate r. When lending resources to the government they account for the possibility of default and break even in expected terms, therefore their policy can be summarized as:

$$q_f = \frac{(1 - \Delta^f)}{1 + r},$$

where q_f is the discount price of government bonds issued with foreign investors and Δ^f is the probability of foreign default.

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[5]Whenever taxes are negative, the household budget constraint yields $c^r = y - T(1 - \tau) + b_h - q_h b'_h$, so that rebates are distortionary and distortion does not increase the amount of resources when taxes are negative. The same is true for the selective and total default cases.

Figure 1.3: Government decision tree
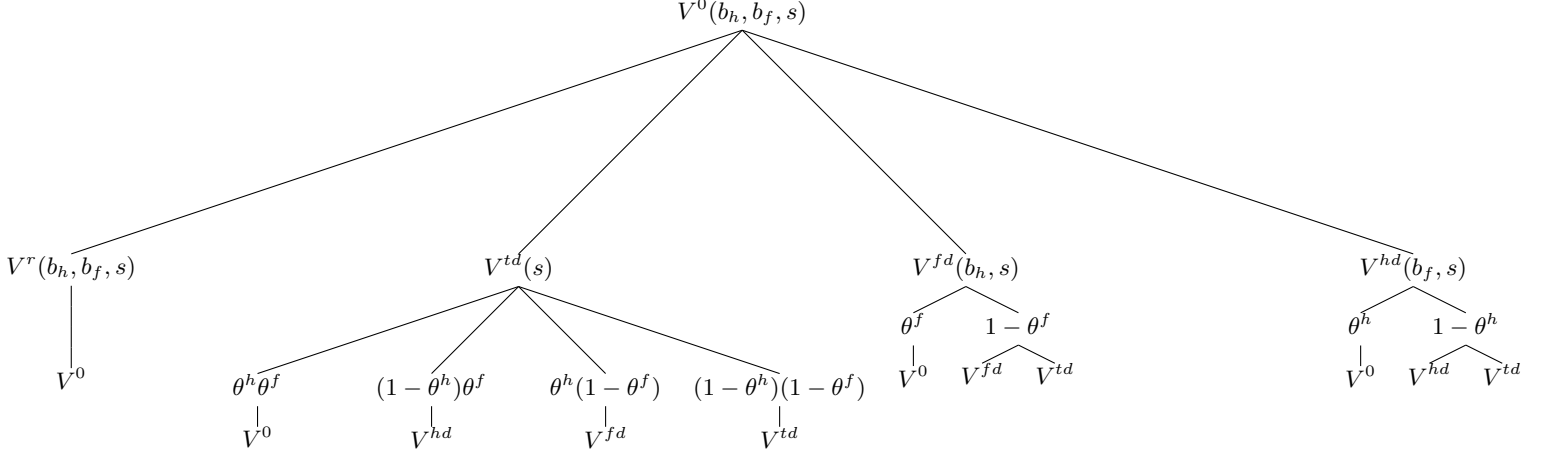
When both markets are open (V^0), the government can decide to repay both debts (V^r), default on both debts (V^{td}), repay only domestic debt (V^{fd}) or repay only foreign debt (V^{hd}). Subsequent possible choices are depicted on the lower levels of the decision tree.

1.4.3   Recursive equilibrium

We define a recursive equilibrium in which domestic households, foreign investors and the government act sequentially and the government acts with discretion. The aggregate state of the economy $S = (b_h, b_f, s)$ is given by two endogenous debts b_h, b_f and two exogenous processes for income and tax distortions $s = (y, \tau)$. Every period, the government decides whether to repay its two outstanding debts, default on domestic debt, default on foreign debt or default on both:

$$V^0(b_h, b_f, s) = max\{V^r(b_h, b_f, s), V^{fd}(b_h, s), V^{hd}(b_f, s), V^{td}(s)\} \qquad (1.4.5)$$

The government's repayment decision is summarized by two default indicators $d_f \in \{0, 1\}$ and $d_h \in \{0, 1\}$, where $d_{i=\{h,f\}} = 0$ stand for repayment, $d_f = 1$ stands for foreign default and $d_h = 1$ for domestic default. After a default, the government is excluded from borrowing on the market and faces probability θ_h, θ_f of returning to borrowing on domestic and foreign markets respectively. The government's choices are presented graphically in Figure 1.3, where tree branches correspond from left to right to: repayment of both debts, default on both debts, default on foreign debt only and default on domestic debt only. After repayment, the government goes back to node V^0. After any type of default, the government first draws probabilities θ^h, θ^f that one or the other market will open. Subsequent possible choices are depicted on the lower levels of the tree. (Total default has been put on the second branch due to graphical reasons.)

If the government decides to repay it solves the following problem:

$$V^r(b_h, b_f, s) = \max_{b'_h, b'_f}\left\{u(c^r) + \beta\mathbb{E}\{V^0(b'_h, b'_f, s')\}\right\} \qquad (1.4.6)$$

subject to households' budget constraint (1.4.1), the foreign bond price schedule

$$q_f(b'_f, s) = \frac{\mathbb{E}\{1 - d'_f(b'_h, b'_f, s')\}}{1 + r} \tag{1.4.7}$$

and households' first-order condition:

$$q_h(b_h, b_f, b'_h, b'_f, s) = \beta \frac{\mathbb{E}\left\{\left(1 - d'_h\left(b'_h, b'_f, s'\right)\right) u'\left(c'\left(b'_h, b'_f, s'\right)\right)\right\}}{u'\left(c\left(b_h, b_f, s\right)\right)}, \tag{1.4.8}$$

where, unlike for foreign bonds, the price of domestic bonds depends not only on the probability of default, but also on households' welfare both today and tomorrow, and the government budget constraint

$$T + q_h b'_h + q_f b'_f = g + b_h + b_f. \tag{1.4.9}$$

If the government defaults on foreign debt (and keeps servicing its domestic obligations) the economy suffers an output cost, and is allowed to return to international borrowing in the future with probability θ^f. With probability $1 - \theta^f$ the country remains only on the domestic bond market and the government can still decide to also default on domestic bonds (yielding total default). The government's problem is summarized by:

$$V^{fd}(b_h, s) = \max_{b'_h}\left\{u(c^{fd}) + \beta\mathbb{E}\left(\theta^f V^0(0, b'_h, s') + (1 - \theta^f)max\{V^{fd}(b'_h, s'), V^{td}(s')\}\right)\right\} \tag{1.4.10}$$

subject to households' budget constraint (1.4.2), households' first-order condition

$$q_h^{fd}(b_h, b'_h, s) = \beta \frac{\mathbb{E}\left\{\left(1 - d^{fd'}(b'_h, s')\right) u'\left(c^{fd'}(b'_h, s')\right)\right\}}{u'\left(c^{fd}(b_h, s)\right)} \tag{1.4.11}$$

(where the number of states is reduced relative to the repayment case, as foreign debt does not affect welfare because it is defaulted on) and the government budget constraint

$$T + q_h^{fd}b'_h = g + b_h. \tag{1.4.12}$$

Third, if the government decides to default on domestic debt outstanding, it remains active on international markets, comes back to domestic borrowing with probability θ^h, can still default on foreign debt and suffers a domestic output penalty:

$$V^{hd}(b_f, s) = \max_{b'_f}\left\{u(c^{hd}) + \beta\mathbb{E}\left(\theta^h V^0(b'_f, 0, s') + (1 - \theta^h)max\{V^{hd}(b'_f, s'), V^{td}(s')\}\right)\right\} \tag{1.4.13}$$

subject to households' budget constraint (1.4.3), the foreign bond price schedule

$$q_f^{hd}(b_f', s) = \frac{\mathbb{E}\{1 - d^{hd'}(b_f', s')\}}{1 + r}$$
(1.4.14)

and the government budget constraint

$$T + q_f^{hd} b_f' = g + b_f.$$
(1.4.15)

Lastly, at any given time the government can decide to pursue total default. The economy suffers output penalties for both domestic and foreign default, and the government comes back to international and domestic borrowing with probabilities θ^f and θ^h respectively. The government's problem is summarized by:

$$V^{td}(s) = u(c^{td}) + \beta \mathbb{E}\left(\theta^f \theta^h V^0(0,0,s) + \theta^f(1-\theta^h)V^{hd}(0,s') + (1-\theta^f)\theta^h V^{fd}(0,s') + (1-\theta^f)(1-\theta^h)V^{fd}(s')\right)$$
(1.4.16)

subject to households' budget constraint (1.4.4) and the government budget constraint

$$T = g.$$
(1.4.17)

Now that actions and optimization problems are defined for each actor in the economy, we can define the equilibrium:

Definition 1. *Recursive equilibrium in this economy is (i) the set of prices in repayment periods for domestic bonds $q_h(b_h, b_f, s)$ and foreign bonds $q_f(b_h, b_f, s)$ and the set of prices in partial default periods $q_h^{fd}(b_h, s)$ and $q_f^{hd}(b_f, s)$; (ii) government debt policies in repayment periods $b_h'(b_h, b_f, s)$ and $b_f'(b_h, b_f, s)$ and in partial default periods $b_h^{fd'}(b_h, s)$ and $b_f^{hd'}(b_f, s)$; and (iii) government default schedules in repayment periods $d_h(b_h, b_f, s)$ and $d_f(b_h, b_f, s)$ and in partial default periods $d_h^{fd}(b_h, s)$ and $d_f^{hd}(b_f, s)$ such that:*
1) Taking as given domestic bond price schedules d_h and d_h^{fd} and government domestic debt issuances b_h' and $b_h^{fd'}$, households' consumptions c^r and c^{fd} satisfy households' budget constraints and first-order conditions.
2) Taking as given government foreign default schedules d_f and d_f^{hd}, prices q_f and q_f^{hd} are consistent with foreign investors' expected zero profits.
3) Taking as given prices q_h, q_f, q_h^{fd} and q_f^{hd}, the government's default schedules d_h, d_f, d_h^{fd} and d_f^{hd} and debt policies b_h', b_f', b_h^{fd} and b_f^{hd} solve the government's optimization problem.
4) Government bond and tax policies and default schedules satisfy the government budget constraint.

1.4.4 Calibration

To solve the model numerically, we need to assume specific functional forms and assign parameters. Table 1.1 represents the parameters, which are selected directly from data. We assume the CRRA utility function with a risk aversion coefficient σ equal to two. The risk-free interest rate r is set to 1.7%, which is the average yearly interest rate of a five-year US Treasury bond during this time period. These parameters are common values used in the real business cycle and default literatures. We calibrate the $AR(1)$ stochastic process for output, based on the series of Argentinian GDP:

$$log(y_t) = \rho_y log(y_{t-1}) + u_t, \tag{1.4.18}$$

where $u_t \sim \mathcal{N}(0, \epsilon_y)$.

The government faces two types of costs upon default. The output cost is assumed to be asymmetric as in Arellano (2008):

$$y_t^{def} = \min\{y_t, \gamma y\}, \tag{1.4.19}$$

where y is the mean of the output process and γ takes one of three values for domestic, foreign and total default respectively. The cost function implies that default is more costly with a high output realization. The level of government expenditure is set to be the average Argentinian government expenditure of 25% of GDP for the period 1993–2011. This number is not substantially different from the cross-country average of 31% for developing countries. Based on Reinhart and Rogoff (2011b) dataset we calculate the median length of domestic default to be 2.5 years and that of foreign default to be 4.6 years.[6] This estimate is slightly low in comparison with the usual average exclusion period of 7.5 years for Argentina usually applied in default literature.[7] Our process of tax distortions is of a reduced form and cannot be directly taken to data, therefore we make two additional assumptions. First, we assume symmetry in the process (switching states from high to low and from low to high happens with the same probability). Second, we assume taxes in the good state to be almost non-distortionary. However, τ_L cannot be zero (as discussed in Proposition 2) as it would make domestic debt riskless and thereby prevent the algorithm from converging.

After choosing eight parameters directly, we are left with six parameters to be calibrated. Table 1.2 summarizes the parameters and moments that we match. We use Reinhart and Rogoff's dataset to calculate frequencies of different types of default, periods of market exclusion and drops in output after different types of default. As in previous literature, we calibrate the discount factor to target a debt service expenditures-to-GDP ratio of 5.53%. The foreign output cost γ^f is calibrated to match the frequency of foreign defaults in Argentina in the last 210 years. Then, we set γ^h such that the output drop after domestic default is on average three times higher than after foreign

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[6]Calculated as the median of averages of defaulting countries

[7]Gelos et al. (2011) measure exclusion as the years between default and the date of the next issuance of public and publicly guaranteed bonds or syndicated loans.

Table 1.1: Parameters selected directly

Parameter	Value	Source
Risk-free interest rate	$r = 1.7\%$	5-year US bond yearly yield
Risk aversion	$\sigma = 2$	Standard in literature
Persistence of output	$\rho_y = 0.945$	Argentina 1993–2001
Std. dev. of output	$\epsilon_y = 0.025$	Argentina 1993–2001
Government expenditure	$g/y = 0.25$	Argentina 1993–2001
Re-entry to foreign market	$\theta_f = 0.22$	4.6 yrs. exclusion (R&R 2011b)
Re-entry to domestic market	$\theta_h = 0.5$	2 yrs. exclusion (R&R 2011b)
Low tax distortion	$\tau_l = 0.01$	Assumed

Table 1.2: Parameters selected by matching moments

Parameter	Value	Target
Discount factor	$\beta = 0.95$	Debt service to GDP 5.53%
Foreign default output cost	$\gamma_f = 0.97$	F-default frequency 3.5%
Domestic default output cost	$\gamma_h = 0.91$	Output drop after D-default
High tax distortion	$\tau_h = 0.1$	D-debt to GDP 24.8%
High distortion persistence	$\pi_{hh} = 0.7$	D-default freq. 2.5%
Low distortion persistence	$\pi_{ll} = 0.7$	Symmetric $\pi_{hh} = \pi_{ll}$

default (as documented by Reinhart and Rogoff). The persistences of distortion states are assumed to be symmetric and are set to match the frequency of domestic defaults in Argentina in the last 210 years.

Unfortunately, Reinhart and Rogoff's dataset does not report debt composition. Therefore, to calculate debt-to-GDP ratios, we employ the dataset of Panizza (2008), who constructs his data based on the legal definition, which is consistent with Reinhart and Rogoff (2011b). We try to match the domestic debt-to-GDP ratio in Argentina of 24.8%, although the model is not quite able to match this particular moment closely.

1.4.5   Simulation results

In this section we analyze default policies, debt policies and equilibrium prices in the calibrated model. Next we examine the quantitative performance of the model against the data. We describe the algorithm for solving the model numerically in Solution Algorithm. Both default and debt policies are four-dimensional objects, as the state space for the economy consists of two endogenous (domestic and foreign debt) and two exogenous (output and tax distortions) states. For each variable of interest, we compare policies for different levels of the same type of debt, keeping the value of the second type of debt constant.

Figure 1.4: Foreign debt policies given $b_h = 1.8$
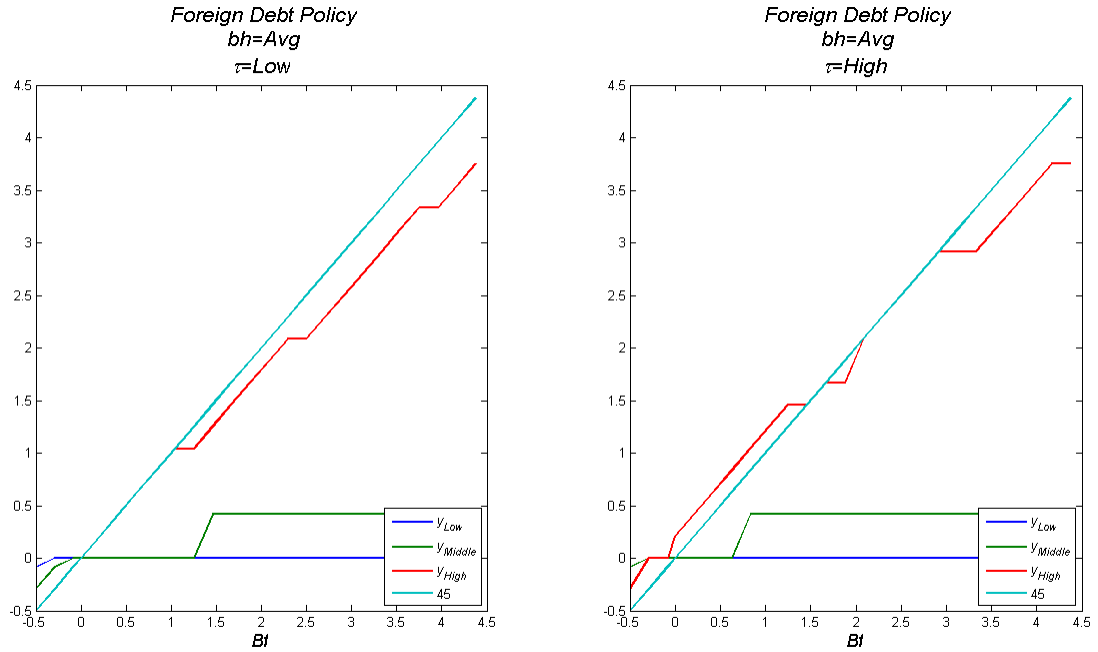
The most interesting findings of the model are revealed by Figures 1.4 and 1.5. Figure 1.4 plots debt policies for foreign debt given that outstanding domestic debt is positive $b_h = 1.8$. Foreign debt policies are similar to those found in other quantitative models of sovereign default. The country accumulates foreign debt when output is high due to low interest rates. Interest rates are low as a result of the default set being decreasing in y. Also, the government accumulates more debt when the economy suffers from high tax distortions. This is explained by the fact that the government avoids using distortionary taxation and instead finances its expenditures via both foreign and domestic (as we shall see) debt.

Figure 1.5 plots policies for domestic debt. When tax distortions are low (left panel), the government finances its expenditures in full via taxation for any level of debt outstanding. This is the situation in which raising taxes comes at the lowest cost for the economy. In fact, the government is building up assets on the domestic debt market (optimal domestic debt is the negative corner solution) in order to be able to accommodate more debt movements in the future, when distortions may be high. When tax distortions are high (right panel) and output is low, the government is in a state of default and no trade is taking place on domestic debt markets. When output is middle or high, the government employs a "gambling for redemption" policy. It finds it optimal to always increase the stock of domestic debt up to the point where it reaches endogenous debt constraints. Thus, the government is piling up domestic debt in the hope that it will be able to repay all of

Figure 1.5: Domestic debt policies given $b_f = 1.8$
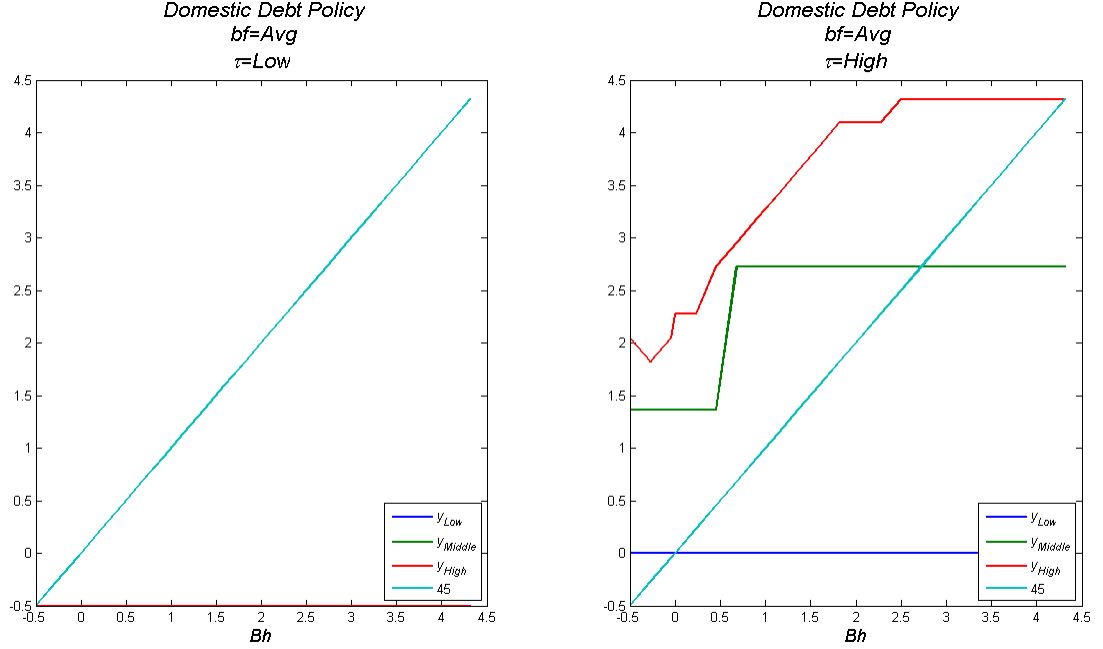
it with taxes, should the low-distortion day arrive. Whenever this day happens, the government repays its debt in full. If this day does not come, the government is forced to default on its domestic debt obligations.

Figures 1.6 and 1.7 plot repayment and default policies in debt–output space. White stands for repayment, light gray for foreign default, dark gray for domestic default and black for total default. We can see that the repayment–default trade-off for foreign debt is mostly driven by the output process, while tax distortions do not matter. On the other hand, the default area for domestic debt is much bigger for the high tax distortion than for the low tax distortion scenario. Also, as in both cases we set the second type of debt to zero, we cannot observe total default.

To assess the performance of the model, we simulate 1,000 paths from the model, each with length 10,000, and burn the first 1,000 simulations of each path. Then we compare the resulting business cycle statistics with the corresponding statistics from the data. Table 1.3 shows that the results for the benchmark calibration are in line with the data. Our model performs well in many dimensions. The model replicates reasonably high debts levels and at the same time reasonably low default probabilities. It predicts that consumption is more volatile than output, and that net exports are strongly countercyclical.[8]

It is worth stressing once again that the two shocks have opposite effects on the economy. While

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[8]See Neumeyer and Perri (2005)

Table 1.3: Cyclical properties

	Data (Argentina)	Model	Arellano (2008)
Foreign default frequency	3.5%	3.5%	3%
Domestic default frequency	2.5%	5.6%	x
Total default frequency	1.5%	0.3%	x
Average foreign spread	12.67pp	8.9pp	3.58pp
Average domestic spread	x	15.5pp	x
Foreign debt-to-GDP	17.22%	3.7%	5.95%
Domestic debt-to-GDP	24.78%	13.7%	x
Consumption std./ Output std.	1.098	1.088	1.098

the tax distortion shock has a substantial impact on domestic debt accumulation, it has a mild impact on foreign debt accumulation. The opposite is true for the output shock.

Figure 1.6: Default sets for foreign debt given $b_h = 0$
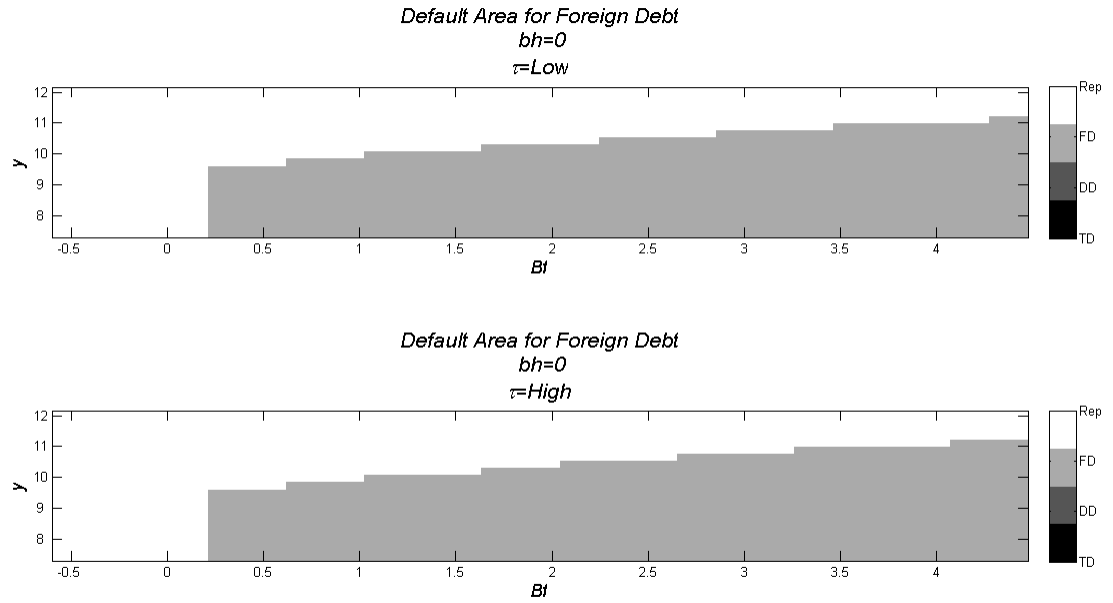
Figure 1.7: Default sets for domestic debt given $b_f = 0$
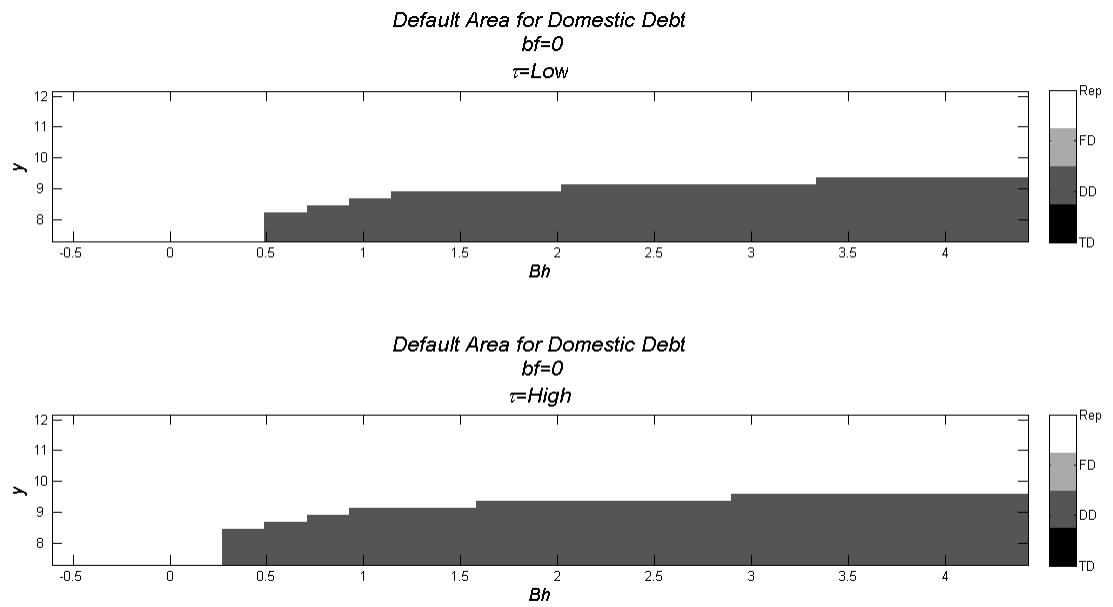
1.5   Empirical Evidence

This section confronts the two main testable implications of our model with the data. First, the model predicts foreign default is more likely in low output states of the world and is almost independent of the level of tax distortions. Second, domestic default is more likely with high tax distortions and is less dependent on the output realizations.

The idea that taxes are distortionary is not new and has been widely applied in both theoretical and empirical literature on optimal taxation and optimal level of government spending. In this paper we abstract from these considerations, but take an insight by Browning (1976) as a starting point. The social cost of financing a marginal dollar of public expenditure is the sum of that dollar, which is diverted from private use plus the change in the total welfare cost of taxation caused by increasing tax revenue by the dollar. Stuart (1984) terms the latter component "marginal excess burden" and its definition fits our notion of tax distortions τ perfectly. The are numerous studies that estimate "marginal excess burden" using quantified theory. Harberger (1964) classic estimate puts it at around 2.5¢per additional dollar raised, while Browning (1976) using the same formula calculates it to be between 9¢and 16¢in 1974. Stuart (1984) proposes a new, general equilibrium approach, which results in estimates being 1.5 times those of Browning. Seminal contribution by Feldstein (1999) using micro level data and accounting for multiple channels of adjustments to tax code changes puts an average dead-weight loss from personal income tax at 32,2% and, more importantly, shows that marginal losses can be as high as 2$ per additional 1$ raised. Our takeaway from this literature is that tax distortions τ are significant, positive and variable[9].

To test our two main predictions we collect the data on both types of defaults, domestic and foreign, and the data on output and taxes. However, there is no readily available measure of tax distortions. The next section explains how we construct a proxy for this.

1.5.1   Methodology

The tax revenue from a specific tax TR_i is by definition equal to the product of the tax rate tr_i and the tax base TB_i.

$$TR_i = tr_i \times TB_i \tag{1.5.1}$$

If a tax is non-distortionary, a change in the tax rate does not affect the tax base. If a tax is distortionary, a change of the tax rate would reduce the tax base. A visual example of this effect is the Laffer curve. When a tax rate increases in the range close to 0 revenue also goes up almost one-to-one. The higher is the tax rate however, increases in revenue are slowing down, as tax base is decreasing (tax distortions start playing a role). At some point maximum is reached, above which reduction in tax base dominates any increase in tax rate and tax revenue goes down.

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[9]When marginal burden is different from average burden as in Feldstein (1999) then any exogenous change in a tax code would result in a change in an average burden.

Moreover, if a government undertakes any changes (decreasing deductions, taming tax avoidance, making labor more inelastic etc.) so that a tax base goes up without any change it a tax rate, if more income could be raised with the same primary tool, this should be also seen as a reduction in tax distortions.

Hence, we any change in the tax base TR_i is a sufficient proxy for the change in tax distortions (model τ_i).

1.5.2   Data

The data on default, as described in the second section of this paper, comes from the updated database accompanying Reinhart and Rogoff (2011b) and covers up to 130 countries for the years 1800-2014. From this database we obtain our dependend variables, dummy indicators for foreign Def^f and domestic Def^d default.

Output data we obtain from Penn World Tables 8.1 (Feenstra et al. (2015)) which cover up to 209 countries for the years 1950-2011. Data on tax revenues comes from The ICTD Government Revenue Dataset (Prichard et al. (2014)) which covers up to 130 countries for the years 1980-2010. Finally, data on tax rates we have obtained and compiled from two main sources: World Tax Database (WTD) by Office of Tax Policy Research (2015) (up to 60 countries between 1950 and 2002) which is our primary source on corporate income tax rates and World Tax Indicators (WTI) by Andrew Young School of Policy Studies (2010) (up to 180 countries for the years 1981-2005) which is our primary source on individual income tax rates. These are complemented by two further sources: Oxford University Centre for Business Taxation (2015) (CBT; up to 48 countries for the years 1979-2014) and KPMG (2015) (up tp 79 countries for the years 2002-2014). All our variables come in yearly frequency. Our estimation sample with the full data coverage is 89 countries for the years 1981-2011 yielding a total of 1432 country-year observations.

1.5.3   Estimation

We estimate the following two regression equations:

$$Pr(Def_{i,t}^f = 1) = \alpha_0^f + \alpha_1^f GDP_{i,t-1} + \alpha_2^f TB_{i,t-1} \tag{1.5.2}$$

$$Pr(Def_{i,t}^d = 1) = \alpha_0^d + \alpha_1^d GDP_{i,t-1} + \alpha_2^d TB_{i,t-1} \tag{1.5.3}$$

where Def is a default indicator and Pr probability of default in country i in period t. Def^f is an indicator for the beginning of a foreign default episode. It takes value 1 if a country i was in a foreign default in year t, but was not in a foreign default in year $t-1$ and 0 otherwise. Def^d is an indicator for the beginning of a *de facto* domestic default episode, which includes both *de jure* domestic default and a hyperinflation crisis. It takes value 1 if a country i was either in a domestic

Table 1.4: Foreign Default

	(1) Probit RE	(2) Logit RE	(3) Logit FE	(4) Logit Pooled
GDP	-0.509**	-0.940**	-0.505	-0.904**
	(0.180)	(0.328)	(0.340)	(0.300)
Tax Base	-0.0302	-0.0808	-0.187	-0.0780
	(0.0208)	(0.0538)	(0.102)	(0.0512)
r2				
N	1490	1490	371	1490

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

default or in a hyperinflation crisis in year t, but was in neither in year $t - 1$ and 0 otherwise[10].

GDP is the rate of growth of real GDP per capita denominated in fixed US dollars and TB is the Tax Base calculated from equation (1.5.1). Our independent variables are lagged one period to avoid possible endogeneity problem. In regressions we use Tax Base for both corporate taxes. There is a good rationale for that. Corporate taxes are, to the best of our knowledge, always flat-rate taxes. This is however not true for personal income taxes, which are usually progressive. Our data sources have good coverage of the highest rate of the personal income tax, which is far from being a good proxy for the average effective rate of the personal income tax. Our model implies that foreign default is mostly driven by fluctuations in output and is almost independent from tax distortion shock, therefore we expect α_1^f to be significant and negative and α_2^f to be zero. On the other hand, in our model domestic default is driven mostly by tax distortion shock but also depends on output shock. Fluctuations in tax distortions τ are inversely related to fluctuations in a tax base TB as explained in the Methodology subsection. Therefore we expect α_2^d to be significant and positive and α_2^f to be non-positive.

We run two benchmark and two robustness regressions for each foreign and domestic default. As a benchmark we run probit and logit with random effects. To check robustness of our results we complement those two pooled logit and logit with fixed effects.

Table 1.4 presents regression results for the foreign default, that is equation (1.5.2). The estimate of the coefficient of the rate of growth of real GDP is positive and significant, while changes in the tax base do not affect the probability of the foreign default. This result confirms our hypothesis, that foreign default is driven by the output fluctuations and tax distortions do not play any significant role.

Table 1.5 presents results for the domestic default, that is equation (1.5.3). As can be seen, the higher is the tax base (which corresponds to the lower distortions) the lower is the probability of

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[10]Following Reinhart and Rogoff (2011b) these crises are defined as follows: foreign default is defined as the failure to meet principal or interest payment on a due date. This definition also applies for domestic default. The distinction between domestic and foreign default is based on *legal* definition of debt. In addition, domestic debt crises have involved the freezing of bank deposits and or forcible conversions. An inflation crisis occurs when annual inflation is 20 per cent or higher.

Table 1.5: Domestic Default

	(1)	(2)	(3)	(4)
	Probit RE	Logit RE	Logit FE	Logit Pooled
GDP	-0.0294	-0.00184	0.387	-0.177
	(0.279)	(0.584)	(0.774)	(0.424)
Tax Base	-0.0479*	-0.110*	-0.127*	-0.0958*
	(0.0225)	(0.0512)	(0.0639)	(0.0407)
r2				
N	1496	1496	387	1496

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

domestic default. As expected, the impact of the corporate tax base is negative and significant. The real rate of GDP growth however, has no impact on domestic default. This confirms our second hypothesis, that domestic default is more likely with high tax distortions and is less dependent on the output realizations.

1.6   Secondary Markets and Haircuts

With the introduction of unconventional monetary policies during the Great Recession, secondary sovereign debt markets have attracted increasing interest among economists. In this section we return to the two-period model setting from Section 1.3 to study how secondary markets affect the government's incentives to repay or to default. We will introduce secondary markets in the second period. Secondary markets open after nature selects the output and taxation shocks. Therefore all participants in the market have perfect foresight of what the government will do (repay or default) if no trade in assets takes place on secondary markets.

1.6.1   Setup

The starting points for the discussion are Propositions 1, 2 and 3, where we have established that with costly tax enforcement there exist finite default thresholds for both foreign and domestic debt, and that both debts can be risky due to the stochastic nature of output and taxation distortions. There are four possible outcomes of the model in the moment at which secondary markets open, which are summarized in Figure 1.2. When either both debts are repaid (situation A) or defaulted on (situation D), the workings of the secondary markets would not change the final outcome. Therefore our discussion will focus on selective foreign default (situation B).[11] Under situation B in the second period output is low $y_2 = y_L$ and tax distortions are low $\tau_2 = \tau_L$.

First we will summarize our assumptions about what is happening in the economy at the moment the secondary markets open, and we introduce some notation. As long as default costs

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[11]Selective domestic default, situation C, is its mirror image.

are positive, there are positive amounts of both foreign and domestic debts outstanding: b_f and b_h. Each debt has its respective default threshold which we derive from (1.3.15) and (1.3.16) and denote in levels: $\bar{B}_f$ and $\bar{B}_h$.

After a good shock to taxation and a bad shock to output, foreign debt is above its default threshold $b_f > \bar{B}_f$ but domestic debt lies below its default threshold $b_h < \bar{B}_h$. As foreigners know they will be defaulted upon, they are willing to sell their claims in the secondary market. As domestic investors know there is still some room for an increase in repayable domestic debt, they are willing to buy them. Bonds in the secondary market sell at discount price q^{SM}.

For the sake of consistency with the model we keep track of domestic debt outstanding. However, our analysis is also valid for the case when $b_h = 0$, as in Broner et al. (2010). Therefore we can see this section as a generalization of their work in which we allow for costly enforcement.[12] As we shall see, what matters for creating repayment incentives through secondary markets is not the level of home or foreign debt outstanding, but the relative difference between above-the-threshold foreign holdings $b_f - \bar{B}_f$ and below-the-threshold domestic accommodation space $\bar{B}_h - b_h$. We will call the former expression "defaultable foreign debt overhang" and the latter "domestic debt accommodation space".

We formulate this situation as a noncooperative game. There are three types of agents: domestic investors, foreign investors and the government. First, both populations of investors take simultaneous decisions on the amounts supplied and demanded in the secondary market given the secondary market discount price and beliefs about the government's subsequent action (default or repay). After trades have taken place, the secondary market closes and the government decides to either repay or default on foreign and domestic investors.

Foreign investors' strategy space is the quantity of bonds supplied in the secondary market:

$$s^f = \{b_f^{SM}(q^{SM}, d_f^{SM})\}, \quad x_f \in [0, b_f].$$

Domestic investors' strategy space is quantity demanded in the secondary market:

$$s^h = \{b_h^{SM}(q^{SM}, d_h^{SM})\}.$$

The government's strategy space consists of two decisions (repay or default) on the two markets:

$$s^g = \{d_f^{SM} \times d_h^{SM}\}, \quad d_f^{SM} \in \{0, 1\}, \quad d_h^{SM} \in \{0, 1\}.$$

Given strategies of the three players we can define payoffs for each player. Because of risk neutrality of the foreign investor her payoff is defined as her consumption in the second period and

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[12]In Broner et al. (2010), a government with discretion wants to default on foreign debt because it faces no penalties upon default $\delta^f = 0$. In our analysis, foreign default is due to the government's discretionary behavior with $\delta^f > 0$ and an unfortunate output shock.

is the function of her decision (quantity supplied on the secondary market b_f^{SM}), domestic investor's decision (quantity demanden on the secondary market b_h^{SM}) and the government's decision (to default or repay foreign debt d_f^{SM}):

$$U^f(b_h^{SM}, b_f^{SM}, d_f^{SM}) = \begin{cases} (b_f - b_f^{SM}) + q^{SM}b_f^{SM} & \text{if } d_f^{SM} = 0 \text{ and } b_f^{SM} = b_h^{SM} \\ q^{SM}b_f^{SM} & \text{if } d_f^{SM} = 1 \text{ and } b_f^{SM} = b_h^{SM} \\ b_f & \text{if } d_f^{SM} = 0 \text{ and } b_f^{SM} \neq b_h^{SM} \\ 0 & \text{if } d_f^{SM} = 1 \text{ and } b_f^{SM} \neq b_h^{SM} \end{cases} \quad (1.6.1)$$

where b_f is the amount of government bonds that foreign investors hold from the first period and q^{SM} is the discount price of bonds on the secondary market in the second period. The first two cases of equation (1.6.1) refer to a situation when demands meets supply and there is trade in bonds on the secondary market. The last two cases refer to a situation when there is no trade on the secondary market. On the other hand first and third case of equation (1.6.1) describe payoffs to a foreign investor when the government repays foreign debt, whereas second and fourth case describe payoffs to a foreign investor when the governments defaults on foreign debt.

Similarly, we define the payoff for the domestic investor. Her payoff differs from foreign investor's payoff mainly due to risk aversion. The payoff of the domestic investor is the utility from consumption ($u(c)$ as defined in equation (1.3.19)) in the second period after secondary market closes. The domestic investor decides on the quatity demanded in the secondary market b_h^{SM} taking the supply of bonds from foreign investors b_f^{SM} and the government decision to default or repay domestic debt d_h^{SM} as given:

$$U^h(b_h^{SM}, b_f^{SM}, d_f^{SM}) = \begin{cases} u\left(y_2 + b_h + b_h^{SM}\left(1 - q^{SM}\right) - T_2\left(1 + \tau_2\right)\right) & \text{if } d_h^{SM} = 0 \text{ and } b_f^{SM} = b_h^{SM} \\ u\left(y_2 - q^{SM}b_h^{SM} - T_2\left(1 + \tau_2\right)\right) & \text{if } d_h^{SM} = 1 \text{ and } b_f^{SM} = b_h^{SM} \\ u\left(y_2 + b_h - T_2\left(1 + \tau_2\right)\right) & \text{if } d_h^{SM} = 0 \text{ and } b_f^{SM} \neq b_h^{SM} \\ u\left(y_2 - T_2\left(1 + \tau_2\right)\right) & \text{if } d_h^{SM} = 1 \text{ and } b_f^{SM} \neq b_h^{SM} \end{cases}$$
$$(1.6.2)$$

Finally, the government moves after the secondary market closes. The government decides whether to default of repay both debts d_h^{SM}, d_f^{SM} taking b_h^{SM} and b_f^{SM} as given and its payoff is defined by (1.6.2). The government decision boils down to two default thresholds policies as shown in derivations (1.3.11)-(1.3.16). These policies, given the trade on the secondary market in the

second period, translate to:

$$d_h^{SM}(b_h^{SM}, b_f^{SM}) = \begin{cases} 0 & \text{if } b_h + b_h^{SM} \leq \bar{B}_h \\ 1 & \text{if } b_h + b_h^{SM} > \bar{B}_h \end{cases} \tag{1.6.3}$$

$$d_f^{SM}(b_h^{SM}, b_f^{SM}) = \begin{cases} 0 & \text{if } b_f - b_f^{SM} \leq \bar{B}_f \\ 1 & \text{if } b_f - b_f^{SM} > \bar{B}_f \end{cases} \tag{1.6.4}$$

A Nash equilibrium of this game is the triplet of strategies $\{s_{f*}, s_{h*}, s_{g*}\}$ for which quantity demanded b_h^{SM} equals quantity supplied b_f^{SM} given market clearing price q^{SM*} and beliefs of investors are consistent with the government decisions d_h^{SM*}, d_f^{SM*}:

$$b^{SM*} = b_f^{SM}(q^{SM*}, d_f^{SM*}) = b_h^{SM}(q^{SM*}, d_h^{SM*}) \tag{1.6.5}$$

$$d_h^{SM*} = d_h^{SM}(b_h^{SM*}, b_f^{SM*}) \tag{1.6.6}$$

$$d_f^{SM*} = d_f^{SM}(b_h^{SM*}, b_f^{SM*}) \tag{1.6.7}$$

We split our analysis into two parts. In the first, we analyze the situation when foreign debt overhang is greater than domestic debt accommodation space $(b_f - \bar{B}_f) > (\bar{B}_h - b_h)$. That is, in order to be repaid, foreign investors have to sell more bonds than domestic investors can accommodate and still be repaid. It is thus impossible that both groups be repaid after the secondary market closes. In the second part, we analyze the reverse situation, when foreign debt overhang is smaller than domestic debt accommodation space $(b_f - \bar{B}_f) < (\bar{B}_h - b_h)$. In this situation domestic investors can safely buy what foreign investors need to supply in order to be repaid. In theory, secondary markets could allow both groups of investors to be repaid.

We will look for Nash equilibria in pure strategies with continuous strategy sets. The precise outcomes of the model will depend on the assumptions we make about the possibility of investor coordination and of voluntary debt haircuts. In terms of investor coordination, we consider two different cases. First, we consider the case in which the set of investors is a continuum (infinite number of investors, each investor has size zero). Second, we modify this assumption and introduce a finite number of investors (each investor has size ϵ). This theoretical notion has a very intuitive interpretation in our game. By assumption, a zero-size investor does not internalize the effects of her individual decision on aggregate action of the set of investors of her class (domestic or foreign), whereas an ϵ-size investors does. If there are externalities in this game (and we shall see that indeed externalities arise) then an ϵ-size investor internalizes them. Therefore it is equivalent to say that zero-size investors cannot coordinate their actions while ϵ-size investors can coordinate. For each of the two parts (foreign debt overhang dominates, domestic accommodation space dominates) we will analyze four cases, when each set of investors either can or cannot coordinate.

The second important assumption is either forbidding or allowing free disposal. When free

Table 1.6: Secondary Markets and Haircuts
when Foreign Debt Overhang is Greater

| | | Foreign Investors | |
		Coordinate	Don't coordinate
Domestic Investors	Coordinate	FD (δ^f); $b^{SM} \in (\bar{B}_h - b_h, b_f - \bar{B}_f)$ SM reduce welfare Haircut equilibrium restores repayment	FD (δ^f); $b^{SM} = \bar{B}_h - b_h$ SM reduce welfare No Haircut equilibrium
	Don't coordinate	DD (δ^h); $b^{SM} = b_f - \bar{B}_f$ SM likely increase Haircut equilibrium restores repayment	TD ($\delta^f + \delta^h$); SM reduce welfare No Haircut equilibrium

disposal is forbidden, the amount of bonds issued must be equal to the amount of bonds claimed. When free disposal is allowed, each investor can voluntarily burn some of her bonds, so the amount of bonds claimed can be lower than the amount of bonds issued. Free disposal also has a very intuitive interpretation in our example. When free disposal is allowed and exercised, we can think of this as a voluntary debt haircut.

Table 1.6 gives a brief summary of the results of secondary markets and haircuts, when foreign debt overhang dominates. We are initially, before the secondary market opens, in situation B: the economy would suffer the foreign default cost δ^f and the amount of domestic debt b^h needs to be either rolled over or repaid by distortionary taxation. If trade on the secondary market does not alter the outcome in terms of default of the primary market (*the first row* of Table 1.6), any trade on secondary market is undesirable from the welfare point of view, because it either increases the risk of default or induces dead-weight losses of distortionary taxation. If trade on the secondary market alters the outcome in terms of default of the primary market(*the second row* of Table 1.6), the welfare analysis is ambiguous in some cases. However, we can provide intuition for some cases. First, if both domestic and foreign investors are infinitesimal, the economy suffers the output loss $(1 - \delta^f)(1 - \delta^h)y$ upon total default instead of the output loss $(1 - \delta^f)y$ upon foreign default, but both debts are set to zero. However, if it was desirable to have total default from the welfare point of view, total default would happen on primary market. Second, if foreign investors are ϵ-size and domestic investors are infinitesimal, the economy suffers the output loss $(1 - \delta^h)y$ upon domestic default instead of the output loss $(1 - \delta^f)y$ upon foreign default and a substantial reduction of foreign debt.

Table 1.7 gives a brief summary of the results of secondary markets and haircuts, when domestic accommodation space dominates. We are initially, before the secondary market opens, in situation B: the economy would suffer the foreign default cost δ^f and the amount of domestic debt b^h needs to be either rolled over or repaid by distortionary taxation. Trade on the secondary market restores repayment of both debt. if both domestic and foreign investors are infinitesimal, the economy suffers the output loss $(1 - delta^f)(1 - delta^h)y$ upon total default instead of the output loss $(1 - delta^f)y$ upon foreign default, but both debts are set to zero. However, if it was desirable to have total default from the welfare point of view, total default would happen on primary market. Second, if

Table 1.7: Secondary Markets and Haircuts
when Domestic Accommodation Space is Greater

		Foreign Investors	
		Coordinate	Don't coordinate
	Coordinate	SM restore repayment on both markets	
Domestic Investors			
	Don't coordinate	Haircut equilibrium restores repayment	No Haircut equilibrium

foreign investors are ϵ-size and domestic investors are infinitesimal, the economy suffers the output loss $(1 - delta^h)y$ upon domestic default instead of the output loss $(1 - delta^f)y$ upon foreign default and a substantial reduction of foreign debt.

1.6.2   Equilibria when foreign debt overhang dominates

Proposition 4. *If both domestic and foreign investors are infinitesimal (cannot coordinate) and the defaultable foreign debt overhang is greater than the domestic debt accommodation space:*
a. Nash equilibrium is indeterminate and degenerate.
b. $b^{SM} \in (\bar{B}_h - b_h, b_f - \bar{B}_f)$, $q^{SM} = 0$.
c. Both debts are defaulted on: $d_h^{SM} = 1$, $d_f^{SM} = 1$.

Proof. See Appendix 1.8.4.   □

The only Nash equilibrium under this specification of the game is indeterminate and occurs at a discount price equal to zero. This specification of the game suffers from a well known equilibrium existence problem due to discontinuous payoffs (see Dasgupta and Maskin (1986a) and Dasgupta and Maskin (1986b)). Because of discontinuous payoffs, the best response functions of both investors do not cross at any positive price, which is demonstrated in the proof of the proposition.

Proposition 4 shows then that under certain circumstances secondary markets do not help create incentives for repayment of government debt, when those incentives are absent on the primary market. Moreover, as the equilibrium is indeterminate and degenerate, the outcome of secondary market trade is uncertain. This result may shed some light on why, in turbulent times, secondary markets may cease to function. Russia in 1998 effectively defaulted on its obligations towards households but repaid its obligations to firms. Why there was no significant re-trade of bonds between households and firms on the secondary market remains an open question, but this proposition may provide some intuition.

We investigate this result further in altering the assumptions that neither domestic nor foreign investors can coordinate their actions. We formalize this idea by relaxing the assumption of each investor being zero-measure. Instead we assume that the measure of each investor is $\epsilon > 0$, so that the economy is populated by $\frac{1}{\epsilon}$ investors.

Figure 1.8: Trade in secondary markets improves welfare (Proposition 5)
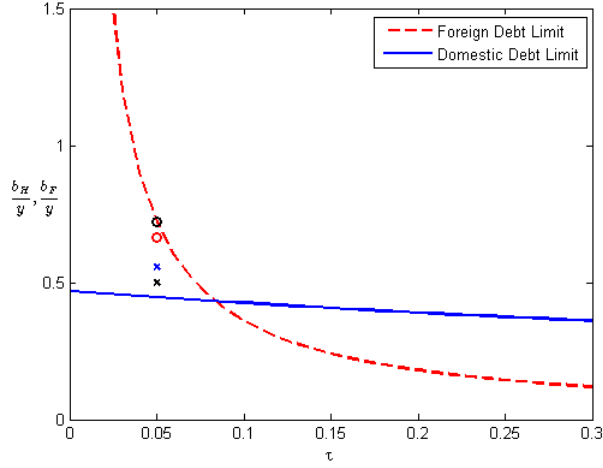
Proposition 5. *If domestic investors are ϵ-size (are able to coordinate) and the defaultable foreign debt overhang is greater than the domestic debt accommodation space:*

a. Nash equilibrium in pure strategies is indeterminate but yields a unique allocation.

b. $b^{SM} = \bar{B}_h - b_h, \qquad q^{SM} = 0$.

c. Domestic debt is repaid $d_h^{SM} = 0$ and foreign debt is defaulted on $d_f^{SM} = 1$.

Proof. See Appendix 1.8.4. $\hspace{1cm}\square$

The result in Proposition 5 is graphically depicted in Figure 1.8. The red circle and the blue cross show the situation before trade on the secondary market. With trade, domestic investors increase their holdings up to their default threshold and are repaid (black circle). Foreign investors decrease their holdings, but are nevertheless defaulted on (black cross) as their bond holdings are still above the default threshold. Note that the equilibrium in Proposition 5 holds when foreign investors both can and cannot coordinate. The ability to coordinate among domestic investors is not only a sufficient condition to sustain repayment incentives on the domestic market, but also allow domestic investors to capture the whole surplus generated by trade on the secondary market ($q^{SM} = 0$). Hence, trade on the secondary market does not affect welfare of foreign investors.

Lastly, let us study the reverse situation. Now foreign investors can coordinate and domestic investors are all zero-measure.

Proposition 6. *If foreign investors are ϵ-size (are able to coordinate), domestic investors are infinitesimal (cannot coordinate) and the defaultable foreign debt overhang is greater than the domestic debt accommodation space:*

a. Nash equilibrium in pure strategies is unique and degenerate.

Figure 1.9: Trade in secondary markets destroys welfare (Proposition 6)
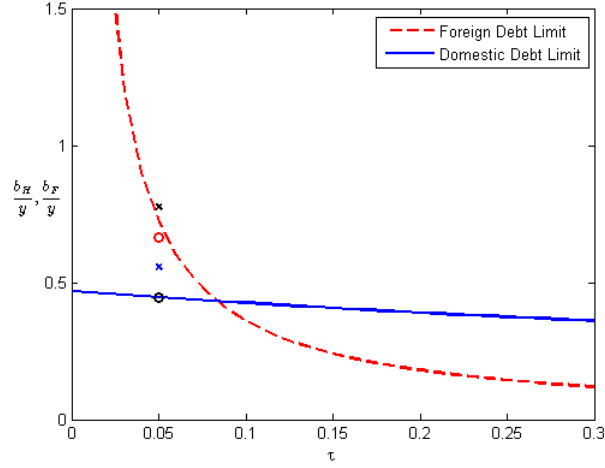
b. $b^{SM} = b_f - \bar{B}_f, \qquad q^{SM} = 0.$

c. Domestic debt is defaulted on $d_h^{SM} = 1$ and foreign debt is repaid $d_f^{SM} = 0.$

Proof. See Appendix 1.8.4. □

Proposition 6 shows an interesting result. Under the mix of unfavorable circumstances for domestic investors (a low accommodation space relative to the foreign debt overhang, and a lack of domestic coordination while foreign investors can coordinate), introducing a secondary market reverses the selective default result that would otherwise occur on the primary market.

This situation is shown in Figure 1.9. Again, the blue cross and the red circle stand for the situation before secondary markets open (foreign default and domestic repayment). Now foreign investors are able to re-trade their defaultable debt overhang to home investors, and are repaid by the government (black circle). Domestic investors exceed the domestic debt default threshold and are defaulted on by the government (black cross). Instead of defaulting on its foreign obligations, the government defaults on domestic debt holdings, and foreign obligations are repaid.

Proposition 7. *If foreign investors are allowed free disposal and are ϵ-size (can coordinate):*

a. *The game is reduced to two players: foreign investors and the government.*

b. *Equilibrium is unique.*

c. $b_f - \bar{B}_f$ *is freely disposed of.*

d. *Both debts are repaid: $d_h = 0$ and $d_f = 0$.*

Proof. See Appendix 1.8.4. □

Proposition 8. *If foreign investors are allowed free disposal and are infinitesimal (cannot coordinate), the Nash equilibrium in pure strategies does not exist.*

Proof. See Appendix 1.8.4.   □

Propositions 7 and 8 show that voluntary haircuts would occur only when foreign investors are able to coordinate. This is because without coordination each investor has incentives to deviate from the haircut allocation and freely dispose less than $b_f - \bar{B}_f$, not expecting this would change the government's decision. After a voluntary haircut, foreign debt is repaid. Domestic debt is unaffected and also repaid. Interestingly, voluntary haircuts increase welfare and restore repayment incentives in situations when secondary markets may fail to deliver a well-behaved equilibrium (Proposition 6).

Results in this section may shed some light on the Greek government debt crisis, when in 2012 private investors agreed to a voluntary haircut while the trade of government bonds on secondary markets was negligible.

1.6.3   Equilibria when domestic accommodation space dominates

In this part we analyze the situation in which the foreign debt overhang is smaller than the domestic debt accommodation space $(b_f + b_h) < (\bar{B}_h + \bar{B}_f)$.

Proposition 9. *If domestic investors can accommodate all of the defaultable foreign debt overhang:*
a. Nash equilibrium is indeterminate (but well-behaved).
b. $b^{SM} \in (b_f - \bar{B}_f, \bar{B}_h - b_h)$, $q^{SM} = 1$.
c. Both debts are repaid: $d_h^{SM} = 0$ and $d_f^{SM} = 0$.

Proof. See Appendix 1.8.4.   □

The result in Proposition 9 is similar to Broner et al. (2010). In their paper, before the secondary market opens the government wants to default on foreign investors (and domestic debt is zero). In the secondary market, foreigners re-trade all of their holdings to domestic investors, and the government repays in full to domestic investors. Here, foreign investors only re-trade the amount above their default threshold (in Broner et al. (2010) this threshold is zero), but it is enough to restore repayment on the foreign market. Domestic investors increase their holdings, but are still below the default threshold (in the cited paper this threshold is infinity) and are therefore also repaid by the government. The necessary condition for secondary markets to restore repayment on both markets when tax enforcement is costly is that the foreign debt overhang is smaller than the domestic debt accommodation space $(b_f - \bar{B}_f) < (\bar{B}_h - b_h)$.

This result affects the workings of the primary market, as it turns risky foreign debt into riskless debt. Therefore the discount price on the primary market is $q_f = \frac{1}{1+r}$.

The aim of this section is to show that the effects of secondary markets for government bonds are ambiguous in the situation where either domestic or foreign debt would otherwise be defaulted on. This section by no means exhausts the topic. What this section proves is that strengthening the

role and efficiency of secondary markets is not a remedy that can automatically solve the sovereign risk problem. We find that the equilibria are dependent on underlying conditions, such as investors' coordination abilities and the relative size of demand and supply of bonds. Clearly more research, both empirical and theoretical, is warranted on the workings of secondary markets during sovereign risk crisis.

1.7 Conclusions

We develop a model of sovereign debt issuance on international and domestic markets, and of selective defaults. By adding domestic investors we introduces a new level of heterogeneity to a standard model of strategic sovereign default. Our model is capable of replicating selective default frequencies and business cycle statistics, and we show that including two types of investors brings the model closer to the data, as it was suggested by Aguiar and Amador (2014). Our model is a useful tool to study how the fractions of investors in public debt arise endogenously in an equilibrium, and how the composition of debt is correlated with spreads and the total debt. Our model shows that although foreign debt is more valuable and can in principle be used to smooth both output and taxation shocks, the government would still use domestic debt to smooth the domestic taxation shock. In a world with two uncorrelated shocks (output and taxation), two types of debt (foreign and domestic) are issued, and selective defaults arise endogenously (as we observe in the data).

On the positive side, we provide a theory of the role of secondary sovereign debt markets in restoring repayment incentives. Trade in secondary markets can restore the government's repayment incentives when the supply of defaultable bonds from foreigners is low compared to demand from domestic investors. However, when the supply of defaultable bonds is high (compared to demand), then secondary markets cannot sustain repayment on both markets. If domestic investors are able to coordinate, then trade in secondary markets can be welfare-improving for both sides. Otherwise, if domestic investors cannot coordinate, then it is uncertain whether any trade would occur on secondary markets.

On the other hand, if foreign investors are able to coordinate then they will be willing to accept a voluntary haircut on the eve of foreign default. This would restore debt repayment on the foreign market. In the absence of coordination, foreign investors will never accept haircuts and foreign debt will be always defaulted on. In particular situations when secondary markets fail to improve the allocation, a voluntary haircut does, and *vice versa*. Our results shed some light on the Greek government debt crisis, when in 2012 private investors agreed to a voluntary haircut while trade in government bonds on secondary markets was negligible.

How investors' coordination may arise endogenously is an interesting and important issue for further research. However, as investors' coordination improves the allocation and welfare outcomes, we hypothesize that within a group each investor has incentives to defect on coordination and free-

ride on the coordinating majority. Instances of this behavior have been seen in recent default episodes, especially prior to the 2014 Argentinian default.

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1.8 Appendix

1.8.1 Two Period Model

A. Algorithm

We solve for the government's optimal domestic and foreign debt policies in the first period following these steps:

1. Assuming that (1.3.17) and (1.3.18) are satisfied in the second period, we write the government's problem as (1.3.19).

2. The solution to the problem is then a set of two first-order conditions (1.3.22) and (1.3.23) and pricing rules (1.3.20) and (1.3.21).

3. We pick a set of parameters and solve (1.3.19) numerically.

4. We confirm that the resulting policy functions b_f, b_h and equilibrium prices q_f, q_h satisfy conditions (1.3.17)–(1.3.18), and therefore that expectations in (1.3.19) are consistent in equilibrium.

5. We vary one parameter at a time within a range where (1.3.17)–(1.3.18) are satisfied to derive comparative statics.

B. Parametrization

Parameter	Value	Range	Description
y	1		Output today / High output tomorrow
σ	1		Risk aversion of Home agents
Π_y	0.72	[0.5 , 1]	Probability of high output
Π_τ	0.8	[0.5 , 1]	Probability of low tax distortion
g	0.7	[0.5 , 0.8]	Gov. expenditure
y_L	0.5	[0.1 0.7]	Low output
τ_1	0.1	[0 , 0.2]	Tax distortions today
τ_H	0.15	[0.1 , 0.2]	Tax distortions tomorrow (high)
τ_L	0.05	[0 , 0.15]	Tax distortions tomorrow (low)
δ_f	0.65	[0.42 , 0.87]	Output cost of Foreign default
δ_h	0.05	[0 , 0.15]	Output cost of Home default
r	0.00		Risk-free interest rate

1.8.2   Solution Algorithm

1. Guess price schedules p_f^0 and p_h^0.

2. Calculate consumption in autarky c^{aut} and value of permanent autarky V^{aut}.

3. Guess four value functions V^{00}, V^{0fd}, V^{0hd} and V^{0td} using V^{aut}.

4. Calculate optimal policies b_f and b_h in repayment given V^{00} as continuation value and prices.

5. Calculate value of repayment V^r given optimal policies and continuation value.

6. Repeat steps 4 and 5 for foreign default and domestic default to obtain V^{1fd} and V^{1hd}.

7. Calculate value of total default V^{1td} given V^{1fd} and V^{1hd} and V^{00}.

8. Derive optimal default policies d comparing four value functions V^r, V^{1fd} V^{1hd} V^{1td} at each grid point $\{b_f, b_h, y, \tau\}$.

9. Derive new value function V^{10} as maximum of four value functions used in previous step at each grid point.

10. Substitute $V^{00} = V^{10}$.

11. Repeat steps 3–9 until convergence in value function.

12. Given optimal default policies d calculate prices of foreign and domestic debt q_f^1 and q_h^1 at each grid point using pricing rules (1.4.8) and (1.4.7).

13. Update prices $q_f^0 = \alpha^f q_f^0 + (1 - \alpha^f) q_f^1$ and $q_h^0 = \alpha^h q_h^0 + (1 - \alpha^h) q_h^1$.

14. Repeat steps 1–13 until convergence in prices.

1.8.3   Two Period Model. Graphical Solutions

Effects of changing Pi

Effects of changing Pi-tau

Effects of changing G

Effects of changing tau2H

Effects of changing tau2L

Effects of changing Y_L
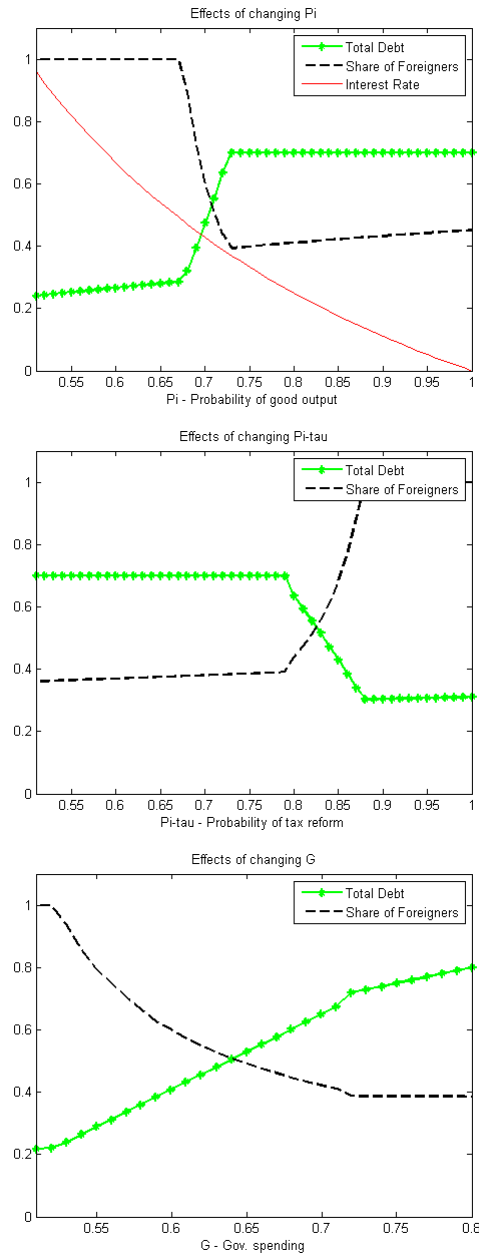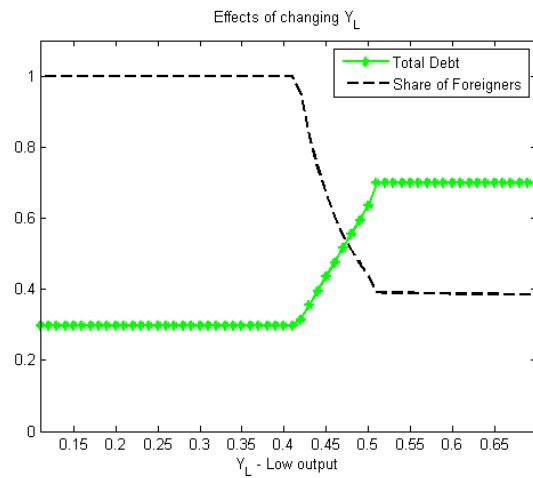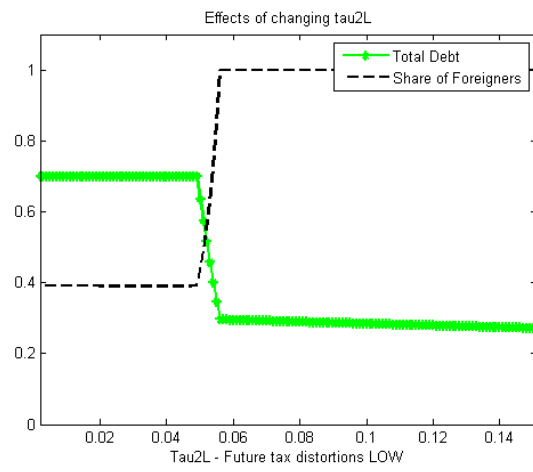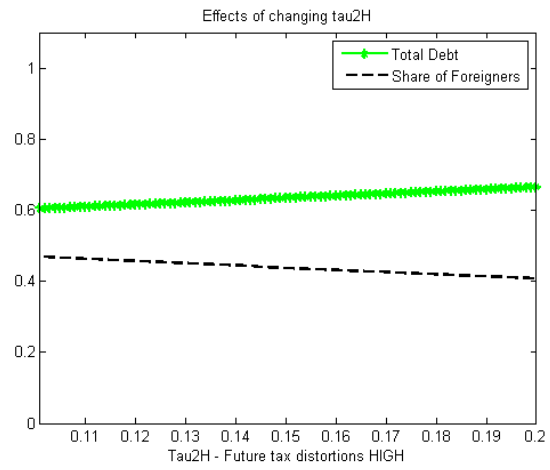
1.8.4   Secondary Markets. Proofs of Propositions

Proof of Proposition 4. We study situation B depicted in the Figure 1.2: outcome on the primary market yields foreign default (FD) and domestic repayment (DR). Before engaging in the trade on the secondary markets, both types of investors (domestic and foreign) need to form expectations about the government's decision to default. There are three possible outcomes: foreign default and domestic repayment (FD, DR); foreign repayment and domestic default (FR, DD) and total default (FD, DD). The repayment of both debts is ruled out by the fact that total debt is greater than the total default limit $b_f + b_h > \bar{B}_h + \bar{B}_f$.

There are two thresholds related to the volume traded in the secondary markets b^{SM}. If the traded volume lies below lower threshold $b^{SM} \leq \bar{B}_h - b_h$, domestic debt is repaid, while foreign debt is defaulted. If the traded volume is between lower and upper threshold $\bar{B}_h - b_h < b^{SM} < b_f - \bar{B}_f - b_h$, both debts are defaulted; if the traded volume lies above upper threshold $b^{SM} \geq \bar{B}_h - b_h$ domestic debt is defaulted, while foreign debt is repaid.

We draw three best-response correspondences: for foreign investors (*the solid red line*), for domestic investors (*the dashed blue line*) and for the government in a single graph with the amount of trade b^{SM} on the horizontal axis and the price q^{SM} of debt on the vertical axis. *The brown shaded area* represents the area of trade, in which the expectations are consistent with the government decision: in the first panel the shaded area represents the amounts traded for which the government will choose (FD, DR), in the second panel the shaded area represents the amounts traded for which the government will choose (FD, DD) and in the third panel shaded area represents the amouts traded for which the government will choose (FR, DD). A crossing of the two best best response correspondences, which lies within shaded area represents a Nash equilibrium in pure strategies (secondary markets clear and expectations of investors are consistent with the government's decision). As can be seen in Figure 1.10, the only outcome that is consistent is the total default. In this case the price on the secondary markets is zero, but the amount of trade is undetermined.

QED

Figure 1.10: Best response functions for infinitesimal investors

(a) (FD, DR)   (b) (FD,DD)   (c) (FR,DD)

□
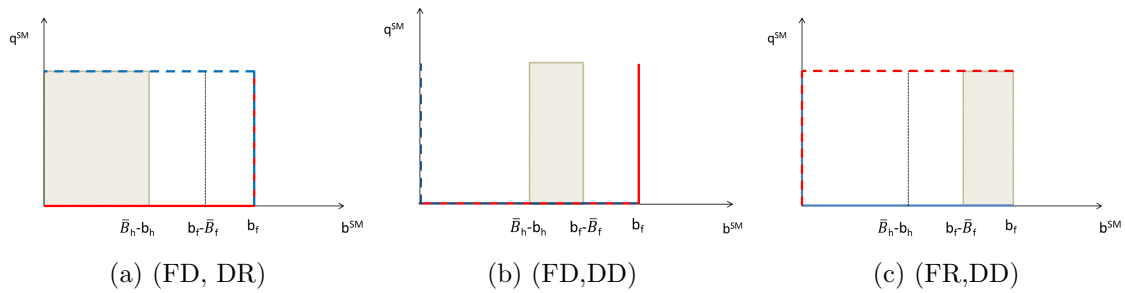
Proof of Proposition 5. We follow a similar procedure to Proof of Proposition 1.8.4. However, there is one substantial difference. If domestic investors are ϵ-size, they internalize the effects of their actions on the government's decision. Since $b_f + b_h > \bar{B}_h + \bar{B}_f$ at least one type of debt will be defaulted. The outcome on the primary market yields domestic repayment. Since each domestic investor is ϵ-size, she will never demand any amount that exceeds domestic default threshold, as this will unambigously decrease her payoff. Hence $b_h^{SM} \leq \bar{B}_h - b_h$. In this, domestic investors can effectively insure domestic repayment.

Therefore, the only possible outcome that is consistent in equilibrium is foreign default and domestic repayment (FD,DR). Contrary to 1.8.4 we can narrow our considerations and study only one game when both types of investors expect (FD, DR). The best response function of single foreign investor depends on whether she is: (a) zero-size, (b) ϵ-size and expecting domestic investors to be zero-size (uninformed foreign investor) or (c) ϵ-size and knows that domestic investors are ϵ-size (informed foreign investor). In Figure 1.11 we draw best response functions for the three cases.

If foreign investors are infinitesimal (panel (a)) they do not coordinate and each of them wants to sell all of her debt holdings (b_f) as long as price on the secondary markets is positive. Hence, there exist a unique equilibrium where at zero price q^{SM} the maximum possible amount of debt $b^{SM} = \bar{B}_h - b_h$, that insures domestic repayment, is traded. Secondly, when foreign investors are ϵ-size but uninformed (panel (b)), they coordinate their supply on the amount that exceeds $b_f - \bar{B}_h$ (that will insure they are repaid by the government in the primary market) as long as price is positive. Similarly, there exist a unique equilibrium where at zero price q^{SM} the maximum possible amount of debt $b^{SM} = \bar{B}_h - b_h$, that insures domestic repayment, is traded. Thirdly, if foreign investors are ϵ-size and informed that domestic investors coordinate (panel (c)), the traded amount remains $b^{SM} = \bar{B}_h - b_h$, but the price is undetermined $q^{SM} \in [0, 1]$.

QED   □

Figure 1.11: Best response functions for ϵ-size domestic investors

(a) Infinitesimal foreign investors   (b) Uninformed ϵ-size foreign investors   (c) Informed ϵ-size foreign investors
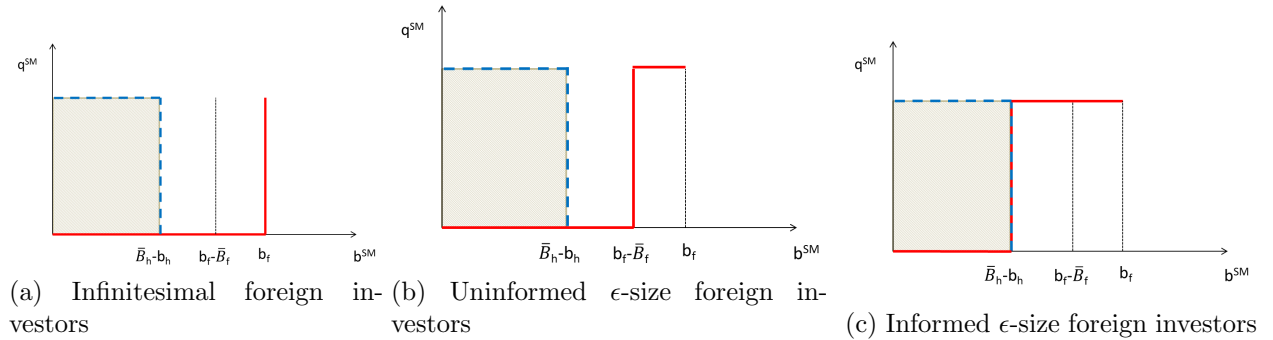
Proof of Proposition 6. We consider the opposite case to the Proof of Proposition 1.8.4. Foreign investors are ϵ-size, they internalize the effect of their actions on the government decision, while

domestic investors are infinitesimal. Since $b_f + b_h > \bar{B}_h + \bar{B}_f$, at least the one type of debt will be defaulted by the government. Hence, foreign investors coordinate to insure foreign repayment (FR). The only possible outcome that is consistent in equilibrium is foreign repayment and domestic default (FR,DD). In Figure 1.12 we draw the best response functions for this case. There exists a unique equilibrium, where at zero price q^{SM} the minimum possible amount $b^{SM} = b_f - \bar{B}_f$, that insures foreign repayment, is traded. QED

Figure 1.12: Best response functions for ϵ-size foreign and infinitesimal domestic investors
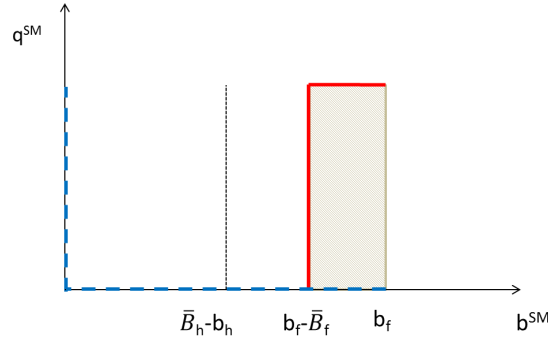
Proof of Proposition 7 and 8. We consider an alternative way (compared to Proposition 6) to bring foreign debt b_f down (weakly) below its default threshold $\bar{B}_f$. Foreign investors are ϵ-size, they internalize the effect of their actions on the government decision. As shown in the previous proposition, engaging in the secondary market does not bring direct benefit for foreign investors, but it might restore foreign repayment under very specific circumstances. The option of free disposal plays a similar role. It does not bring a direct benefit, but it insures foreign repayment as long as foreign investors can coordinate on the minimum amount of a haircut $b_f - \bar{B}_f$. The free disposal requires only the coordination between foreign investors. QED

Proof of Proposition 9. We study situation B depicted in the Figure 1.2: outcome on the primary market yields foreign default (FD) and domestic repayment (DR). Before engaging in the trade on the secondary markets, both types of investors (domestic and foreign) need to form expectations about the government's decision to default. There are three possible outcomes: foreign default and domestic repayment (FD, DR); foreign repayment and domestic default (FR, DD) and total default (FD, DD). The repayment of both debts is ruled out by the fact that total debt is greater than the total default limit $b_f + b_h > \bar{B}_h + \bar{B}_f$.

There are two thresholds related to the volume traded in the secondary markets b^{SM}. If the traded volume lies below lower threshold $b^{SM} \leq \bar{B}_h - b_h$, domestic debt is repaid, while foreign debt

is defaulted. If the traded volume is between lower and upper threshold $\bar{B}_h - b_h < b^{SM} < b_f - \bar{B}_f - b_h$, both debts are defaulted; if the traded volume lies above upper threshold $b^{SM} \geq \bar{B}_h - b_h$ domestic debt is defaulted, while foreign debt is repaid.

We draw three best-response correspondences: for foreign investors (*the solid red line*), for domestic investors (*the dashed blue line*) and for the government in a single graph with the amount of trade b^{SM} on the horizontal axis and the price q^{SM} of debt on the vertical axis. *The brown shaded area* represents the area of trade, in which the expectations are consistent with the government decision. A crossing of the two best best response correspondences, which lies within shaded area represents a Nash equilibrium in pure strategies (secondary markets clear and expectations of investors are consistent with the government's decision).

In Figure 1.13 we draw best response correspondences for the case of infinitesimal foreign and inifinitesimal domestic investors. Only in panel (b), depicting the case when both types of investors expect domestic repayment and foreign repayment (FR, DR), best correspondences cross in the shaded area, which means that expectations are consistent in equilibrium. In a unique equilibrium both debt are repaind, the volume volume is however undetermined $b^{SM} \in (b_f - \bar{B}_f, \bar{B}_h - b_h)$ and the price is equal to one $q^{SM} = 1$.

Figure 1.13: Best response functions for infinitesimal foreign and infinitesimal domestic investors

(a) (FD, DR)   (b) (FR, DR)   (c) (FR, DD)
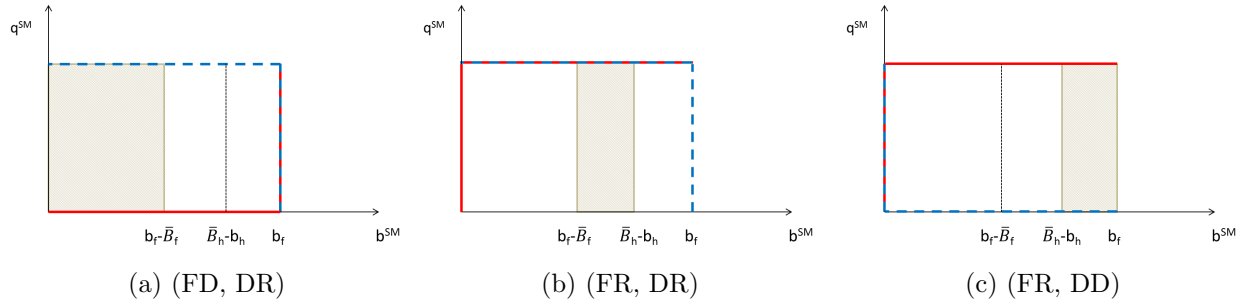
Since $b_f + b_h < \bar{B}_h + \bar{B}_f$, both debts can be potentially repaid, even without coordination. Coordination of foreign/domestic investors reinforces foreign/domestic repayment. Interestingly, coordination does not change the outcome. In Figure 1.14 we plot best response correpospondences of domestic and foreign investors together with government's optimal default decision in single graphs for three remaining cases: (a) ϵ-size foreign and infinitesimal domestic investors, (b) infinitesimal foreign and ϵ-size domestic investors and (c) ϵ-size foreign and ϵ-size domestic investors. For each case best response correspondences differ slightly, but an equilibrium is the same across all three cases.

Finally, let us consider two other cases, in which one class of investors consists of ϵ-size agents, whereas the other of infinitesimal agents. As shown in Propositions 5 and 6 the class that consists of agents of ϵ-size has an advantage, as they can coordinate on their most favourable outcome. We

Figure 1.14: Best response functions for ϵ-size investors

(a) ϵ-size foreign and infinitesimal domestic investors

(b) infinitesimal foreign and ϵ-size domestic investors

(c) ϵ-size foreign and ϵ-size domestic investors
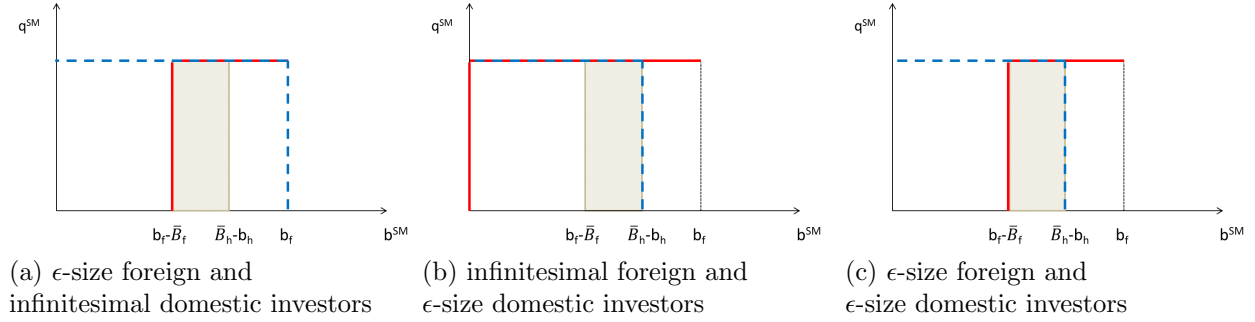
Figure 1.15: Best response functions with one-sided advantage

(a) ϵ-size foreign and infinitesimal domestic investors (FR, DD)

(b) infinitesimal foreign and ϵ-size domestic investors (FD, DR)

want to check, whether in the case studied here, the side with an advantage can coordinate on their most favourable outcome. In panel (a) of Figure 1.15 we plot best response correspondences when foreign investors are ϵ-size (have an advantage) and domestic investors are infinitesimal. Both investors expect government to default on domestic debt and repay the foreign debt (FR, DD). Even though foreign investors might potentially coordinate on any level of debt, for example $\bar{B}_h - b_h$, they would not do so. This volume and the price $q^{SM} = 0$ cannot be an equilibrium, because there is a profitable deviation for each foreign investors to reduce her traded volume down to $b_f - \bar{B}_f$ and therefore to secure domestic repayment. Foreign repayment and domestic default (FR, DD) cannot be sustained as an equilibrium.

In panel (b) of Figure 1.15 we plot best response correspondences when domestic investors are ϵ-size (have an advantage) and foreign investors are infinitesimal. Both investors expect government to default on foreign debt and repay the domestic debt (FD, DR). Even though domestic investors might potentially coordinate on any level of debt, for example $b_f - \bar{B}_f$, they would not do so. This volume and the price $q^{SM} = 0$ cannot be an equilibrium, because there is a profitable deviation for each domestic investors to always increase the traded volume, up until the point, where it meets

supply from foreign investors if $\bar{B}_h - b_h$ and therefore to secure foreign repayment. Foreign default and domestic repayment (FD, DR) cannot be sustained as an equilibrium.

QED

$\square$

Chapter 2

Optimal Inflation, Average Markups and Asymmetric Sticky Prices

Abstract

In state-of-the-art New Keynesian model firms are monopolistically competitive and prices are sticky. However, the average markup resulting from the staggered price setting is usually assumed away either by production subsidy or by the zero-inflation steady state. Also, in models of an open economy the same level of price stickiness is assumed for both countries. In this paper I study the optimal rate of inflation in a two country model keeping the average markup and allowing price stickiness to differ between countries. There are two channels that govern the optimal rate of inflation. First, with local currencies an inflation tax is partly imposed on the foreign country, so it is optimal to inflate. Second, the average markup constitutes a cost of holding money so it is optimal to deflate. The paper has four novel findings: 1) in the local currencies regime the first motive dominates and the optimal inflation is positive. 2) In a monetary union the first motive is absent and the optimal inflation is negative and below the Friedman rule. 3) A monetary union improves global welfare even when stickiness is different in two countries. However, when this difference is large, only one country (the one with higher stickiness) benefits from the integration. 4) A monetary union can be welfare improving for each country, if a transfer is introduced from the more sticky to the more flexible country of (depending on the parameters up to) 2% of its GDP.[1]

Keywords: optimal inflation, monetary union, international spillovers, monetary policy
JEL Classification: E52, F41, F42

2.1   Introduction

In this paper I ask two half-century-old questions. The first one is about the optimal rate of inflation. In a New Keynesian literature firms are monopolistically competitive and price stickiness is the main transmission channel of a monetary policy. An inflation rate affects real variables (consumption, labor supply and output) through both of these frictions. Therefore both are important to determine the optimal rate of inflation. However, the New Keynesian literature almost exclusively relies on the assumption of zero steady-state inflation. In this steady-state the average markup is constant and independent of an inflation rate, therefore one of the frictions is effectively assumed away. I lift this assumption and look for the optimal steady-state inflation in a simple two-country model of overlapping generations. The two countries setup allows me to study optimal outcomes under two different regimes: local currencies and a monetary union[2].

In the local currencies economy there are two effects that determine the optimal rate of inflation. One is an international dimension of an inflation tax (the spillover effect) and the other one is that the average markup depends on the rate of inflation (the markup effect). The spillover effect works in the following way. Inflation reduces a return on money holdings. This reduces labor supply. The gain from inflation, increased utility from leisure, lies entirely within the economy. The cost of inflation, the reduced return from money holdings, is however spread across the two economies, as foreigners also hold the domestic currency (cash in advance) to buy imports. This creates an inflationary pressure in an economy with local currency. Like in Cooper and Kempf (2003) the local monetary authority finds it optimal to manipulate the terms of trade and create excessive inflation.

The markup effect works similarly to the Friedman rule. Friedman (1969) argued that the optimal rate of inflation should equalize costs and benefits of holding money. The real interest rate is the opportunity cost of holding money. As long as the real interest rate is positive the optimal rate of inflation should be negative, to compensate for this cost. In this paper the real interest rate is zero, but the average markup constitutes a real cost of holding money. The markup effect therefore creates a disinflationary pressure in an economy. For plausible parameter values the spillover effect dominates the markup effect in the economy with a local currency and optimal inflation is always positive.

In a monetary union however, the spillover effect is absent. The common monetary authority fully internalizes international spillovers and incentives to exploit the inflation tax disappear. The common monetary authority only cares about the average markup. Therefore, in a monetary union optimal inflation is always negative and, when price stickiness is symmetric in both countries, equal to one minus the average markup, that is below the Friedman rule. The monetary union setup can also be interpreted as a model of a closed economy. Schmitt-Grohe and Uribe (2010)

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[2]In this paper these settings correspond to other settings often studied in the literature: cooperation vs non-cooperation and flexible exchange rates vs. fixed exchange rates.

provide an excellent review of state-of-the-art literature and some new findings on the optimal rate of inflation. They identify the striking puzzle that available theories consistently imply that the optimal rate of inflation ranges from the Friedman rule to numbers insignificantly above zero, which is at odds with the empirical regularity regarding the size of the inflation targets around the world. This paper reinforces this puzzle by showing, among other things, that in a closed economy (or in a monetary union) with monopolistic competition and sticky prices the optimal rate of inflation is in fact below the Friedman rule. One of the novel contributions of Schmitt-Grohe and Uribe (2010) is the proof that in a closed economy with sticky prices and monopolistic competition (and without a production subsidy[3]) the optimal rate of inflation is in fact zero. This result is in stark contrast to Paustian and Stoltenberg (2008) and Khan et al. (2003), which show that the negative trend inflation according to the Friedman rule yields higher welfare than the zero-inflation. This is further reinforeced by the fact that the latter two contributions assume production subsidy, which, if anything, increases the level of steady-state optimal inflation. The result in my paper is in line with those two contributions. Because I do not assume any production subsidies, in my model the optimal rate of inflation is in fact below the Friedman rule. Later in the paper I explain the possible reason of the discrepancy of the mentioned results. All three mentioned papers however, deal with a closed economy setup. In contrast, this paper assumes two countries setup, which is suitable to study the trade-off between the average markup and inflation tax channels.

The two countries setup is also suitable to study the second, half-century-old question: are monetary unions optimal? It may seem that the large existing body of literature has exploited this question in every dimension. In a classical trade-off first formulated by Friedman (1953) and Mundell (1961), the benefit of a monetary union over a flexible exchange rates regime is the reduction in transaction costs, while the cost is the inability of a country to respond to its idiosyncratic shocks. In the Mundellian view the benefits from elimination of a currency conversion and nominal exchange rate fluctuations would encourage more integration in goods and capital markets. Both the upside and the downside of a Mundell-Friedman argument has been largely extended and widely studied in theory and in practice ever since. This paper focuses on the upside of this argument. The common monetary authority internalizes the interdependence of the two economies, the spillover effect disappears and joint welfare goes up.

Surprisingly however, the role of price stickiness on the optimal design of a monetary union has not yet been studied in detail. In a New Keynesian literature, where price stickiness is the main transmission channel of a monetary policy, the same level of stickiness is a common assumption in modes of an open economy[4]. A notable exception is Liu and Pappa (2008), who study gains from a monetary policy coordination when sectoral composition is different in two countries and (among other things) sectors may have different price stickiness. In their paper gains from coordination are

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[3]Starting with Rotemberg and Woodford (1999) it is common in the DSGE literature to undo the monopolistic competition distortion by a small production subsidy that renders steady-state efficient.

[4]See for example Clarida et al. (2001), Clarida et al. (2002), Pappa (2004), citeGM2008.

significant and due to a fact, that a single social planner can eliminate terms-of-trade externality that individual policymakers overlook. In this paper it corresponds to the elimination of the spillover effect. Also, as Liu and Pappa (2008) study a policy coordination rather than a monetary union, a single social planner is able to set subsidies individually for each sector in each country. In this paper a common monetary authority only sets a common inflation rate. When the assumption of symmetric price stickiness is lifted, gains from a monetary union are distributed unevenly. The country with more sticky prices benefits more from the monetary integration than the country with more flexible prices. When the difference is large, only one country benefits.

With the asymmetric stickiness the optimal choice of inflation in the local currencies regime differs between the countries. The country with higher price stickiness faces a stronger contraction bias and chooses lower inflation in equilibrium than the country with more flexible prices. In a monetary union inflation is reduced in both countries, as the spillover effect is removed. When the difference between the price stickiness between the two economies is high, a monetary union could in fact reduce welfare in the more flexible economy, as the optimal rate of inflation in the union is inefficiently low. The country with higher price stickiness reaps all the benefits of integration at the expense of the more flexible country. From the joint welfare perspective however, a monetary union is always strictly welfare improving. Therefore joining the union could also be sustained as an optimal choice for the economy with more flexible prices if coupled with a lump sum transfer from the economy with more sticky prices, who is a net beneficiary of an integration. The integration with a compensating transfer is therefore a Pareto improvement upon the local currencies regime. For plausible parameter values the size of this transfer is never greater than 2% of output of the contributor country.

In this paper high inflation in the local currencies regime can be viewed as an example of a free-rider problem as in Cooper and Kempf (2003), where inflation arises as a suboptimal equilibrium solution to the game between two monetary authorities and not between a central bank and private agents, as in Alesina and Barro (2002). In this paper monetary authorities, both in the local currencies and in the monetary union regime do not have any commitment problem. Creating a monetary union enables the single monetary authority to overcome this free-riding problem and reduces inflation to the welfare-maximizing level. The novelty of this paper is generalizing Cooper and Kempf (2003) framework by introducing sticky prices.

There is a large body of the New Open Economy Macroeconomics literature that studies the issue of a monetary cooperation and unions under sticky prices. Pappa (2004) studies the optimal monetary policy arrangements under cooperation, non-cooperation and union subject to technology shocks. She finds that monetary cooperation is welfare improving, however, countries are assumed to have same level of price stickiness and the model is evaluated around the zero steady-state inflation. I generalize her result by showing what happens when the two assumptions are relaxed.

Finally, I rely on the empirical evidence of price stickiness offered by Dhyne et al. (2005) and

Dhyne et al. (2009) who estimate price change frequencies and offer different indicators on price stickiness measures for the Euro area countries. They find that prices change infrequently and that there is substantial degree of heterogeneity in frequency of price changes across products and countries. Table 2.1 shows that the differences in the average monthly frequency of price changes in the Eurozone countries can be as high as double. This is the reason to allow for the possibility of asymmetric price stickiness in the model.

The remainder of this paper is organized as follows. In the next section I derive competitive equilibrium outcomes of an open economy given inflation rate. Section 3 studies the optimal inflation rate in an economy with local currency. Section 4 studies the optimal inflation rate and welfare gains in a monetary union. Section 5 shows how the monetary union can be Pareto improving upon the local currencies regime when price stickiness in the two countries is highly asymmetric. Last section concludes.

Table 2.1: Monthly frequency of price adjustment (in %) across some Eurozone countries

Country	Frequency
Germany	13.5
Spain	13.3
France	20.9
Italy	**10.0**
Portugal	**21.1**

Source: Dhyne et al. (2005)

2.2   The model

The aim of this paper is to study the consequences of a price stickiness on optimal conduct of monetary policy under local currencies and monetary union regimes. I build a two-country overlapping generations model with monopolistically competitive firms and nominal rigidity in the form of the staggered price adjustment as in Calvo (1983). Firms facing dynamic Calvo-type rigidities are optimizing as in Yun (1996), Woodford (2011) and King and Wolman (2013). Consumers are active in two periods. In first period they work, in second period they consume. The only mean to transfer labor revenues to the next period is through paper money. This generates money demand in the model economy. Both countries are populated by continuum of homogeneous agents. Consumers consume goods manufactured both at Home country and Foreign country. Labor is immobile. At time zero a monetary authority commits to a stable (time independent) money supply growth rate. Changes in money supply come as lump sum transfers for an old generation and are perfectly anticipated by a young generation. Two countries can differ in the level of price stickiness. Throughout the analysis I will denote real variables with lower case letters and nominal variables with capital

Table 2.2: Timing within a period in Home country

Firms	Young	Old
Signal to update prices		Receive money transfer
Set prices	Supply labor	Demand goods
Produce	Get paid in Home currency	Exchange currencies for Home and Foreign goods
	Exchange currencies	

letters. Foreign variables are denoted by a $*$ and the derivations for foreign variables are skipped whenever possible. The timing of events in Home country within one period is presented in Table 2.2.

Total consumption by Home consumers is an aggregate of consumptions of Home and Foreign goods:

$$c_t = (c_t^h)^\theta (c_t^f)^{1-\theta} \tag{2.2.1}$$

where θ is a parameter representing home bias in consumption. Both Home and Foreign consumption are aggregates over differentiated goods produced across firms indexed by z:

$$c_t^i = \left(\int_0^1 c_t^i(z)^{\frac{\epsilon-1}{\epsilon}} dz \right)^{\frac{\epsilon}{\epsilon-1}} \qquad i = \{h, f\}$$

where $\epsilon \geq 0$ is elasticity of substitution among differentiated goods. In next sections I analyze price setting behavior of firms and labor supply and consumption decisions of individuals.

2.2.1   Firms

In each country there is a continuum of monopolistically competitive firms producing differentiated goods. Each firms sells its goods to consumers in both Home and Foreign country. Each firm faces two demand schedules (from Home and Foreign consumers) given by individuals' solution to their expenditure minimization problem:

$$c_t^h(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon} c_t^h \tag{2.2.2}$$

$$c_t^{h*}(z) = \left(\frac{P_t^*(z)}{P_t^*} \right)^{-\epsilon} c_t^{h*} \tag{2.2.3}$$

where $c_t^h(z)$ and $c_t^{h*}(z)$ are the demands for Home variety z from Home and Foreign consumers. Home demand for variety z is a function of an aggregate demand c_t^h for Home goods by Home consumers, a relative price of variety z $\frac{P_t(z)}{P_t}$ and the elasticity of substitution ϵ.

Firms are assumed to be able to change their price only in specific states of nature and must

satisfy all demand at a quoted price. Each period every firm faces probability $1 - \lambda$ that it will be able to adjust its price:

$$P_t(z) = \begin{cases} P_{t-1}(z) & \text{with prob. } \lambda \\ P_t^{\#}(z) & \text{with prob. } 1 - \lambda \end{cases}$$

where $P_t^{\#}(z)$ is an optimal price that a firm sets when it receives the signal to reset. Since there is a chance that a firm will face the same price for many periods, the pricing problem becomes dynamic. Firms will discount profits j periods into the future by $\Delta_{t,j}\lambda^j$, where $\Delta_{t,j}$ is a discount factor and λ is the probability of not updating next period. As money is the only store of value, the proper discount factor in this economy is the reverse of gross inflation:

$$\Delta_{t,j} = \frac{1}{(1+\pi)^j}.$$

When updating its price each firm maximizes the discounted sum of future real profits:

$$\max_{P_t^{\#}(z)} E_t \sum_{j=0}^{\infty} \Delta_{t,j}\lambda^j \left(\frac{P_t^{\#}(z)y_{t+j}(z)}{P_{t+j}} - \frac{W_{t+j}n_{t+j}(z)}{P_{t+j}} \right) \qquad (2.2.4)$$

subject to (2.2.2), (2.2.3), linear production function:

$$y_t(z) = n_t(z) \qquad (2.2.5)$$

and imposing that output equals demand at both country and product level:

$$y_t(z) = c_t^h(z) + c_t^{h^*}(z) \qquad (2.2.6)$$

$$y_t = c_t^h + c_t^{h^*}. \qquad (2.2.7)$$

From the first order condition each updating firm will choose the same reset price $P_t^{\#}$, so that firm index z can be dropped:

$$P_t^{\#} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{j=0}^{\infty} \Delta_{t+j}\lambda^j W_{t+j} P_{t+j}^{\epsilon-1} y_{t+j}}{E_t \sum_{j=0}^{\infty} \Delta_{t+j}\lambda^j P_{t+j}^{\epsilon-1} y_{t+j}}. \qquad (2.2.8)$$

In a stationary steady state with a constant rate of inflation equation 2.2.8 reduces to:

$$P^{\#} = \frac{\epsilon}{\epsilon - 1}W.$$

A firm that is able to reset its price optimally in a given period would charge a constant markup over marginal cost, which I define it as the marginal markup: $\mu_t^* = \frac{\epsilon}{\epsilon-1}$. A fact that a firm's pricing decision is in fact static is a direct conseqence of the CES preference structure. Each period all

producers share the same cost structure and face the same, due to CES preferences static demand schedule. Hence, their optimal pricing decision is not only symmetric but also static[5].

In an inflationary equilibrium however, the average markup P_t/W_t is different than the marginal markup, as prices are sticky. This stochastic price setting specification results in a stationary distribution of firms in terms of the time since their last price adjustment. The fraction of firms that last adjusted j periods ago is $\phi_j = (1-\lambda)\lambda^j$. Thus, aggregate price level evolves according to:

$$P_t = \left(\sum_{j=0}^{\infty} \phi_j \left(P_{t-j}{}^{\#} \right)^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}$$

or, more simply:

$$P_t = \left((1-\lambda)(P_t^{\#})^{1-\epsilon} + \lambda(P_{t-1})^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}. \tag{2.2.9}$$

I define the average markup μ_t as aggregate nominal price to nominal wage. I can rewrite average markup as:

$$\mu_t = \frac{P_t}{W_t} = \frac{P_t}{P_t^{\#}} \frac{P_t^{\#}}{W_t} \tag{2.2.10}$$

where the first expression I define as "price adjustment gap" and the second expression is given by the marginal markup mu^*. In an inflationary steady-state by evaluating (2.2.9) in a situation where both P_t and $P_t^{\#}$ grow at the same rate π I obtain the formula for price adjustment gap:

$$\frac{P_t}{P_t^{\#}} = \left(\frac{1 - \lambda\left(1+\pi\right)^{\epsilon-1}}{1-\lambda} \right)^{\frac{1}{\epsilon-1}}. \tag{2.2.11}$$

Then the average markup is:

$$\mu = \frac{\epsilon}{\epsilon-1} \left(\frac{1 - \lambda\left(1+\pi\right)^{\epsilon-1}}{1-\lambda} \right)^{\frac{1}{\epsilon-1}}. \tag{2.2.12}$$

Average markup in this economy is time-independent, goes down with inflation, goes up with price stickiness when inflation is negative and goes down with price stickiness when inflation is positive. Figure 2.1 plots how the average markup changes with inflation and stickiness. For the firms to generate non-negative profits average markup must be no lesser than one. The necessary and sufficient condition for this is given by 2.2.13. This condition will limit the choice of inflation

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[5]A notable example of departure from CES is Bergin and Feenstra (2000), who show that Calvo rigidity under translog demand structure implies a price-setting rule that is dynamic and gives weight to prices set by competitors.

Figure 2.1: Inflation and average markup at different λ levels
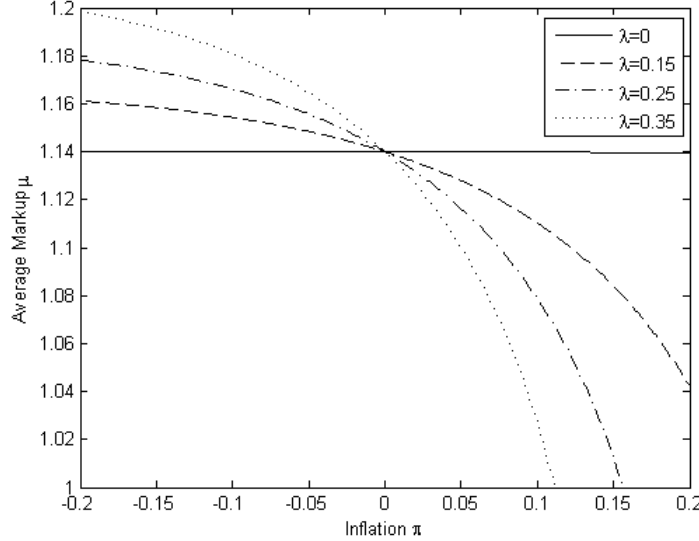
rates studied in the next chapter.

$$\pi \leq \lambda^{\frac{1}{1-\epsilon}} \left(1 - \left(\frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} (1-\lambda) \right)^{\frac{1}{\epsilon-1}} - 1 \tag{2.2.13}$$

With firms behaving as explained, monetary authority can in principle use inflation to undo the friction caused by monopolistic competition. With prices sticky enough higher levels of inflation π result in smaller 'price adjustment gap'.

2.2.2 Households

Households are active in two periods. In first period households supply labor to firms, receive wages and profits and choose levels of Home and Foreign money holdings. In the second period they consume Home and Foreign goods. The optimization problem of a representative household in Home country is given by

$$\max_{m_t^h, m_t^f, n_t} E_t \left(log\left(c_{t+1}\right) - g\left(n_t\right) \right) \tag{2.2.14}$$

subject to (2.2.1) and first and second period budget constraints:

$$W_t n_t + \Pi_t = m_t^h + e_t m_t^f \tag{2.2.15}$$

$$c_{t+1}^h = \frac{m_t^h + \tau_{t+1}}{P_{t+1}} \qquad c_{t+1}^f = \frac{m_t^f}{P_{t+1}^*} \tag{2.2.16}$$

where m_t^h are Home money holdings, m_t^f are Foreign money holdings, Π_t is an average nominal profit of Home firms, τ_{t+1} is Home lump sum money transfer from the monetary authority, P_{t+1} and P_{t+1}^* are aggregate nominal prices of Home goods and Foreign goods in local currecies and e_t is the exchange rate. Labor disutility function $g(n_t)$ is assumed to be increasing and convex. Taste preference for home goods θ is assumed to be constant and same for both countries $\theta \in [0, 1]$ with $\theta > 0.5$ representing the home bias.

First order conditions with respect to Home and Foreign money holdings yield the following Euler equation:

$$\frac{1 - \theta}{e_t m_t^f} = \frac{\theta}{m_t^h + \tau_{t+1}^h} \tag{2.2.17}$$

which implies that future money supply will be held in constant proportions between currencies by the old generation. This in turn implies, that every period old generation would consume constant fraction of home output. With respect to labor supply FOC gives:

$$g'(n_t) = \frac{\theta W_t}{m_t^h + \tau_{t+1}^h} = \frac{\theta W_t}{P_{t+1} c_{t+1}^h} \tag{2.2.18}$$

2.2.3   Market clearing

In every period three markets clear in each country: goods market, labor market, money market and one international foreign exchange market. Goods market clearing in Home country is given by (2.2.7). Labor market clears:

$$n_t = \int_0^1 n_t(z) dz. \tag{2.2.19}$$

where n_t is solution to individuals FOC on labor supply (2.2.18). Monetary authority supplies money, which is held by old generation, who spends it on consumption goods and then firms divide it between wages and profits:

$$M_t = P_t^h(c_t^h + c_t^{h*}) = W_t n_t + \Pi_t \tag{2.2.20}$$

The evolution of money stocks at Home country is given by

$$M_{t+1} = M_t(1 + \sigma) \tag{2.2.21}$$

where σ is fixed growth rate of home money supply. In next section, it will become decision variable for monetary authority and is taken by agents as given. Additional money supply finances

lump-sum transfers to home old generation agents:

$$\tau_{t+1} = \sigma M_t \tag{2.2.22}$$

Exchange market clears:

$$m_t^{*h} = e_t m_t^f \tag{2.2.23}$$

Finally, the stock of each currency after the exchange market closes is distributed between home and foreign agents according to:

$$M_t = m_t^h + m_t^{*h}$$

2.2.4   Equilibrium

Given the conditions for optimization by agents and market clearing conditions in two countries I first characterize optimal steady-state levels of employment and consumption given stable money growth rates. A monetary stationary rational expectations equilibrium is given by labor supply functions (n_t, n_t^*), consumption functions $(c_t^h, c_t^f, c_t^{*h}, c_t^{*f})$ and system of price expectations (P_t, P_t^*, e_t) such that agents optimize and markets clear. Equations (2.2.16), (2.2.17), (2.2.20), (2.2.21) and (2.2.23) give the following:

$$m_t^h + \tau_{t+1}^h = \theta(1 + \sigma)M_t. \tag{2.2.24}$$

This together with budget constraint (2.2.16), goods market clearing (2.2.7), production function (2.2.5) and money market clearing (2.2.20) imply that consumption in equilibrium is:

$$c_t^h = \theta n_t \tag{2.2.25}$$

$$c_t^f = (1 - \theta)n_t^* \tag{2.2.26}$$

Domestic consumption is therefore always a fixed fraction of domestic output. This stationary property of consumption combined with money market clearing (2.2.20) and evolution of money stock implies equilibrium property of price evolution:

$$P_{t+1} \stackrel{\text{def}}{=} P_t(1 + \pi) = P_t(1 + \sigma) \tag{2.2.27}$$

which shows that money is neutral in the long run as $\pi = \sigma$. Changes is money supply M_t only affect prices P_t. Last two equations combined with FOC on labor supply (2.2.18), stationary property of equilibrium and definition of average markup (2.2.10) imply stationary level of labor supply. Because of the stationarity time indices can be dropped:

$$g'(\bar{n})\bar{n} = \frac{1}{\mu(1 + \sigma)} \tag{2.2.28}$$

where $\bar{n}$ stands for steady-state equilibrium level of labor supply. In steady-state equilibrium labor and consumption of Home and Foreign goods in both countries and exchange rate are constant and home and foreign prices grow at the rates σ and σ^*. Equilibrium condition (2.2.28) reveals interesting properties. The model manifests long run neutrality of money (as permanent changes in quantity of M only affect prices and not output) but not superneutrality. There will be real effects of sustained long run inflation stemming from two sources: the average markup and the inflation tax.

Proposition 1. *Inflation has two equilibrium effects on real activity. It increases labor supply and consumption through a decreased level of the average markup and decreases labor supply and consumption through the inflation tax.*

Proof. First part of proposition derives from equations (2.2.10) and (2.2.11). Second part of proposition follows from convexity of $g(n)$.   □

This result differs significantly from Cooper and Kempf (2003), where under flexible prices, positive money growth rate worked only as an inflation tax, decreasing steady-state optimal labor supply. This proposition shows that in the sticky prices environment there are two effects of monetary policy working in opposite directions. First, the inflation tax effect (which works similarly to long term Phillips curve) discourages agents from work, so they optimally choose lower labor supply level. Second, the average markup effect (which works similarly to short term Phillips curve) derives from the fact that prices at firm level move infrequently. In non-reseting firms with higher inflation costs rise faster. They take wages as given and must satisfy all demand at posted price, so they need to cut their profits, which results in lower average markups and higher average output. In the remainder of the paper, wherever it is necessary to impose functional form on the labor disutility function I use the following specification:

$$g(n) = \frac{1}{2}n^2. \tag{2.2.29}$$

From (2.2.28) and $\pi = \sigma$ optimal labor supply reads:

$$\bar{n}(\sigma) = \left(\frac{\epsilon}{\epsilon - 1} \left(\frac{1 - \lambda(1 + \sigma)^{\epsilon-1}}{1 - \lambda} \right)^{\frac{1}{\epsilon-1}} (1 + \sigma) \right)^{-\frac{1}{2}} \tag{2.2.30}$$

To calculate the net effect of inflation on labor supply I first evaluate first derivative of 2.2.30 and later plot how optimal labor supply reacts to inflation and stickiness in Figure 2.2.

$$\frac{\partial \bar{n}(\sigma)}{\partial \sigma} = \underbrace{-\frac{1}{2} \left(\frac{\epsilon}{\epsilon - 1} \right)^{-\frac{1}{2}}}_{<0} \underbrace{(1 + \sigma)^{-\frac{3}{2}}}_{>0} \underbrace{\left(\frac{1 - \lambda(1 + \sigma)^{\epsilon-1}}{1 - \lambda} \right)^{-\frac{1}{2(\epsilon-1)}}}_{>0 \text{ since } (2.2.13) \text{ holds}} \underbrace{\left(1 - \frac{\lambda(1 + \sigma)^{\epsilon-1}}{1 - \lambda(1 + \sigma)^{\epsilon-1}} \right)}_{\lessgtr 0}. \tag{2.2.31}$$

Figure 2.2: Inflation and optimal labor supply at different λ levels
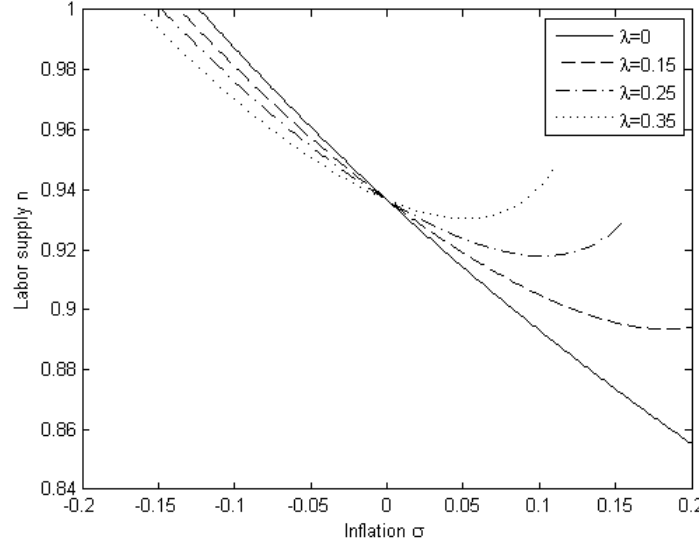
From (2.2.31) it follows that the sign of the derivative depends on the sign of the expression in the last parenthesis. The first effect (inflation tax or long-term Phillips curve) will therefore dominate, so the labor supply will decrease with inflation, whenever:

$$\sigma < \left(\frac{1}{2\lambda}\right)^{\frac{1}{\epsilon-1}} - 1 \qquad (2.2.32)$$

and the second effect (sticky prices or short-term Phillips curve effect) will dominate, so the labor supply will increase with inflation, whenever the reverse is true. This can be easily seen in Figure 2.2. When prices are flexible $\lambda = 0$ condition 2.2.32 is always met, so optimal labor supply decreases in inflation. When prices are sticky $\lambda > 0$ the above condition is only met for some values of σ. For example, when marginal markup is equal to 1.14 (which gives $\epsilon = 8.14$) and $\lambda = 0.15$ labor supply goes down with inflation up to $\sigma = 0.18$. Higher inflation decreases return on money holdings and this discourages households from supplying labor. Inflation tax effect dominates. Above this point the average markup effect dominates. Higher inflation reduces average markup in the economy, which in turn increases return on money. For $\lambda = 0.25$ and $\lambda = 0.35$ this switch occurs at $\sigma = 0.11$ and $\sigma = 0.05$.

It can be easily shown, that condition (2.2.32) is always more restrictive than (2.2.13) so that both relationships are possible within the support of σ. This result has profound consequences on optimal money supply rules chosen by monetary authorities, the topic I turn to next.

2.3　Optimal Monetary Policy with Local Currencies

In this section I look for the rate of inflation that solves the monetary authority optimization problem. By manipulating the rate of growth of the monetary base local monetary authority chooses a steady state which yields highest welfare for households and it takes equilibrium outcomes and market clearing conditions as constraints:

$$V(\sigma, \sigma^*) = \max_{\sigma} \left(u\left(c \right) - g\left(n \right) \right) \tag{2.3.1}$$

subject to optimal consumption decision (2.2.25) and optimal labor supply decision (2.2.30). Substituting in we get:

$$V(\sigma, \sigma^*) = \max_{\sigma} \left\{ \theta log\theta + \theta log(\bar{n}(\sigma)) + (1 - \theta) log\left(1 - \theta\right) + (1 - \theta) log(\bar{n}^*(\sigma^*)) - g(\bar{n}(\sigma)) \right\}. \tag{2.3.2}$$

Foreign country monetary authority optimization problem is symmetric. First order condition for the problem reads:

$$\frac{\theta}{n(\sigma)}\bar{n}'(\sigma) - g'(\bar{n}(\sigma))\bar{n}'(\sigma) = 0. \tag{2.3.3}$$

The above condition combined with optimal labor supply condition 2.2.28 gives the following two roots:

$$\frac{1}{\mu(\sigma_1)(1 + \sigma_1)} = \theta \tag{2.3.4}$$

$$\bar{n}'(\sigma_2) = 0. \tag{2.3.5}$$

The problem is highly non-linear therefore I proceed by solving two simplified benchmark cases first. The first benchmark is the economy with no frictions (perfect competition and flexible prices). The second benchmark is the economy with only one friction (monopolistic competition). Both benchmarks have closed form solutions. After that I proceed with the third, full benchmark case, that is the economy with both frictions (monopolistic competition and sticky prices).

Benchmark 1. Open economy with flexible prices and perfect competition

This economy is analogous to Cooper and Kempf (2003). Prices are flexible ($\lambda = 0$) and average and marginal markups are equal to one ($\mu = 1$).

Proposition 2. *In the economy with flexible prices and perfect competition first order condition (2.3.3) of the monetary authority optimization problem has only one solution, σ_1 in (2.3.4). Optimal*

rate of inflation maximizing households utility is therefore:

$$\sigma^{B1} = \frac{1 - \theta}{\theta} \tag{2.3.6}$$

Proof. See Appendix.   □

Solution to (2.3.5) yields $\sigma_2 = -1$, which is outside of the support for sigma and would bring an immediate collapse of the economy, with no exchange, no production and no consumption.

With positive rate of inflation monetary authority exploits international spillovers to run inflationary, 'beggar-thy-neighbor' policy. Both labor supply and home output is lower than under no inflation. However, fraction of output is consumed abroad, so inflation tax is partly exercised on foreign individuals. Home individuals can enjoy more leisure without paying full cost of lost output. It is worthwhile to notice, that if both Home and Foreign country form monetary union all spillovers are internalized by common monetary authority. There is no possibility to exercise inflation tax on foreign individuals, as there is no 'neighbor to beggar'. It is equivalent to the situation of a closed economy, that is $\theta = 1$, so $\sigma^{B1} = 0$.

Benchmark 2. Open economy with flexible prices and imperfect competition

In this economy the average markup is equal to the marginal markup $\mu = \mu^{\#} = \frac{\epsilon}{\epsilon - 1}$ and is independent from the inflation rate. It follows that:

Proposition 3. *In the economy with flexible prices and monopolistic competition first order condition (2.3.3) of the monetary authority optimization problem has only one solution, σ_1 in (2.3.4). Optimal rate of inflation maximizing households utility is therefore:*

$$\sigma^{B2} = \frac{1 - \mu^{\#}\theta}{\mu^{\#}\theta} \tag{2.3.7}$$

Proof. See Appendix.   □

It is straightforward to notice that in the imperfect competition economy with flexible prices optimal level of inflation is strictly smaller than in the economy with perfect competition and flexible prices $\bar{\sigma}^{B2} < \bar{\sigma}^{B2}$. It is due to the fact that the markup has the same effect on the real economy as inflation tax, it reduces optimal level of labor supply. As the inflation tax and the markup are substitutes, a lower level of inflation is sufficient to achieve optimal level of labor supply satisfying $g'(\bar{n})\bar{n} = \theta$. It may be the case that for a high markup or high openness the optimal level of inflation is negative. Similarly to Benchmark 1 case, the second root of the first order condition is $\bar{\sigma}_2 = -1$ and is outside of the support for σ.

In this benchmark case a monetary authority in a monetary union would no longer choose zero, but strictly negative level of inflation $\bar{\sigma}^{B2} = \frac{1 - \mu^{\#}}{\mu^{\#}}$. The intuition holds the same. A monetary

Table 2.3: Parameter Values

Parameter	Description	Value
ϵ	Elasticity of substitution	8.14
θ	Home bias in consumption	0.8
λ	Probability that firm will not be able to update	$(0,\ 0.32)$

authority wants to undo a negative effect of markups on optimal labor supply decision, therefore encourages individuals to work more by imposing a negative inflation tax.

## Benchmark 3. Open economy with sticky prices

On top of the effects documented in the Benchmark 2 scenario now inflation also affects the size of the average markup. As the first order conditions 2.3.4 and 2.3.5 do not have analytical solutions I solve the problem numerically. I discipline the model with the standard parametrization. The elasticity of substitution ϵ is equal to 8.14, which results in the marginal markup being equal to 1.14. The second parameter, home bias θ I set equal to 0.8, as in Pappa (2004). The stickiness parameter λ I vary between 0 and 0.32 to asses how the model diverges from benchmark cases studied before. The value $\lambda = 0.32$ is a yearly equivalent of 0.75 on a quarterly basis, a standard stickiness value assumed in a quantitative literature.

Figure 2.3 plots numerical solution of all three benchmark models of the open economy for the chosen parameter values ϵ and θ and varying the stickiness parameter λ. The optimal level of inflation in Benchmark 3 model is always lower than in the perfect competition (Benchmark 1) model. Intuition behind this result is similar to the one explained in Benchmark 2 case. The existence of the average markup in the economy takes away some of the inflation tax power, as it discourages individuals from supplying labor. Therefore, in the economy with imperfect competition a monetary authority always chooses the lower level of inflation than in the economy with perfect competition.

Comparing to Benchmark 2 for low stickiness λ local monetary authority now chooses higher levels of inflation. Labor supply goes up with stickiness and is convex in inflation (see Figure 2.2). Therefore, to counter increasing labor supply resulting from higher stickiness, local monetary authority decides for higher inflation to decrease labor supply. Consumption rises in stickiness, as average markups are decreasing both in inflation and in stickiness (see Figure 2.1).

Optimal inflation goes up with stickiness until $\lambda = 0.15$ and the optimal rate of inflation is $\sigma_1 = \sigma_2 = 0.18$. This is a point, where labor supply is at its minimum. Beyond this point 2.3.4 does not have a solution, so σ_1 does not exist and the maximum of the monetary authority's problem is reached at σ_2, that is where $\bar{n}'(\sigma) = 0$. For high stickiness the optimal rate of inflation

Figure 2.3: Optimal Inflation with Local Currencies
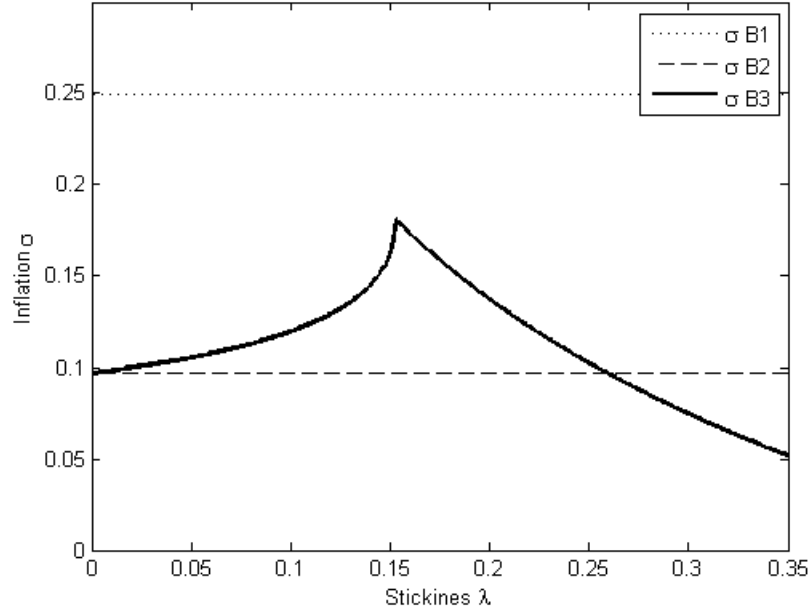
is the one, which minimizes labor supply. Labor supply is still increasing in stickiness, therefore, to counter the effect of increasing stickiness, local monetary authority must now choose the rate of inflation that minimizes labor supply. As is evident from Figure 2.2 the minimum labor supply point is a decreasing function of stickiness.

2.4   Optimal Monetary Policy in a Monetary Union

The structure of the world economy is the same as before. The only difference is that now the two countries are subject to central monetary policy conducted by a single monetary authority. The monetary authority problem is now different, as it choses only one money supply growth rate equal for both economies in order to maximize the joint welfare of the two. Let σ^U be the growth rate of the money stock in the monetary union, then the joint welfare of the two economies V^U is:

$$V^U(\sigma^U) = wV(\sigma^U, \sigma^U) + (1-w)V^*(\sigma^U, \sigma^U) \qquad (2.4.1)$$

where w is a weight assigned by the single monetary authority to the Home country. The single monetary authority maximizes (2.4.1) subject to optimal consumption decisions (2.2.25), (2.2.26) and optimal labor supply decision (2.2.30) for both Home and Foreign countries. Substituting in we get:

$$V^U \left(\sigma^U \right) = \max_{\sigma^U} \Bigg(\theta log\theta + (1 - w - \theta - 2w\theta) \, log \left(\bar{n} \left(\sigma^U \right) \right)$$

$$+ (1 - \theta) \, log \, (1 - \theta) + (\theta + w - 2w\theta) \, log \left(\bar{n}^* \left(\sigma^U \right) \right)$$

$$-wg \left(\bar{n} \left(\sigma^U \right) \right) - (1 - w) \, g \left(\bar{n}^* \left(\sigma^U \right) \right) \Bigg) \tag{2.4.2}$$

The first order condition assuming equal weights $w = \frac{1}{2}$ for the problem reads:

$$\frac{1}{2} \bar{n}'(\sigma^U) \left(\frac{1}{\bar{n}(\sigma^U)} - g' \left(\bar{n}(\sigma^U) \right) \right) + \frac{1}{2} \bar{n}^{*'}(\sigma^U) \left(\frac{1}{\bar{n}^*(\sigma^U)} - g' \left(\bar{n}^*(\sigma^U) \right) \right) = 0 \tag{2.4.3}$$

As in the previous section, as the problem is highly non-linear, I proceed by solving two simplified benchmark cases first. The first benchmark is the monetary union economy with no frictions (perfect competition and flexible prices). The second benchmark is the monetary union economy with only one friction (monopolistic competition). Both benchmarks have closed form solutions. After that I proceed with the third, full benchmark case, that is the monetary union economy with both frictions (monopolistic competition and sticky prices). I split the third benchmark case into two and study the optimal rate of inflation and the welfare gains when price stickiness is symmetric and asymmetric in the two countries.

Benchmark 1. Monetary union with flexible prices and perfect competition

With $\lambda = \lambda^* = 0$ Foreign and Home labor supplies are equal. The first order condition (2.4.3) boils down to:

$$\bar{n}'(\sigma^U) \left(\frac{1}{\bar{n}(\sigma^U)} - g' \left(\bar{n}(\sigma^U) \right) \right) = 0. \tag{2.4.4}$$

The above condition gives the following two roots:

$$\mu(\sigma_1^U)(1 + \sigma_1^U) = 1 \tag{2.4.5}$$

$$\bar{n}'(\sigma_2^U) = 0. \tag{2.4.6}$$

Proposition 4. *In the economy with with flexible prices and perfect competition the optimal rate of inflation in a monetary union is zero and adopting a common currency is welfare improving from both individual and joint welfare perspectives.*

$$\sigma^{B1U} = 0 \tag{2.4.7}$$

Proof. See Appendix. □

The common central bank now fully internalizes the spillovers created by the inflationary tax, namely the loss of consumption which happens not only in Home country, but also in Foreign country. So the incentives to inflate are reduced.

In the economy with local currencies there are incentives to distort allocation by imposing inflation tax on the Foreign country. As Foreign country also deviates from efficient solution, the loss of utility not compensated by reduced working hours occurs in both countries. The common monetary authority overcomes this externality. The common central bank internalizes cross-border spillovers from inflation. Without markups it is optimal in a union to not inflate at all.

Benchmark 2. Monetary union with flexible prices and imperfect competition

With $\lambda = \lambda^* = 0$ Foreign and Home labor supplies are equal. First order condition (2.4.3) boils down to (2.4.4).

Proposition 5. *In the economy with with flexible prices and monopolistic competition the optimal rate of inflation in a monetary union is lower than in the local currency economy and adopting a common currency is welfare improving from both individual and joint welfare perspectives.*

$$\sigma^{B2U} = \frac{1 - \mu^{\#}}{\mu^{\#}} \tag{2.4.8}$$

Proof. See Appendix.   □

In the economy with constant markups incentives of a local central bank to inflate are reduced. However, as markups discourage individuals from working, it is efficient to impose negative inflation rate to undo this distortion. Another way to see this result is to look directly at the first order condition 2.4.5. Whenever the markup is higher than one inflation must be negative for the condition to be met. Right hand side of this first order condition can be interpreted as the inverse of the gross interest rate (which is 1 in this model). Left hand side is the cost of holding money. Both the average markup and inflation are costs of holding money. A monetary authority sets negative inflation rate to compensate for the average markup cost of holding money. In such a union inflation is always lower than in the economy with local currency.

Benchmark 3a. Monetary union with symmetric sticky prices

With $\lambda = \lambda^* > 0$ Foreign and Home labor supplies are equal. The first order condition (2.4.3) boils down to (2.4.4). In the monetary union with sticky prices incentives to 'beggar-thy-neighbor' also vanish, so the optimal level of inflation in the union is always lower than in the local currency economy. However, now the average markup is also a function of inflation. The negative level of inflation increases average markups discouraging individuals from work compared to Benchmark 2.

Figure 2.4: Optimal Inflation in the monetary union with symmetric stickiness $\lambda = \lambda^*$

Proposition 6. *In the world economy with symmetric sticky prices and monopolistic competition the optimal rate of inflation in a monetary union is: a) lower than in the local currency economy, b) lower than in the flexible prices monetary union c) lower than the Friedman rule, and adopting a common currency is welfare improving from both individual and joint welfare perspectives.*

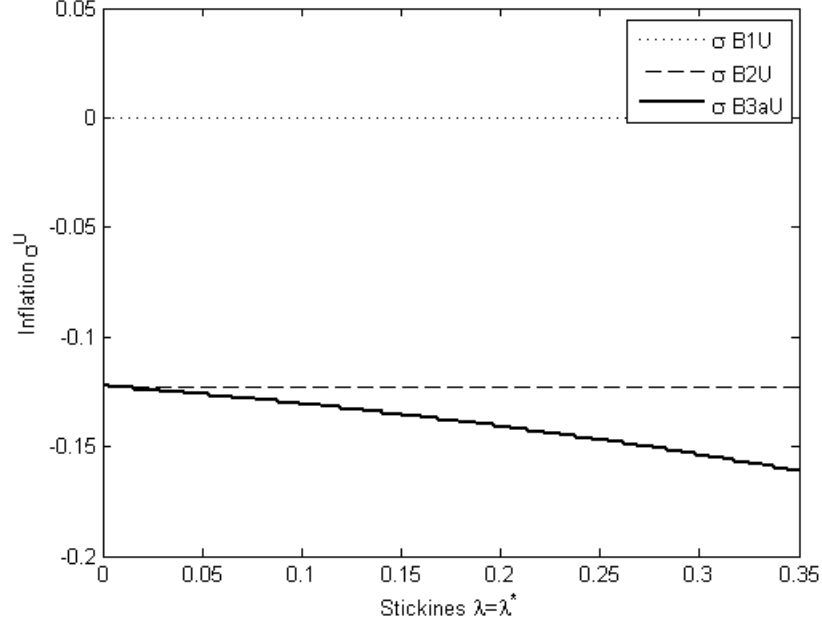*Proof.* The first part of the proof for a) and b) is done numerically and the result is presented in Figure 2.4, c) follows from the fact, the the gross interest rate in this economy is one, so the Friedman rule would prescribe zero inflation. The optimal inflation in this economy is negative, so it is below Friedman rule. For the proof of the second part of the Proposition see Appendix.   □

Figure 2.4 plots numerical solution of the three benchmark models for the chosen parameter values ϵ and θ and varying the symmetric stickiness parameter λ. As incentives to impose inflation tax are removed in a monetary union, the optimal level of inflation is always lower than in the local currencies economy in each respective benchmark and when competition is not perfect it is always negative. To understand this result let us think about a monetary union with symmetric sticky prices as a big closed economy. This allows us to compare this result with the results for the closed economy with the same features presented in Chapter 6 of Schmitt-Grohe and Uribe (2010). As their setup is more general, my results should be a special case of theirs. It is not the case however, as their results say, that in a closed economy with monopolistic competition and sticky prices the optimal level of inflation is zero. To start the discussion let us concentrate on the first

order condition 2.4.5, which is presented below for convenience:

$$\mu(\sigma^U)(1 + \sigma^U) = 1$$

and let's think about μ, the average markup, as a distortion, and $(1 + \sigma^U)$ as a cost of holding money. In my setup the monetary authority has only one tool, the rate of growth of the monetary stock (σ^U), which in equilibrium is equal to inflation. If the monetary authority (or any other authority with a causative power) had an additional instrument that would affect μ and nothing else, it would use this instrument to set $\mu = 1$. Next, as the average markup distortion had been removed from the economy, the authority would set $\sigma = 0$, such that benefits of holding money (minus the rate of inflation) are equal to costs (net interest rate, which in this setup is equal to 0). In Chapter 6.2 of Schmitt-Grohe and Uribe (2010) authors consider the economy with production subsidies. These production subsidies are financed by lump sum taxes and can address the average markup distortion, so constitute a perfect candidate instrument that fits the above description.

The Benchmark 3a economy can be interpreted as a special case of Chapter 6.3 of Schmitt-Grohe and Uribe (2010) where authors consider the economy without production subsidies. They claim that in this economy the optimal rate of inflation is also zero. In my Benchmark 3a economy this is not the case, because $\mu(\sigma^U)$ is always greater than one. The discrepancy of our results can be traced down to the setup of their proof, where they postulate that Ramsey planner maximizes agents' welfare with respect to independently inflation and price dispersion (which in their notation is $\tilde{p}_t$ and in my notation would be $\frac{\mu(\sigma)}{\mu^{\#}}$). In this, their Ramsey planner effectively has access to an additional tool, that fits the above description. Absent this second tool the optimal rate of inflation would be strictly negative and below the Friedman rule.

Figure 2.4 also shows, that the optimal rate of inflation is further decreasing in stickiness. This is because the slope of the average markup as a function of inflation is increasing in stickiness, as can be seen in Figure 2.1. Therefore, when stickiness goes up, the cost of holding money $\mu(\sigma)$ goes up for any given σ. To compensate this additional cost the monetary authority increases benefits of holding money, by reducing σ.

Benchmark 3b. Monetary union with asymmetric sticky prices

With $\lambda \neq \lambda^*$ Foreign and Home labor supplies are not equal. The first order condition (2.4.3) does not have a closed-form solution and the model is solved numerically. The average markup, as in Benchmark 3a is also a function of inflation. The average markup and Home and Foreign labor supply change in σ, λ and λ^*.

Figure 2.5 plots numerical solution of the Benchmark 3b economy for the chosen parameter values ϵ and θ and varying the asymmetric stickiness parameters λ (on the horizontal axis) and λ^* (four different plots represent four different values of λ^*). The optimal rate of inflation in the monetary union economy is decreasing in both Home and Foreign stickiness, as the intuition from

Figure 2.5: Optimal Inflation in a Union with Asymmetric Stickiness $\lambda \neq \lambda^*$
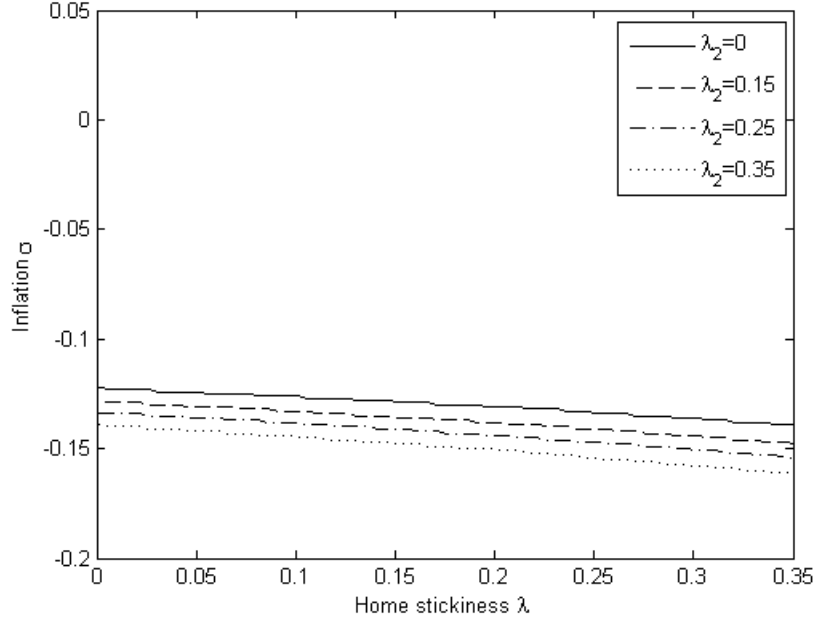
the Benchmark 3a would suggest.

Proposition 7. *In the economy with imperfect competition and sticky prices adoption of the common currency is not always welfare improving.*

Proof. Done numerically. For exposition see Figure 2.6   □

Let's focus our attention on a special case where the Home country has flexible prices and the Foreign country has very sticky prices. The optimal level of inflation in the monetary union economy is negative, and below the level that would prevail if the Foreign country was symmetric to the Home country. Under such a high level of deflation the average markup in the Home country increases so much, that the gains from removing inflation tax inefficiencies are not be sufficient to compensate for this loss. This situation is shown in Figure 2.6 where the Home country with low λ experiences a welfare loss after forming a monetary union with the Foreign country that has high λ. For the cases where stickiness is equal (Benchmark 3a) or relative differences in stickiness are not too large monetary union is welfare improving from the individual welfare perspective.

Figure 2.6: Welfare gains and welfare losses from a union with asymmetric price stickiness
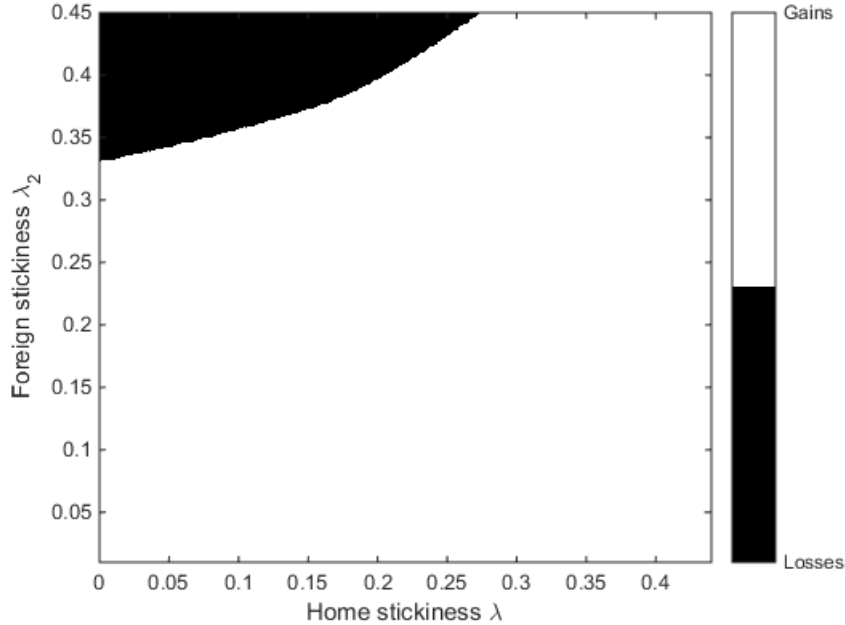
2.5   Reinstating Optimality

From the Home country's perspective a monetary union may be welfare reducing if the Foreign country has much higher price stickiness. The single monetary authority would then be inclined to choose a very low level of inflation. This low inflation would increase the average markup much more in the Home country than in the Foreign country. Both countries would enjoy welfare gains stemming from reduction in inflation tax (higher consumption), but the Home country would suffer from reduced leisure. However:

Proposition 8. *A monetary union is always welfare improving from the joint welfare perspective.*

Proof. Done numerically. Code available upon request.   □

Therefore the optimality of a union from the individual Home country's perspective can be reinstated. This could be done in many different ways, of which I consider an outright transfer within the union from net beneficiary (the Foreign country) to the net contributor (the Home country). Formally, I find a proportion γ of the Foreign country production in the monetary union Benchmark 3b economy $n^*(\sigma^{B3bU})$, which has to be transfered to the Home country to make it at

Figure 2.7: Lump sum transfer within a union in % of Foreign GDP
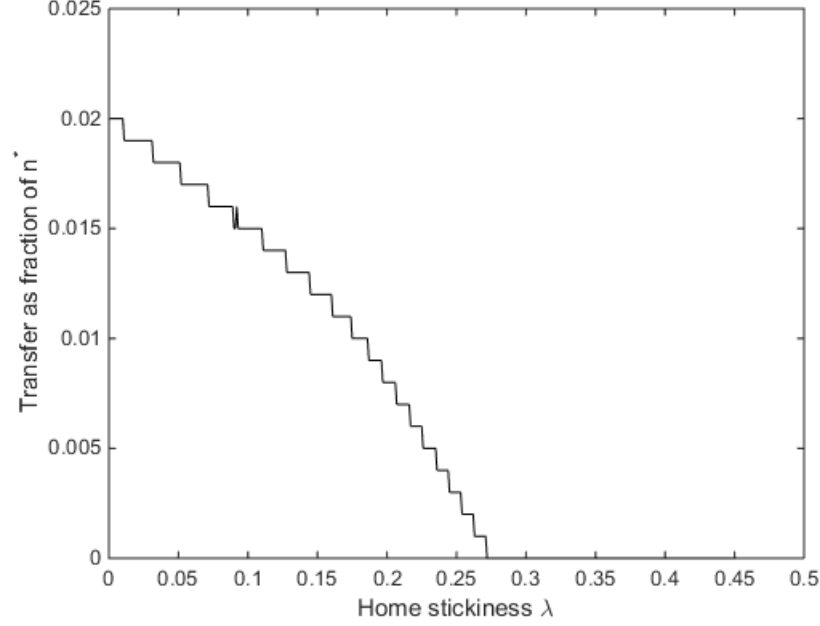
least as well off as in the Benchmark 3b local currency economy:

$$V_\gamma(\sigma^{B3bU}, \sigma^{B3bU}) = \theta log\left(\theta\bar{n}(\sigma^{B3bU})\right) + (1-\theta) log\left((1-\theta)(1+\gamma)\bar{n}^*(\sigma^{B3bU})\right) - g(\bar{n}(\sigma^{B3bU})) \geq V(\sigma^{B3}, \sigma^{*B3})$$

$$(2.5.1)$$

where V_γ is the welfare of the Home country in the monetary union with the γ-transfer and V is the welfare of the Home country in the local currency economy defined in (2.3.2). Subject to the Foreign country not being worse off in a the union with the γ-transfer when compared the local currency economy:

$$V_\gamma^*(\sigma^{B3bU}, \sigma^{B3bU}) = \theta log\left(\theta(1-\gamma)\bar{n}^*(\sigma^{B3bU})\right) + (1-\theta) log\left((1-\theta)\bar{n}(\sigma^{B3bU})\right) - g(\bar{n}^*(\sigma^{B3bU})) \geq V^*(\sigma^{*B3}, \sigma^{B3}).$$

$$(2.5.2)$$

I solve 2.5.1-2.5.2 numerically assuming that the Foreign country is very rigid ($\lambda^* = 0.45$) and the stickiness in Home country varies between 0 and 0.45. Figure 2.7 plots the minimum γ at different levels of λ for which (2.5.1) holds with equality. In the most extreme scenario ($\lambda = 0, \lambda^* = 0.4$) a lump sum transfer to Home country equivalent to 2% of the Foreign country's production would make the Home country indifferent between keeping local currency and joining the monetary union. Naturally, as Home stickiness λ goes up, relative differences between the economies become smaller

and required transfer becomes smaller. At $\lambda > 0.27$ Home country finds it optimal to join a union without any transfer.

2.6 Conclusions

Are monetary unions welfare improving? There are three main ideas supporting a positive answer. First, a monetary union reduces transaction costs. Second, it may help to promote international trade. Third, the common central bank gains more independence which helps to overcome possible problems with commitment or time-inconsistency. In this model I refrain from these considerations adding new dimension to existing knowledge. Transaction costs are assumed to be non-existent, trade does not depend on the structure of the monetary policy and commitment of any central bank is assumed to always be in place. This paper explores another channel. Because of having a common central bank, in a monetary union countries can effectively commit to not tax each other with inflation. In this model monetary union always improves joint welfare.

A new finding of this paper is that, although joint welfare goes up in a monetary union, individual welfare does not necessarily so. This is because prices are sticky and the degree of price stickiness may vary among the economies. With asymmetric stickiness the optimal choice of inflation in the local currencies economy differs between countries. The country with higher price stickiness chooses lower inflation than the country with more flexible prices. In a monetary union inflation is reduced in both countries, as the inflation tax effect is removed. When the difference in price stickiness is high, joining a union is welfare improving for the economy with more stickiness and is welfare reducing for the economy with less stickiness. Joining a union could be sustained as the optimal choice for the economy with more flexible prices if coupled with a lump sum transfer from the economy with more sticky prices. Integration with a compensating transfer is therefore a Pareto improvement upon the local currencies regime.

Another contribution of this paper is a theoretical study of the optimal rate of inflation. I reinforce the puzzle identified by Schmitt-Grohe and Uribe (2010) that available theories consistently imply that the optimal rate of inflation in a closed economy ranges from the Friedman rule to numbers insignificantly above zero. In this model the optimal rate of inflation in a closed economy is in fact below the Friedman rule. When production is done by monopolistically competitive firms and prices are sticky, the average markup constitutes a cost on holding money. The only way the monetary authority can compensate for this cost is to set the negative rate of inflation. As the net interest rate in this model is zero, the optimal rate of inflation is therefore below the Friedman rule.

In the open economy however, this is is not necessarily the case. The equilibrium outcome of the game between two monetary authorities is to impose impose an inflation tax on each other. As part of home consumption is in foreign goods, and is not affected by local monetary policy, the loss in consumption is not fully internalized by local monetary authority. In the open economy the monetary authority faces two effects: the spillover effect, which brings the optimal inflation up,

and the average markup effect, which brings the optimal inflation down. For reasonable parameter values the first effect is stronger and the optimal rate of inflation is positive.

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2.7   Appendix

2.7.1   Derivations

2.1 Households

Plugging in 2.2.1 and 2.2.16 the maximization problem becomes:

$$\max_{m_t^h, m_t^f, n_t} E_t \left(\theta log \left(\frac{m_t^h + \tau_{t+1}}{P_{t+1}} \right) + (1 - \theta) log \left(\frac{m_t^f}{P_{t+1}^*} \right) - g(n_t) \right) \tag{2.7.1}$$

subject to 2.2.15. The three first order conditions are:

$$\frac{\theta}{\frac{m_t^h + \tau_{t+1}}{P_{t+1}}} \frac{1}{P_{t+1}} - \nu_t = 0 \tag{2.7.2}$$

$$\frac{1 - \theta}{\frac{m_t^f}{P_{t+1}^*}} \frac{1}{P_{t+1}^*} - \nu_t e_t = 0 \tag{2.7.3}$$

$$-g'(n_t) + \nu_t W_t = 0 \tag{2.7.4}$$

where ν_t is a Lagrange multiplier associated with the first period budget constraint 2.2.15. Combining 2.7.2 with 2.7.3 gives 2.2.17 and combining 2.7.2 with 2.7.4 gives 2.2.18.

2.7.2 Proofs

Proof of Proposition 2. *Feasible choices for σ are $\sigma \in (-1, \infty)$. First I show that σ_2 is outside of the support of σ. From 2.3.5:*

$$\bar{n}'(\bar{\sigma}_2) = 0. \tag{2.7.5}$$

Plugging in $\lambda = 0$ to 2.2.31 we get:

$$\bar{n}'(\bar{\sigma}_2) = -\frac{1}{2}\left(\frac{\epsilon}{\epsilon-1}\right)^{-\frac{1}{2}}(1+\sigma_2)^{-\frac{3}{2}}\left(\frac{1-0\,(1+\sigma_2)^{\epsilon-1}}{1-0}\right)^{-\frac{1}{2(\epsilon-1)}}\left(1-\frac{0\,(1+\sigma_2)^{\epsilon-1}}{1-0\,(1+\sigma_2)^{\epsilon-1}}\right)$$

$$= -\frac{1}{2}\left(\frac{\epsilon}{\epsilon-1}\right)^{-\frac{1}{2}}(1+\sigma_2)^{-\frac{3}{2}} = 0$$

$$\Rightarrow \sigma_2 = -1 \tag{2.7.6}$$

Therefore it must be that σ_1 is the optimal inflation rate. Plugging in $\mu = 1$ to 2.3.4 we get:

$$\frac{1}{1+\sigma_1} = \theta$$

$$\theta + \theta\sigma_1 = 1$$

$$\sigma_1 = \frac{1-\theta}{\theta} \tag{2.7.7}$$

QED

Proof of Proposition 3. *As $\lambda = 0$ it must be that $\sigma_2 = -1$ as shown in the Proof of Proposition 2. The second part of the proof is analogous. Plugging in $\mu = \mu^{\#}$ to 2.3.4 we get:*

$$\frac{1}{\mu^{\#}(1+\sigma_1)} = \theta$$

$$\theta\mu^{\#} + \theta\mu^{\#}\sigma_1 = 1$$

$$\sigma_1 = \frac{1-\mu^{\#}\theta}{\mu^{\#}\theta} \tag{2.7.8}$$

QED

Proof of Proposition 4. *The proof of the first result, zero inflation in a monetary union, is analogous to the Proof of Proposition 2. As $\lambda = \lambda^* = 0$ it must be that $\sigma_2^U = -1$. Therefore it must*

be that σ_1^U is the optimal inflation rate. Plugging in $\mu = 1$ to 2.4.5 we get::

$$\frac{1}{1 + \sigma_1^{B1U}} = 1$$

$$1 + \sigma_1^{B1U} = 1$$

$$\sigma_1^{B1U} = 0 \qquad\qquad (2.7.9)$$

Next I prove the second result, the welfare improvement from adoption of a common currency. As countries are symmetric it is enough to prove the welfare improvement for Home country. Welfare gains from the adoption of a common currency in this economy (Benchmark 1) are defined as a difference in utility between the monetary union equilibrium and the local currency equilibrium of each generation in the Home country :

$$WG^{B1} = V(\sigma^{B1U}, \sigma^{B1U}) - V(\sigma^{B1}, \sigma^{*B1}) \qquad\qquad (2.7.10)$$

where $V(.)$ is defined in 2.3.2, $\sigma^{B1U} = 0$ is the optimal rate of inflation in the monetary union economy and $\sigma^{B1} = \sigma^{*B1}$ is the optimal rate of inflation in the local currencies economy. Substituting in equilibrium relationships we get:

$$WG^{B1} = \theta log(\theta \bar{n}(\sigma^{B1U})) + (1 - \theta) log((1 - \theta) \bar{n}^*(\sigma^{B1U})) - g(\bar{n}(\sigma^{B1U}))$$
$$- \theta log(\theta \bar{n}(\sigma^{B1})) - (1 - \theta) log((1 - \theta) \bar{n}^*(\sigma^{B1})) + g(\bar{n}(\sigma^{B1}))$$
$$= log(n(0)) - log(n(\sigma^{B1})) + g(n(\sigma^{B1})) - g(n(0)) \qquad\qquad (2.7.11)$$

Proposition 1 established that inflation has two equilibrium effects on labor supply. It increases labor supply through the markup effect and decreases the labor supply through the inflation tax effect. In the Benchamrk 1 economy prices are flexible, so the markup effect is shut down and labor supply is decreasing in inflation. The following relations hold:

$$0 < \sigma^{B1}$$
$$n(0) > n(\sigma^{B1})$$
$$log(n(0)) > log(n(\sigma^{B1})).$$
$$g(n(0)) > g(n(\sigma^{B1})). \qquad\qquad (2.7.12)$$

Therefore:

$$WG^{B1} = \underbrace{log(n(0)) - log(n(\sigma^{B1}))}_{>0} + \underbrace{g(n(\sigma^{B1})) - g(n(0))}_{<0} \qquad\qquad (2.7.13)$$

To asses the sign of the welfare gains I substitute in the functional form for $g(n)$ assumed in

2.2.29 and the result for $n(\sigma)$ obtained in 2.2.30 with $\lambda = 0$ and $\frac{\epsilon}{\epsilon-1} = 1$:

$$
\begin{aligned}
WG^{B1} &= log(1) + \frac{1}{2}log(1 + \sigma^{B1}) + \frac{1}{2}(1 + \sigma^{B1})^{-1} - \frac{1}{2}(1)^{-1} \\
&= \frac{1}{2}\left(log(1 + \sigma^{B1}) + \frac{1}{1 + \sigma^{B1}} - 1\right) \\
&= \frac{1}{2}\left(log(1 + \sigma^{B1}) - \frac{\sigma^{B1}}{1 + \sigma^{B1}}\right) \\
&\approx \frac{1}{2}\left(\sigma^{B1} - \frac{\sigma^{B1}}{1 + \sigma^{B1}}\right) \\
&= \frac{1}{2}\left(\frac{(\sigma^{B1})^2}{1 + \sigma^{B1}}\right) > 0
\end{aligned}
\tag{2.7.14}
$$

QED

Proof of Proposition 5. *The proof of the first result, the optimal rate of inflation in a monetary union, is analogous to the Proof of Proposition 2. As $\lambda = \lambda^* = 0$ it must be that $\sigma_2^U = -1$. Therefore it must be that σ_1^U is the optimal inflation rate. Plugging in $\mu = \mu^\#$ to 2.4.5 we get::*

$$
\begin{aligned}
\frac{1}{\mu^\#(1 + \sigma^{B2U})} &= 1 \\
1 + \sigma^{B2U} &= \frac{1}{\mu^\#} \\
\sigma^{B2U} &= \frac{1 - \mu^\#}{\mu^\#}.
\end{aligned}
\tag{2.7.15}
$$

It is immediate to see, that as $\theta < 1$ it must be that:

$$
\frac{1 - \mu^\#}{\mu^\#} < \frac{1 - \theta\mu^\#}{\theta\mu^\#} \iff \sigma^{B2U} < \sigma^{B2}
\tag{2.7.16}
$$

Next I prove the second result, the welfare improvement from adoption of a common currency, following the logic of the Proof of Proposition 4. Welfare gains from the adoption of a common currency in the Benchmark 2 economy are:

$$
\begin{aligned}
WG^{B2} &= V(\sigma^{B2U}, \sigma^{B2U}) - V(\sigma^{B2}, \sigma^{*B2}) \\
&= \theta log(\theta\bar{n}(\sigma^{B2U})) + (1 - \theta)\,log((1 - \theta)\,\bar{n}(\sigma^{B2U})) - g(\bar{n}(\sigma^{B2U})) \\
&\quad - \theta log(\theta\bar{n}(\sigma^{B2})) - (1 - \theta)\,log((1 - \theta)\,\bar{n}^*(\sigma^{B2})) + g(\bar{n}(\sigma^{B2})) \\
&= log(n(\sigma^{B2U})) - log(n(\sigma^{B2})) + g(n(\sigma^{B2})) - g(n(\sigma^{B2U}))
\end{aligned}
\tag{2.7.17}
$$

To asses the sign of the welfare gains I substitute in the functional form for $g(n)$ assumed in

2.2.29 and the result for $n(\sigma)$ obtained in 2.2.30 with $\lambda = 0$:

$$n(\sigma^{B2U}) = (\mu^{\#})^{-\frac{1}{2}}(1 + \sigma^{B2U})^{-\frac{1}{2}} \tag{2.7.18}$$

$$n(\sigma^{B2}) = (\mu^{\#})^{-\frac{1}{2}}(1 + \sigma^{B2})^{-\frac{1}{2}} \tag{2.7.19}$$

$$
\begin{aligned}
WG^{B2} &= -\frac{1}{2}log(\mu^{\#}) - \frac{1}{2}log(1 + \sigma^{B2U}) + \frac{1}{2}log(\mu^{\#}) + \frac{1}{2}log(1 + \sigma^{B2}) \\
&\quad + \frac{1}{2}(\mu^{\#})^{-1}(1 + \sigma^{B2})^{-1} - \frac{1}{2}(\mu^{\#})^{-1}(1 + \sigma^{B2U})^{-1} \\
&= \frac{1}{2}\left\{ log(1 + \sigma^{B2}) - log(1 + \sigma^{B2U}) + \frac{1}{\mu^{\#}(1 + \sigma^{B2})} - \frac{1}{\mu^{\#}(1 + \sigma^{B2U})} \right\} \\
&\approx \frac{1}{2}\left\{ \sigma^{B2} - \sigma^{B2U} + \frac{1}{\mu^{\#}(1 + \sigma^{B2})} - \frac{1}{\mu^{\#}(1 + \sigma^{B2U})} \right\} \\
&= \frac{1}{2}\left\{ \sigma^{B2} - \sigma^{B2U} + \underbrace{\frac{\sigma^{B2U} - \sigma^{B2}}{\mu^{\#}(1 + \sigma^{B2})(1 + \sigma^{B2U})}}_{>1} \right\} \\
&> \frac{1}{2}\left\{ \frac{\sigma^{B2} - \sigma^{B2U}}{\mu^{\#}(1 + \sigma^{B2})(1 + \sigma^{B2U})} + \frac{\sigma^{B2U} - \sigma^{B2}}{\mu^{\#}(1 + \sigma^{B2})(1 + \sigma^{B2U})} \right\} = 0 \\
&\iff WG^{B2} > 0 \tag{2.7.20}
\end{aligned}
$$

As countries are symmetric, if adopting a common currency improves welfare of a single country it also improves joint welfare. QED

Proof of Proposition 6. *First, notice that from 2.2.30 and 2.2.28:*

$$n(\sigma) = (\mu(\sigma)(1 + \sigma))^{-\frac{1}{2}} \tag{2.7.21}$$

next, from 2.3.4:

$$\mu(\sigma^{B3})(1 + \sigma^{B3}) = \frac{1}{\theta} \tag{2.7.22}$$

and from 2.4.5

$$\mu(\sigma^{B3aU})(1 + \sigma^{B3aU}) = 1. \tag{2.7.23}$$

Therefore, as $\lambda = \lambda^*$:

$$n(\sigma^{B3}) = n^*(\sigma^{B3}) = \theta^{\frac{1}{2}} \tag{2.7.24}$$

$$n(\sigma^{B3aU}) = n^*(\sigma^{B3aU}) = 1 \tag{2.7.25}$$

Welfare gains from the adoption of a common currency in the Benchmark 3a economy therefore are:

$$WG^{B3a} = V(\sigma^{B3aU}, \sigma^{B3aU}) - V(\sigma^{B3}, \sigma^{B3}) = log(n(\sigma^{B3aU})) - log(n(\sigma^{B3})) + g(n(\sigma^{B3})) - g(n(\sigma^{B3aU}))$$

$$= log(1) - log(\theta^{\frac{1}{2}}) + \frac{1}{2}\theta - \frac{1}{2} = \frac{1}{2}(\theta - 1 - log(\theta)) > \frac{1}{2}(\theta - 1 - \theta + 1) = 0$$

$$\Longleftrightarrow WG^{B3a} > 0 \qquad\qquad\qquad\qquad (2.7.26)$$

As countries are symmetric, if adopting a common currency improves welfare of a single country it also improves joint welfare. QED

Chapter 3

Foreign Banks and Monetary Policy in Central and Eastern Europe

Joint with Piotr Denderski (VU University Amsterdam)

Abstract

We provide new evidence on the bank lending channel of monetary policy using bank-level panel data from Central and Eastern Europe economies. We examine loan granting behavior of 440 banks in the period between 1998 and 2012. Our findings are: i) banks adjust their loans to changes in host country's monetary policy, ii) foreign-owned banks are less responsive to monetary policy of a host country than domestic-owned banks, iii) contrary to previous studies we document that the effects i) and ii) are present not only in the times of a crisis, but also in normal times. Using a DSGE model with the bank lending channel we present two mechanisms that can explain the second effect. First, foreign banks may have access to funds from parent banks, which makes them less dependent on the cost of money in a host country. Second, foreign banks may have a competitive advantage in a sense that they serve more profitable borrowers and therefore their loan portfolio adjusts less. The first mechanism renders monetary policy less effective in the level of foreign banks penetration, while the second one does not. We derive testable implications of the two hypotheses and show that data do not unambiguously favor one over the other. [1]

3.1   Introduction

Financial liberalization has led to an increased integration of financial markets over the last 30 years. The emerging and developing countries, however, entered this process with under-capitalized and weak banks. In result, large shares of the financial sector in these countries are controlled by subsidiaries of foreign banks. Thus, the financial integration was accompanied by a development of asymmetric cross-border owner-subsidiary relationships.

We explore the consequences of this asymmetric integration in the particular area of the Central and Eastern Europe (CEE). Banks dominate financial structure of the CEE economies and most of these banks are majority foreign-owned. As of 2009 the share of the majority foreign-owned banks in the total assets of the banking sector in the CEE economies is greater than 80 percent on average. For the other European Union members this number stands at 25 percent[2]. The relationship between bank ownership and the growth of credit is currently receiving an increased interest in the literature starting with Peek and Rosengren (1997), who show that Japanese-owned banks in the US contracted their lending significantly in a response to a slump in the Japanese stock market. Micco and Panizza (2006) show, using the world-wide sample of 119 countries in the years 1995-2002, that the lending of state-owned banks is less responsive to macroeconomic shocks than that of privately-owned banks .

The CEE transition countries have become a natural field for empirical studies of foreign-owned banks behavior. Bonin et al. (2005) find that in the CEE countries foreign-owned banks are more cost-efficient and provide better services, Naaborg and Lensink (2008) in the similar sample find a somewhat contrary result, that foreign-owned banks are less profitable. de Haas and van Lelyveld (2006) is the first study that looks at the relationship between a foreign ownership in the CEE countries and the growth of credit. They show that in the years 1993-2000 there is a positive relationship between foreign banks and the private sector credit growth, during crisis periods domestic banks contract their credit base, while greenfield foreign banks do not, and that the conditions in a home country matter for the foreign bank growth in a host country. Aydin (2008) studies the period 1988-2005 and further confirms that credit growth is higher in foreign banks. However, contrary to the former, she shows that conditions in a home country do not matter for the credit granting behavior of a foreign bank in a host country. Allen et al. (2013) show that during domestic financial crises foreign banks provide credit, while government banks contract and that the reverse has happened during the global financial crisis of 2008[3]. None of the cited studies

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[2]Own calculations based on Claessens and Van Horen (2013). In 2009 in the eleven CEE economies this number varies between 64 and 99 percent. In the non-CEE EU economies foreign bank penetration is more heterogeneous and varies from 2 percent (Spain and Netherlands) to 95 percent (Luxembourg), with Ireland, Belgium and Luxembourg having more than 50 percent of their banking system foreign-owned.

[3]Another contributions that look at the role of foreign banks during the global financial crisis in a wider geographical setting are Adams-Kane et al. (2013), Ongena et al. (2013), while Popov and Udell (2012) use paired firm-banking data in 16 CEE economies to show, *inter alia*, that firm's access to credit reflects the balance sheet conditions of foreign parent bank.

however, pay attention to monetary policy in host countries and whether foreign and domestic banks reactions to changes in interest rates are different. That is, in other words, how presence of foreign banks affects the bank lending channel of the monetary policy transmission.

The bank lending channel pioneered by Bernanke and Blinder (1992) on aggregate data and Kashyap and Stein (2000) on bank-level data assumes that, at the bank-level, deposits and other financing are imperfect substitutes. Therefore, when a central bank raises interest rates, the supply of credit at the bank level goes down. The only contribution in the literature that studies the bank lending channel in the CEE economies (pooled together with Latin America and South-East Asia economies) is Wu et al. (2011). Using bank level data for the period of 1996-2003 they show that foreign banks are less responsive to monetary shocks in host countries. After a monetary policy contraction the growth of credit in foreign banks goes down less compared to domestic banks (and the reverse is true after a monetary policy expansion). They suggest that the most convincing mechanism that can explain those differences is an access of foreign banks to funding from parent banks through an internal capital market. However, a close inspection of their results shows that the existence of the bank lending channel and differences between domestic and foreign banks reactions are only present during periods of crises and not in tranquil times.

In this paper we contribute to the empirical literature by documenting that lending by foreign banks is less responsive to both tightening and loosening of host country's monetary policy in both tranquil times and during financial crisis. We collect data on credit growth and ownership for 440 banks in the eleven CEE countries[4] in the years 1998-2012. We regressthe real rate of growth of net credit on the foreign ownership dummy, the change in the monetary policy rate and their interaction (plus bank-level and macroeconomic controls). Next, we explicitly control for the effects of the global financial crisis, and finally we run a battery of robustness checks to control for possible endogeneity issues and different monetary policy regimes. At each stage we employ three different empirical strategies: pooled OLS, fixed effects panel estimation and a difference GMM estimation. The existence of the bank lending channel and the differences between domestic and foreign banks in both crisis and normal times comes out as a robust finding of the empirical part of this paper.

Next, we build a theoretical, stylized DSGE model with the bank lending channel and show that the observed data patterns can be driven by the two equally plausible mechanisms: the internal capital market as in Wu et al. (2011) (later referred to as the *internal market hypothesis*) and a market segmentation that favors foreign banks (later referred to as the *market segmentation hypothesis*). The bottom line of the theoretical analysis is that observing a different *micro* lending behavior of foreign and domestic-owned banks on its own is not a sufficient statistic for deriving conclusions on shifts in the *aggregate* lending channel.

The first explanation assumes that foreign-owned banks may trade easily within the financial conglomerate they are a part of, which would make host country monetary policy less relevant for

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[4]Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia.

their operations. Foreign-owned banks could also be forced to transfer liquidity in the case of a direct dependence, especially when a parent bank is in troubles.

The second explanation assumes that the links with a parent bank are not important for the credit granting behavior of a foreign bank in a host country, but instead assumes that foreign banks operate their business differently than domestic banks. We highlight two possible rationales. First, a foreign bank may inherit credit relationships with firms that are clients of its parent bank. When there is selection into foreign expansion, then foreign-owned banks lend to more productive companies. Such credit is less sensitive to changes of host country's monetary policy because of implicit costs embedded in adjusting terms of contracts. De Haas and Naaborg (2006) find that an acquisition of a domestic bank by a foreign bank leads to a bias in the acquired bank's lending towards large multinational companies. Second, if foreign-owned banks have better know-how (e.g. screening technology or marketing) then they grant credit to more reliable customers which can still service their liabilities under higher interest rates. In this world, domestic banks have larger shares of contracts that are prone to termination because of an increase in interest rates. Bonin et al. (2005) shows evidence that foreign banks indeed bring know-how into the CEE economies banking sector.

Our theoretical model borrows from the framework put forth in Gerali et al. (2010) and Gambacorta and Signoretti (2014). This environment facilitates handling bank ownership heterogeneity by using of the analytically tractable monopolistic competition framework[5]. We put the two hypotheses to race in the model. Most importantly, we demonstrate that while the *internal market hypothesis* implies weakening of the bank lending channel in the aggregate, the *market segmentation hypothesis* does not. Despite its ability to reproduce observed differential loans responses to monetary shocks, the model falls short of replicating the size of these differences. Using the panel data from the empirical part of the paper we show that data do not unambiguously favor one over the other and at this stage we can assert that both can be at play.

3.2 Empirical Analysis

3.2.1 Data

We construct our sample using bank-level and macroeconomic data. Our primary source of data is Bankscope, a commercial database provided by Bureau van Dijk. Bankscope provides a large set of standardized and comparable bank-level data in a form of a panel. Our sample with identified ownership structure includes 440 banks in the CEE countries active for at least one year between 1998 and 2012 (out of the total number of 514 banks registered in Bankscope) giving rise to a total number of 4008 bank-year observations. Schmitz (2004) compares Bankscope data with the IFS data and finds that approximately 70% to 90% of total banking assets is covered by Bankscope

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[5]albeit at the expense of shutting down other margins of dynamic competition like entry, exit and bank size

for the CEE countries. Mathieson and Roldos (2001) on the other hand estimate data coverage to be about 90% of the total banking assets in the CEE countries. The coverage of Bankscope data increases in time due to market concentration and data quality improvements.

We use data on net loans to construct our dependent variable, the real rate of growth of net loans at the bank level. We also use Bankscope to construct four bank control variables: size, liquidity, capitalization and profitability[6]. The first one is a ratio of total assets of a bank in a given year to the sum of total assets in all banks in the same country in the same year. The remaining three are ratios of each bank's liquid assets, operating profit and total equity to total assets. All original variables are denominated in local currencies.

Identifying foreign-owned banks is the most important (and the most cumbersome) aspect of our data collection. We define a bank as foreign-owned if immediate shareholders owning more than 50 percent of its capital are located in a different country than the bank itself. The ownership data however, is not easily accessible. Bankscope does not provide a panel view of the ownership data, only the most recent record. We collected the data on banks' ownership using three sources: Claessens and Van Horen (2013) dataset, most recent records on Bankscope and investigating individual bank reports history both on Bankscope and outside this database (banks' websites). We use the same procedure to identify banks that are government-owned. Our final sample with identified ownership covers on average 97.25% of the volume of net loans reported in Bankscope. Tables 3.9 and 3.10 in the Appendix present data coverage of our sample broken down into individual countries and years. The coverage of the ownership data is reasonably balanced across both years and countries.

The second key variable in our study is the interest rate set by a central bank. We collect data on central bank monetary policy instruments from Eurostat and central bank websites. Our variable of interest is a change in the yearly average of the short term interest rate. The sample covers rich variation in the stance of monetary policy across countries. Between years 1998 and 2012 negative interest rate changes stood for about 60% of all covered cases. The pre-2008 sample is more balanced: negative changes correspond to 55% of all cases. We use the same sources for the macroeconomic controls, the growth rate of GDP, inflation and (for the robustness analyses) the euro exchange rates.

We document in detail the cross-section facts about foreign and domestic banks in Appendix A. We find that in our sample foreign-owned banks are larger than domestic banks, have lower liquidity and capitalization but are more profitable. We also find that the capitalization and liquidity measures were decreasing in time in both groups. The average size of a domestic bank declined sharply after 2002 which roughly corresponds to the end of the biggest wave of penetration

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[6]This similar set of controls is also used in related studies: Allen et al. (2013) use the same set plus a lagged ratio of deposits to total assets, de Haas and van Lelyveld (2006) use the same set plus a a net interest margin to measure efficiency, Wu et al. (2011) use size, liquidity, capitalization, cost efficiency and credit risk, while Aydin (2008) uses somewhat different measures for size, liquidity and capitalization, two measures for profitability plus a net interest margin, costs to income and deposits and loan loss provisions to total assets.

of local markets by foreign banks.

3.2.2   Panel Estimation

We estimate the model of the real rate of growth of loans of bank i in country j at time t, denoted by ΔL_{ijt}. To test if there are differences between foreign and domestic banks reactions to monetary policy we employ the following model specification:

$$\Delta L_{ijt} = \beta_1 FGN_{it} + \beta_2 \Delta MP_{jt} + \beta_3 \Delta MP_{jt} * FGN_{ijt} + \beta_4 \text{Bank}_{it} + \beta_5 \text{Economy}_{jt} + \beta_0 \qquad (3.2.1)$$

We introduce the foreign ownership dummy FGN_{it} that takes one if more than 50% of bank's capital is owned by shareholders located abroad and zero otherwise. In this, we label FGN both subsidiaries of foreign banks operating in host country j and independent banks that have majority owership located abroad. If foreign banks have different credit policies then this estimate should be significant, as in Aydin (2008) and Allen et al. (2013), who find it to be significant and positive. Our main variables of interest are: the change in the monetary policy instrument in country j in time t denoted by ΔMP_{jt} and its interaction with the foreign dummy $\Delta MP_{jt} * FGN_{it}$. If the bank lending channel is at work then the first estimate will be significant and negative. If the bank lending channel operates differently in foreign and domestic banks then the second estimate will be significant. If foreign banks react more to changes in monetary policy then we should see a negative estimate, if on the other hand they react less, we should see positive estimate that is less in absolute value than the estimate of ΔMP_{jt}.

Apart from the foreign dummy we employ four bank controls $Bank_{it}$ of bank i in time t including size $Size_{it}$ (0), liquidity Liq_{it} (+/-), capitalization Cap_{it} (+) and profitability $Prof_{it}$ (+) with expected signs in parentheses[7]. Lastly, we add macroeconomic conditions $Economy_{jt}$ differing across countries j and time t by putting the GDP growth rate GDP_{jt} and the inflation rate π_{jt} to control for possible demand effects. We expect credit growth to respond positively to GDP growth and negatively to inflation. The details of construction of the all variables are provided in the Appendix A.

We estimate three versions of the model. For start, we run a classical OLS regression. We recognize however, that the estimates from the OLS might be biased due to the endogeneity problem. Firstly, our main variable of interest, the bank ownership, might not be exogenous to the credit policy of a bank. In theory, it is possible, that domestic-owned banks that exhibit faster growth of credit are more prone to be bought by a foreign owner. Secondly, bank-level control variables

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[7]Out of the four most related studies to ours Wu et al. (2011) do not report estimates of bank controls, others find consistently that size does not matter for credit growth, Allen et al. (2013) find positive estimate of profitability, negative of liquidity and capitalization to be not significant, de Haas and van Lelyveld (2006) find positive estimate of profitability and capitalization and liquidity to be not significant, while Aydin (2008) finds mixed evidence for profitability and positive estimate for liquidity.

(size, capitalization, liquidity and profitability) might also be endogenous to the credit growth and macro controls.

Secondly, we apply fixed effects panel estimation (FE). We control for bank and time fixed effects. Controlling for time fixed effects allows us to remove any possible trend or time-specific factors that may affect credit behavior of all banks in a given year[8].

Some studies related to ours[9] deal with the endogeneity problem by employing one period lag for bank control variables. We follow this approach augmented by the difference GMM estimation[10] developed by Arellano and Bond (1991). In this estimation we allow dependent variable (ΔL_{ijt}) to be potentially autocorrelated, contemporary bank controls ($Size_{it}$, Liq_{it}, Cap_{it} and $Prof_{it}$) to be endogenous[11] and ownership (FGN_{ijt}) to be predetermined but not strictly exogenous. Macro controls (GDP_{jt} and π_{jt}), lagged bank controls ($Size_{it-1}$, Liq_{it-1}, Cap_{it-1} and $Prof_{it-1}$) and independent variable (ΔMP_{jt}) are treated as strictly exogenous and therefore in the estimation process are potential instruments for the differenced endogenous variables. Formally, we estimate differenced equation 3.2.1, where lagged credit growth and lagged levels of banks controls deal as potential instruments for the differenced independent variables. In each specification to avoid spurious inference, we cluster the errors on a country level.

3.2.3   Baseline Results

In Table 3.1 we present the results of the estimation of the benchmark model from the equation (3.2.1). First, the results confirm the existence of the bank lending channel. Banks contract their credit action after an increase in the monetary policy rate (and expand after a decrease in the MP rate). Second, foreign banks react differently than domestic banks to changes in the monetary policy rate. The reaction of their credit is more tamed (by more than a half). Interestingly, previous studies found that the very fact of banks being foreign-owned affects their credit granting behavior. In none of our estimations foreign dummy variable FGN is significant, but in all three methods its interaction with the monetary policy rate is significant, positive and less than the estimate of the change in monetary policy rate in absolute value. Our results show that the differences between foreign and domestic banks come exclusively from their reactions to the monetary policy rate, that is through the bank lending channel.

In the two models (OLS and FE) the size of a bank, as expected, does not affect its credit granting behavior. However, a difference GMM estimation shows that credit grows faster in bigger banks. More liquid banks and better capitalized banks extend less credit (as in Allen et al. (2013)). As expected, profitability increases the growth of credit at the bank-level in all three estimations.

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[8]Formally we estimate bank and time-specific intercepts $\beta_0 = [\beta_i \quad \beta_t]$.

[9]Wu et al. (2011), Adams-Kane et al. (2013), Claessens and Van Horen (2013), Gambacorta (2005) and Brzoza-Brzezina et al. (2010)

[10]We would like to thank the anonymous referee for suggesting this approach.

[11]For the sake of brevity we suppress coefficient estimates for the lagged bank controls in all regression results tables

Table 3.1: Determinants of bank lending 1998-2012

	OLS	FE	GMM
FGN	-1.243	2.967	1.438
	(2.298)	(3.152)	(2.791)
MP	-1.582***	-1.734***	-1.332***
	(0.281)	(0.378)	(0.351)
FGN*MP	1.137***	0.930***	1.137**
	(0.342)	(0.228)	(0.499)
Size	-0.0416	-0.0160	2.292**
	(0.0630)	(0.277)	(1.008)
Liq	-0.0687	-0.353***	-0.713***
	(0.0479)	(0.0617)	(0.120)
Cap	-0.235**	-0.648**	-2.103***
	(0.0937)	(0.203)	(0.406)
Prof	1.581***	1.561***	1.756***
	(0.451)	(0.408)	(0.238)
GDP	2.204***	1.156***	0.825**
	(0.304)	(0.157)	(0.259)
Pi	-0.382	-1.099***	-1.027***
	(0.234)	(0.145)	(0.179)
L.Delta Net Loans			0.212***
			(0.0256)
Observations	2403	2403	2001

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

Macroeconomic controls that affect the demand for credit work as expected. The volume of credit at the bank-level increases in GDP growth and decreases in inflation. According to the results of the difference GMM estimation the growth of credit is positively autocorrelated, albeit the coefficient is not high.

Once we bring domestic monetary policy in the picture, the significance of foreign ownership dummy, found in other studies, vanishes. The data suggest that it is the differential response to the domestic monetary policy that is differentiating foreign-owned banks from domestic banks.

3.2.4   Results - Financial Crisis

Next we distinguish between reactions to monetary policy in normal times and during financial turmoil by estimating the following equation:

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\begin{aligned}
\Delta L_{it} = \beta_1 FGN_{it} + \beta_2 \Delta MP_{jt} + \beta_3 \Delta MP_{jt} * FGN_{ijt} + \beta_4 \text{Bank}_{it} + \beta_5 \text{Economy}_{jt} \\
+ \beta_5 Crisis * \Delta MP_{jt} + \beta_6 Crisis * \Delta MP_{jt} * FGN_{it} + \beta_0
\end{aligned}
\tag{3.2.2}
$$

where we include the interaction of the crisis dummy, that takes value one for the period 2008-2012 and zero otherwise, with the change in monetary policy rate $Crisis * \Delta MP_{jt}$ and the interaction of the crisis dummy with both change in monetary policy rate and the foreign dummy $Crisis *$

Table 3.2: Determinants of bank lending - including Financial Crisis

	OLS	FE	GMM
FGN	-1.154	2.692	1.655
	(2.145)	(3.052)	(2.742)
MP	-1.628***	-1.904***	-1.307***
	(0.403)	(0.434)	(0.376)
FGN*MP	0.660**	0.735**	1.137*
	(0.273)	(0.241)	(0.571)
Crisis*MP	0.407	1.442	-0.131
	(1.162)	(0.810)	(0.555)
Crisis*MP*FGN	2.549***	0.987	0.0573
	(0.606)	(0.559)	(0.664)
Size	-0.0376	-0.0327	2.295**
	(0.0615)	(0.290)	(1.011)
Liq	-0.0725	-0.356***	-0.713***
	(0.0493)	(0.0627)	(0.120)
Cap	-0.236**	-0.651**	-2.105***
	(0.0918)	(0.206)	(0.406)
Prof	1.579***	1.561***	1.754***
	(0.453)	(0.413)	(0.235)
GDP	2.068***	1.144***	0.824**
	(0.244)	(0.161)	(0.258)
Pi	-0.456*	-1.079***	-1.038***
	(0.228)	(0.159)	(0.184)
L.Delta Net Loans			0.211***
			(0.0256)
Observations	2403	2403	2001

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

$\Delta MP_{jt} * FGN_{it}$. We do not need to include crisis dummy itself, as we estimate the model with time fixed effects.

In Table 3.2 we present the results of the estimation of the benchmark model enriched with the Financial Crisis dummy and their interactions as in equation (3.2.2). We see that controlling for Financial Crisis does not change the baseline results. The bank lending channel is still significant and of the same magnitude and the difference between domestic and foreign banks reaction to changes in the monetary policy rate is still significant and of the same magnitude. Most importantly, we find that during financial turmoil of 2008-2012 in the CEE countries bank lending channel did not change neither for domestic banks nor for foreign-owned banks. This further confirms our benchmark results and shows that the differences in reactions to the monetary policy instrument between domestic and foreign banks cannot be attributed to the idiosyncrasy of the financial crisis episode.

3.2.5   Robustness - Monetary Policy Regimes

Our sample consists of countries with similar, albeit not identical monetary policy arrangements. While in the analyzed time-frame the majority of the countries followed an independent monetary policy interest rate setting rule, some countries had their exchange rate pegged to the euro and some did not enjoy an independent monetary policy at all, due to their presence in the common currency area. In this subsection we analyze how do different monetary policy regimes affect our findings from two previous sections. Our hypothesis is that banks, when deciding on their credit growth, take into account monetary policy rate regardless of what a monetary policy regime produced that interest rate. Our findings confirm this hypothesis.

In order to verify our hypothesis we run five additional regressions. In the regression presented in column (1) of the Table 3.11 (see Appendix) we include country fixed effects. This allows us to capture differences in the mean growth of credit at the bank level stemming from time invariant particular characteristics of the economy and institutions, like the monetary policy regime. Additionally, we also add time fixed effects to control for common, time-variant global shocks. Our main finding, that foreign banks reaction to monetary policy is more tamed compared to domestic banks, is unaffected.

Secondly, we expand our baseline model to include the dummy variable $IndependentMP$. This variable takes value 1 for countries that in the given year enjoyed independent monetary policy regime and 0 otherwise. Results of this analysis are reported in column (2). The monetary policy independence does not affect the growth of credit at the bank-level. In column (3) of Table 3.11 we present the results of the more detailed exercise. Additionally, we employ time fixed effects and bank fixed effects. Including the latter allows us to capture the differences in mean credit growth stemming from the time invariant particular credit policies of each bank. Similarly to the previous analysis, the choice of a monetary policy regime does not affect credit policy at the bank level.

In column (4) we take a somewhat different approach. Instead of looking at the institutional arrangements regarding the monetary policy conduct directly, we take a look at possible symptoms. Different degrees of freedom in setting interest rate lead to different volatilities in local exchange rates, particularly versus the euro. Thus, we expand the set of independent variables to include the yearly relative change in the exchange rate of a local currency versus the euro. The variable turns out to be significant. Local currency depreciation of a 1% leads to a decrease in the average growth of a credit at the bank level by 0.39 p.p.. Extending the set of controls does not affect our key finding, however. In column (5) we expand the analysis from column (4) by adding country and time fixed effects. We observe that the significance of the exchange rate found in column (4) vanishes and again, our main finding is still unaffected.

3.2.6   Robustness - Further Evidence

To further confirm the robustness of our results we run two alternative specifications of our benchmark model. In the first we include government ownership dummy GOV_{it} and its interactions with the change in the monetary policy rate and with the crisis dummy (see Table 3.12 in Appendix). Contrary to previous studies[12] we find that public-owned banks neither differ in their credit granting behavior from private domestic banks, nor do they differ in their reaction to monetary policy rate changes. Controlling for public banks we confirm the robustness of our baseline results.

Next, we take a close look at takeovers of domestic banks by foreign owners. Table 3.13 show the results of estimations in which we address possible problem of the ownership endogeneity. We drop all observations of banks that became foreign owned. We also have to drop the variable FGN_{it} as it becomes co-linear with the sum of bank fixed-effects for foreign-owned banks. We find that our baseline results are robust both qualitatively and quantitatively.

3.3   Sketch of the DSGE model

Our theoretical analysis builds on Gerali et al. (2010) and Gambacorta and Signoretti (2014). The details of the derivations are explained in Appendix 3.6.4. Here we discuss the most important equations and building blocks of the model.

There are two groups of agents in the private sector: households and entrepreneurs. Both groups are risk averse, households care about consumption and leisure while entrepreneurs are only concerned with consumption. Because of different rate of time preferences, entrepreneurs borrow while households save. Entrepreneurs buy capital from capital producing firms and hire labor in the competitive market. There is a central bank that sets nominal interest rates.

There is a unit mass of banks, of which a fraction μ is foreign-owned. Each bank comprises of two branches: a wholesale branch that deals on the interbank market and collects deposits in a perfectly competitive market and a retail branch that grants loans. Foreign direct owners take decisions on the balance sheet structure of their subsidiaries by deciding on dividends. Adjusting the dividends implies costs on the owner bank.

There is a set of financial frictions at play. Both savings and borrowing can only be done via intermediaries. Borrowing is also subject to a borrowing constraint such that the amount borrowed is related to the valuation of entrepreneur's capital. We also postulate that due to product differentiation loans at different banks are imperfect substitutes.

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[12]Micco and Panizza (2006) for worldwide study of banks lending behavior between 1995-2002 and Allen et al. (2013) for study of CEE banks between 1994-2010.

3.3.1   Households and Entrepreneurs

Households discount future at a rate β_H. Each period each household decides how much to consume $c_t(i)$, how much labor to supply $l_t^H(i)$ and how much to save in bank deposits $d_t(i)$ given the wage rate W_t and last period savings $d_{t-1}(i)$ to maximize expected stream of utilities. Households own banks and retail good packers and receive their dividends and profits. Formally, household i solves:

$$\max_{c_t^H, l_t^H, d_t^H} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_H^t \left(\log\left(c_t^H(i)\right) - \frac{l_t^H(i)^{1+\phi}}{1+\phi} \right) \tag{3.3.1}$$

$$\text{subject to: } c_t^H(i) + d_t^H(i) \leq w_t l_t^H(i) + \left(1 + r_{t-1}^d\right) d_{t-1}^H(i) + T_t^H. \tag{3.3.2}$$

with T_t^H is a transfer including dividends from retail firms and bank dividends, π_t inflation and r_t^d the nominal return on deposits.

We assume that entrepreneurs maximize the utility of consumption discounted at a rate $\beta_E < \beta_H$. Entrepreneur i solves:

$$\max_{c_t^E, l_t^E, k_t^E, b_t^E} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_E^t \log\left(c_t^E(i)\right) \tag{3.3.3}$$

$$\text{subject to: } y_t^E(i) = a_t^E \left(k_t^E\right)^{\alpha} \left(l_t^E(i)\right)^{1-\alpha}, \tag{3.3.4}$$

$$\frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i) = c_t^E(i) + w_t l_t^E(i) + \left(1 + r_{t-1}^{bE}\right) b_{t-1}^E(i) + q_t^k k_t^E(j), \tag{3.3.5}$$

$$\left(1 + r_t^{bE}\right) b_t^E(i) \leq m^E E_t \left(q_{t+1}^k (1-\delta) k_t^E(i)\right). \tag{3.3.6}$$

where 3.3.4 is the production function, 3.3.5 is the budget constraint and 3.3.6 the borrowing constraint, all denoted in real terms. l_t^E is demand for labor, k_t^E is the chosen stock of capital, a_t^E is a TFP random variable, y_t is the quantity of the intermediate good, q_t^k is the price of capital. Parameter m^E measures the severity of the collateral constraint.

Investment decisions are taken by competitive capital producers. The relative price of capital q_t^k is a ratio of the nominal price of capital P_t^K and the aggregate price level P_t (for capital good producers problem solution see Appendix D).

3.3.2   Aggregate price level

The model features monopolistically competitive retail good packers that aggregate goods produced by each entrepreneur to the single final good and sell it at a markup. The optimization of retail good packers yields a Phillips curve featuring persistence with respect to inflation rate and its deviation from the steady state level (see Appendix D).

3.3.3 Banks

Each bank has two branches: a wholesale and a retail branch. The wholesale branch owns bank equity (also called bank capital) $K^b(o, j)$ and collects deposits $D_t(o, j)$ from households on which it pays the interest rate set by the central bank r_t^{ib}. It also issues wholesale loans to retail branch $B_t(o, j)$ commissioning the interest rate $R_t^b(o, j)$. Following GNSS we assume that there exists a target value of the ratio of bank capital to loans ν (leverage or capitalization ratio). This assumption is crucial to generate realistic interactions between real and financial sectors.

We differentiate banks by ownership $o \in \{dom, fgn\}$. Each bank has to obey the basic balance sheet identity:

$$B_t(o, j) = D_t(o, j) + K_t^b(o, j). \qquad (3.3.7)$$

Bank capital of a domestic bank is financed from the retained earnings:

$$K_t^b(dom, j) = (1 - \delta_b) K_{t-1}^b(dom, j) + (1 - \omega_H) J_{t-1}^b(dom, j), \qquad (3.3.8)$$

while a foreign bank's dividends stream is a choice variable of the parent bank:

$$K_t^b(fgn, j) = (1 - \delta_b) K_{t-1}^b(fgn, j) + (1 - \omega_t(fgn, j)) J_{t-1}^b(fgn, j), \qquad (3.3.9)$$

with ω_H denoting the share of the earnings paid out to households by domestic banks. The market for deposits is competitive with the quantity of deposits pinned down exactly by the choice of the risk-free rate by the central bank. The key idea here is that the adjustment of the dividends stream acts implicitly as the internal market for bank capital. Domestically owned banks have a rigid dividends policy because their ownership is more dispersed. The presence of a dominant foreign owner, who has access to outside capital however, allows for adjusting the dividends. We also assume that there are quadratic costs of adjusting the dividend parameter from the reference value (equal to ω_H):

$$Adj(\omega_t, \omega_H) = \frac{\kappa_\omega}{2} (\omega_t - \omega_H)^2. \qquad (3.3.10)$$

The optimization problem of a foreign bank is identical with one exception. The foreign bank owner decides on the allocation of the dividends, taking into account how it affects future profits. If the dividends increase too much today, they will negatively affect the subsidiary's profits next period. Formally foreign bank owner solves:

$$Div_t^* = \max_{\omega_t(j)} \int_\mu \left(\omega_t(j) J(fgn, j) - \frac{\kappa_\omega}{2} (\omega_t(j) - \omega_H)^2 \right) dj + \beta^{H*} \mathbb{E} Div_{t+1}^*. \qquad (3.3.11)$$

There are two points to be made here. First, the foreign owner bank can potentially mitigate the costs stemming from changes in monetary policy in the Home country trading them against the costs of adjusting the dividends. Second, observe that setting $\kappa_\omega \mapsto \infty$ yields the foreign and

domestic banks identical, as it forces $\omega_t = \omega_H$ and in this case these banks are homogeneous.

3.3.4   Wholesale branch

The wholesale branch solves:

$$\max_{D_t(o,j),B_t(o,j)} \{R_t^b(o,j) B_t(o,j) - r_t^{ib} D_t(o,j) - \frac{\kappa_b}{2} \left(\frac{K_t^b(o,j)}{B_t(o,j)} - \nu\right)^2 K_t^b(o,j)\} \tag{3.3.12}$$

subject to the balance sheet identity for pre-determined bank capital. The last expression in 3.3.12 is a loans adjustment cost function. We follow the assumption that it is a quadratic function in adjustment from the target leverage ratio ν^b and is multiplicative in the level of bank capital $K_t^b(o,j)$. We plug the balance sheet constraint into the target function and calculate the first order conditions to get:

$$R_t^b(o,j) = r_t^{ib} - \kappa_{Kb} \left(\frac{K_t^b(o,j)}{B_t(o,j)} - \nu^b\right) \left(\frac{K_t^b(o,j)}{B_t(o,j)}\right)^2. \tag{3.3.13}$$

Banks optimal policy collapses to choosing a time-varying markup over the central bank's rate.

Loan branch   The loan branch collects the wholesale loans and differentiates them at no cost generating monopolistic power over its own loan type j of the total loan variety which gives rise to the standard demand equation:

$$b_t^E(o,j) = \left(\frac{r_t^{bE}(o,j)}{r_t^{bE}}\right)^{-\varepsilon^{bE}} b_t^E. \tag{3.3.14}$$

with pricing equation involving a markup on the wholesale rate $R_t^b(o,j)$ which is proportional to the elasticity of substitution between loans of different banks:

$$r_t^{bE}(o,j) = \frac{\varepsilon^{bE}}{\varepsilon^{bE} - 1} R_t^b(o,j). \tag{3.3.15}$$

The law of motion for profits of bank j reads:

$$J_t^b(o,j) = r_t^{bE}(o,j) b_t^E(o,j) - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b(o,j)}{B_t(o,j)} - \nu^b\right)^2 K_t^b(o,j) - Adj_t^B(o,j) \tag{3.3.16}$$

with the last term being the cost of adjustment of bank capital structure. Equilibrium conditions and aggregation equations are relegated to the Appendix.

3.3.5   Central bank and monetary policy

The central bank follows a Taylor rule that features smoothing of rates in addition to tracking the deviations of inflation and product:

$$(1 + r_t) = (1 + r)^{1-\phi_R} (1 + r_{t-1})^{\phi_R} \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi (1-\phi_R)} \left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_\pi (1-\phi_R)} \varepsilon_t^R. \qquad (3.3.17)$$

3.4   Simulations

Before proceeding to simulation-based comparative exercises we go over the response of the homogeneous-banks version of the model to a monetary shock. In Figure 3.1 we plot the response of bank profits, bank capital, loans and deposits to a one standard deviation monetary shock. The decrease of loans is intuitive. In this model the deposits also fell because of entrepreneurs reducing their labor demand and capital stock due to the tightening of the borrowing constraint. Despite the higher rate of return the households consume part of their deposits to smooth the negative income shock triggered by firms cutting production inputs. Because the drop in deposits is stronger than the drop in the loans, the initial bank profits rise to then fall sharply. The response of profits determines the path of bank capital - there is initial accumulation in the initial period and de-accumulation on the convergence to the steady state.

The increase in bank profits is driven by the preference parameters of the households and the entrepreneurs, especially how the hours worked changes are weighted in the utility function. The second component that contributes to our results is the tightness of the borrowing constraint. With more relaxed constraint the immediate effect of the change in interest rates on the loans would be weakened. Note, however, that due to parameter heterogeneity the results we present here are not directly comparable to the results of the next section.

We do two thought experiments, using a calibration borrowing from the literature to investigate the response of bank lending conditional on the composition of the banking sector (how many banks are foreign banks), and adjust some parameters of the model to mimic the *internal market* and *market segmentation* hypotheses. We vary the parameters governing the bank balance sheet dynamics of the foreign-owned banks.

First, we decrease the punishment parameter κ_{K_b} for deviations from the target leverage ratio. This is to model the possibility of liquidity transfer from and to the bank owner. We also decrease the target ratio of bank capital to bank loans for foreign-owned banks, allowing them to fund more loans with a given level of bank capital. Also, foreign bank can freely (but costly) adjust their dividends ratio, while this possibility is ruled out for domestic banks. This exercise corresponds to *internal market hypothesis.*

Second, we shut the dividend smoothing channel and leverage smoothing channel and assume
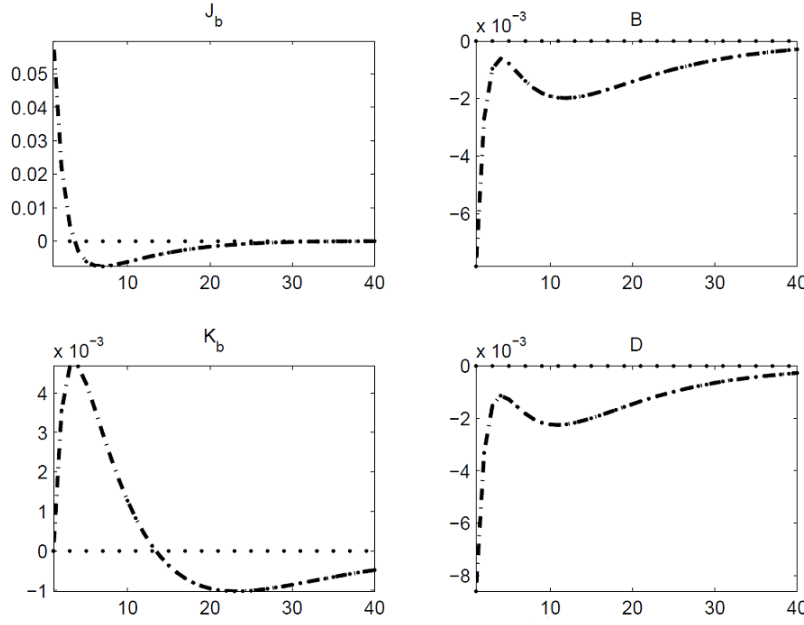
Figure 3.1: Response of banking variables to a one standard deviation monetary shock, homogeneous banks model

same target leverage and same penalties upon deviations from target leverage and target dividends. Instead, we introduce two sub-markets in the market for loans, each with different elasticity of substitution $\varepsilon_{bE}^l < \varepsilon_{bE} < \varepsilon_{be}^h$ picking the values of ε_{bE}^l and ε_{bE}^h such that under the assumption that the two sub-markets are penetrated proportionately by foreign-owned and domestic banks the dynamics of the model remain as in the homogeneous case corresponding to one elasticity ε_{bE} to facilitate comparison. This exercise corresponds to *market segmentation hypothesis*.

For each of the parameters combinations we hit the economy with a one standard deviation monetary shock. We are interested in how the total volume of loans reacts to this shock and how foreign banks loans responses differ from domestic banks loans responses within a one year horizon (one period in our model). We also want to know how the two objects vary with the level of banking sector penetration μ. This exercise is aimed at answering two questions. First, any dependence of the response of total loans on μ would constitute an indirect measure of the strength of the bank balance sheet transmission channel. Second, the differential response of foreign and domestic banks would be a validation test for the model to replicate qualitatively our empirical findings.

The internal market mechanism operates through the wholesale interest rate setting equation. Upon a monetary shock, the foreign owner adjusts the stream of dividends which reduces the response of the wholesale branch rate that pins down the loan rate. The market segmentation mechanism operates primarily through the demand for loans.

3.4.1 Internal market hypothesis

In Figure 3.2 we plot the response of total loans to a monetary shock under low, $\mu = 0.05$ and high $\mu = 0.95$ penetration of a domestic banking system by foreign banks. What we find is that the response of aggregate loans is tamed when foreign-owned banks dominate the domestic banking system. Thus, the balance sheet transmission channel is weakened due to the more flexible adjustment of bank capital in the foreign owned banks. The model can also replicate a weaker response of the foreign banks, as expected. Under the parametrization that corresponds to the results presented in this sub-section we managed to get the first-period response of foreign-owned banks loans to be weaker by about one-third than the reaction of domestic banks loans.
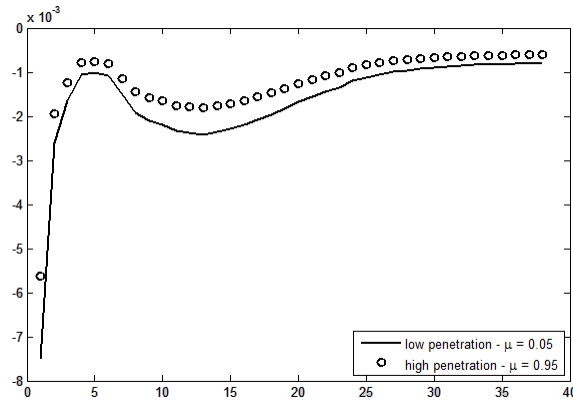
Figure 3.2: Response of a total bank lending to a one standard deviation monetary shock in internal market hypothesis.

The deterioration of the bank lending transmission channel implies that the real effects of monetary shocks are diminished. Thus, the response of prices to monetary policy is also mitigated, in a somewhat similar fashion to the monetary policy trilemma mechanism in a small open economy. The response of the interest rate set by the bank is tamed thanks to a more flexible adjustment of bank capital which leads to a smaller change in the deposits and hence, consumption.

3.4.2 Market segmentation hypothesis

Now, we assume that the banks balance sheet parameters are the same among the two types of banks. We postulate, however, that they manage to introduce some form of market segmentation, where foreign owned banks access more profitable segments of the market for loans. We assume that there are two markets for loans and each entrepreneur is confined to pick from a portfolio of loans in one of the sub-markets. The size of each market is fixed: γ_l for low-elasticity market and $\gamma_h = 1 - \gamma_l$ for the high elasticity market.

Then, we assume that a fraction $\mu^{\varepsilon_l} > 0.5$ of foreign banks operate in the low-elasticity market. In this way we introduce a skew in the composition of the foreign-owned banks loans portfolio such
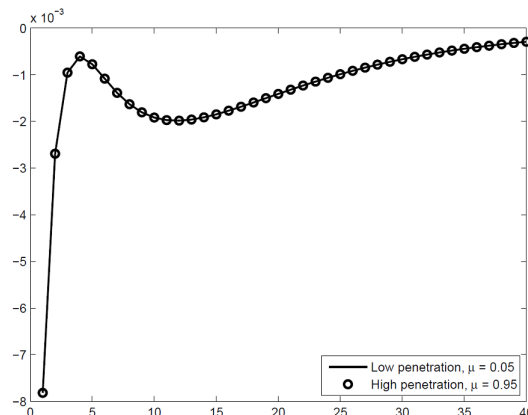
Figure 3.3: Response of a total bank lending to a one standard deviation monetary shock in market segmentation hypothesis.

that out of the total measure of 1 of all banks $\mu\mu^{\varepsilon_l}$ are foreign-owned banks in the low elasticity market and $(1-\mu)\,\mu^{\varepsilon_l}$ is the measure of the domestic banks operating in the low-elasticity market etc. We keep γ_l fixed in our experiments as changing it would change the steady state of the model.

What we find is an increasing differential in the response of loans across two types of banks. In this scenario the level of profits (in the steady state with $\mu = 0.5$ and $\mu^{\varepsilon_l} = 0.8$) differs across banks. We find that foreign banks have steady-state profits roughly equal to 1.5 times the profits of domestic banks. We also find the first-period response of foreign banks loans to be weaker by about 15% than the reaction of domestic banks loans.

Importantly however, switching from low to high penetration scenario makes almost no difference in the dynamics of the total loans after a monetary shock. Regardless of whether there are many foreign banks in the domestic banking sector ($\mu = 0.95$) or very few ($\mu = 0.05$) the reaction of gross credit in the economy to the change in the interest rates is the same. We document this finding in Figure 3.3. The solid line represents reaction of an economy with many foreign banks, while dotted line represents a reaction of an economy with few foreign banks to a one standard deviation monetary shock. Unlike in Figure 3.2 the two economies are indistinguishable. Foreign banks penetration does not affect the aggregate bank lending channel.

Notice that the market segmentation hypothesis implies that the distinction between "foreign" and "domestic" banks boils down to recovering underlying demand heterogeneity. With all the banks being "foreign" or "domestic" no observable difference between the banks would show up in the panel estimation assuming uniform access to both sub-markets. This is why the aggregate response functions don't differ, although on a micro level the differences in the elasticity of the demand for loans introduce differentiated lending patterns.

3.4.3   Discussion

Our simulations show that the two different types of bank heterogeneity lead to qualitatively similar results when it comes to differences in banks lending response to a monetary shock. Lending by foreign-owned banks is less responsive to monetary policy either because of low demand elasticity, or because the bank capital adjustment is smoother. There are several caveats to our results, however. First, the stability of the steady-state of the model hinges on the size of the penalty parameters measuring deviations from target dividend rates and leverage which comes from the deposits and bank capital being perfect substitutes in the balance sheet identity. Second, the mechanism of competition between banks is to a large extent shut down because of absence of entry and exit. Relaxing those assumptions is left for future research.

The implications for the behavior of the total loans of the two mechanisms are different, though. If the main outcome of ownership heterogeneity is flexibility in adjusting the bank capital, then an increased presence of foreign-owned banks weakens monetary policy transmission channel and is prone to instability abroad, as foreign bank import foreign shocks through the internal capital market. On the other hand, due to low dependence on host country conditions foreign banks are less prone to variations not only in the monetary policy rate, but also in host country's GDP. If, however, different ownership leads to bank customer heterogeneity then, what we see is a different partition of the banking sector profits, with no impact on total loans dynamics.

The data used or the empirical part of this paper do not allow us to detect internal capital market directly. However, we can test which of the two hypotheses is more relevant indirectly, by testing assumption and implications.

Testing Assumptions.   In this section we have simulated the DSGE model under two different parametrizations to reflect the two different hypotheses regarding the foreign banks credit granting behavior. First, to mimic the *internal market hypothesis* we made three assumptions: i) the target leverage ratio is lower in foreign banks, ii) the penalty multiplier on deviations from the target leverage is lower in foreign banks, iii) the penalty multiplier on deviations from the target dividends ratio is lower in foreign banks. Those assumption yield following consequences, that should be observed at the bank-level data: i) capitalization in domestic banks is significantly higher than in foreign banks, ii) standard deviation of capitalization in foreign banks is significantly higher than in domestic banks, iii) standard deviation of dividend ratio in foreign banks is significantly higher than in domestic banks.

Second, to mimic the *market segmentation hypothesis* we made only one assumption: more foreign banks operate in the segment where the elasticity of substitution is lower. The consequence of this assumption that we should be able to observe in the data, is that domestic banks are on average less profitable than foreign banks. We collect assumption, testable consequences and data test results in Table 3.3.

Table 3.3: Testing Assumptions Behind Two Hypotheses

Hypothesis	Assumption	Data Test	Result	Verification
Internal market	$\nu^{fgn} < \nu^{dom}$	$Cap^{dom} - Cap^{fgn}$	$= 2.087^{***}$	YES
	$\kappa_b^{fgn} < \kappa_b^{dom}$	$\sigma(Cap^{fgn}) - \sigma(Cap^{dom})$	$= -0.951^{***}$	NO
	$\kappa_\omega^{fgn} < \kappa_\omega^{dom}$	$\sigma(Div^{fgn}) - \sigma(Div^{dom})$	$= -4.005$	NO
Market segmentation	$\epsilon_{bE}^{fgn} < \epsilon_{bE}^{fgn}$	$Prof^{dom} - Prof^{fgn}$	$= -0.133$	NO

* $p<0.10$, ** $p<0.05$, *** $p<0.010$

As indicated in the Table 3.3 the data slightly favour assumptions behind the *internal market hypothesis*: mean capitalization is lower in foreign banks. Contrary to our assumptions however, both capitalization (significantly) and dividends ratio (not significantly) are less volatile in foreign banks than in domestic banks. Regarding the assumption behind the *market segmentation hypothesis*, the data shows that foreign banks are on average more profitable, but the difference is not significantly different from zero.

Testing Implications. Next, we test implications of each hypothesis. The *internal market hypothesis* implies that foreign banks should react to innovations abroad, namely to the changes in the interest rate and GDP in the country of the parent bank. Also, foreign banks, because of the facilitated access to funds from abroad, should react less to the changes in the host country GDP. The second hypothesis on the other hand implies that foreign banks do not react to the innovations abroad and that their reaction to the changes in the host country GDP are the same as domestic banks. To test these assumptions we expand our regression equation in 3.2.1 to include additional terms: monetary policy in the country of the parent bank $MPinFGN$, change in the GDP in the Eurozone $EzoneGDP$ and its interaction term with the foreign ownership dummy $FGN*EzoneGDP$ and an interaction term of the foreign ownership dummy with changes in the host country's GDP $FGN*GDP$. The results of the augmented regression are presented in Table 3.4. Again, we run three different models: pooled OLS, fixed effects and a difference GMM.

The results of this regression show, that none of the three implications of the *internal market hypothesis* are to be found in the data. Foreign banks neither react to the monetary policy nor to changes in the GDP in their home country. Also, foreign banks do not react differently to the changes in the host country GDP, as the existence of the internal capital market would suggest. This, on the other hand, points towards the direction of the alternative hypothesis, the *market segmentation*. To conclude, we show that the data do not unambiguously favor one hypothesis other the other. Although the assumptions of the *internal market hypothesis* are valid, the implications

Table 3.4: Determinants of bank lending - testing implications

	OLS	FE	GMM
FGN	-1.022	1.895	0.797
	(1.622)	(3.164)	(2.246)
MP	-1.542***	-1.648***	-1.302***
	(0.320)	(0.407)	(0.441)
FGN*MP	1.018**	0.811***	1.099**
	(0.340)	(0.201)	(0.533)
GDP	2.554***	1.210***	0.957**
	(0.464)	(0.309)	(0.386)
Pi	-0.388	-1.103***	-1.032***
	(0.232)	(0.142)	(0.140)
Eurozone GDP	-1.089	1.725**	0.253
	(0.921)	(0.670)	(0.822)
EurozoneGDP*FGN	1.112	0.743	0.877
	(0.991)	(0.803)	(0.926)
MPinFGN	1.618	0.292	-0.239
	(1.148)	(0.638)	(1.027)
FGN*GDP	-0.525	-0.0445	-0.190
	(0.338)	(0.391)	(0.491)
Observations	2403	2403	2001

Standard errors in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.010

Table 3.5: Testing Implications of Two Hypotheses

Hypothesis	Implication	Verification
Internal market	Foreign banks react to changes in foreign monetary policy	NO
	Foreign banks react to changes in foreign GDP	NO
	Foreign banks react less to changes in domestic GDP	NO

are not. Conversely, although the assumption of the *market segmentation* hypothesis are not validated in the data, the implications find much more support.

3.5   Lessons for policy and directions for future research

We have documented that foreign-owned banks presence may pose additional challenges for policy makers not only during the times of financial turmoil. Using a variant of a DSGE model featuring monopolistic competition between banks we have demonstrated that the differential response to monetary policy stemming from different ownership does not have to be driven by flows between the subsidiary and the owner. If that was the case, then an increased presence of foreign owned banks would decrease the strength of the bank balance sheet transmission channel.

We argue that industry competition dynamics in the banking sector may also be driving the

empirical patterns. If that is indeed the case then an increased presence of foreign-owned banks in the economy *does not* weaken the bank balance sheet transmission channel but may skew the impact of monetary policy within the banking sector negatively towards domestic owned banks. That is, an increasing penetration by foreign banks may up to some point yield competition concerns for the policy makers. If the weakest, least productive banks are not taken over by foreign banks then monetary policy may affect their profitability and sector concentration.

Our empirical results confirm that the bank ownership can be a worry for monetary policy makers in times of financial distress. Monitoring of bank-owner financial health can prove vital for assessing the risks present in the domestic banking sector.

We think it is worthwhile to approach the issue of foreign banks penetration and monetary policy in a dynamic industry competition model which we leave for future research. It would be interesting to analyze individual country data complementing the cross-country patterns. Possibly different individual experiences can be explained in greater detail by country-specific banking competition factors.

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3.6   Appendix

3.6.1   Data construction and definitions

Table 3.6: Definitions of variables

ΔL_{ijt}	Growth rate of Net Loans in bank i in country j in year t less Inflation rate in country j in year t multiplied by 100. To neutralize the impact of outliers this variable is winsorized at 5th and 95th percentile. Net Loans reported in local currency. Source of Net Loans: Bankscope. Source of Inflation: Eurostat.
Monetary Policy	
MP_{jt}	Monetary policy tool; yearly average of Repo Rate of the central bank in country j in year t less yearly average in year $t-1$. To neutralize the impact of outliers this variable has been cleaned from values lower than -10 (no observations were higher than +10). Source: ECB and central bank's websites.
$MPinFGN_{ijt}$	Foreign monetary policy tool; defined only for observations with $FGN = 1$; yearly average of Repo Rate of the central bank in a residence country of major foreign owner in year t less yearly average in year $t-1$. Source: ECB and central bank's websites.
$IndependentMP$	Independent Monetary Policy dummy; takes value 0 if a country is withing a Eurozone or in a currency peg and 1 otherwise.
Ownership	
FGN_{ijt}	Foreign ownership dummy. Takes value 1 if more than 50% of the shares of bank i in country j in year t are owned by a party located in country different than j. Source: Bankscope and individual banks' websites.
GOV_{ijt}	Government ownership dummy. Takes value 1 if more than 50% of the shares of bank i in country j in year t are owned by a government of country j. Source: Bankscope and individual banks' websites.
Bank Controls	
$Size_{ijt}$	Bank's size; Total Assets in bank i in country j in year t divided by the sum of Total Assets in all banks in country j in time t times 100; winsorized at 99th percentile. Total Assets reported in local currency. Source: Bankscope.
Liq_{ijt}	Bank's liquidity; Liquid Assets divided by Total Assets in bank i in country j in year t times 100; winsorized at 99th percentile and cleared from negative values. Total Assets and Liquid Assets reported in local currency. Source: Bankscope.
Cap_{ijt}	Bank's capitalization; Total Equity divided by Total Assets in bank i in country j in year t times 100; winsorized at 99th percentile and cleared from negative values. Total Assets and Total Equity reported in local currency. Source: Bankscope.
$Prof_{ijt}$	Bank's profitability; Operating Profit divided by Total Assets in bank i in country j in year t times 100; winsorized at 1st and 99th percentile. Total Assets and Operating Profit reported in local currency. Source: Bankscope.
Macro Controls	
GDP_{jt}	Growth rate of real GDP per capita in country j in year t. Source: Eurostat.
$EzoneGDP$	Growth rate of real GDP per capita in Eurozone in year t. Source: Eurostat.
Pi_{jt}	Inflation in country j in year t. Source: Eurostat.
$Crisis$	Financial Crisis dummy, takes value 1 for years 2008-2012.
Exchange Rates	
EUR *x-rate*	Relative change of a yearly average local currency to Euro exchange rate in country j in year t. Source: Eurostat.

Table 3.7: Comparison of bank controls across countries and ownership

	Size DOM	Size FGN	Liquidity DOM	Liquidity FGN	Capitalization DOM	Capitalization FGN	Profitability DOM	Profitability FGN
BG	4.28	6.22	40.05	28.58	17.74	13.02	1.13	1.34
CZ	3.30	3.89	33.12	24.71	10.55	10.19	0.42	1.04
EE	2.12	8.22	35.42	26.96	16.62	15.70	0.61	0.24
HR	1.39	5.82	30.06	28.64	15.76	13.40	0.55	0.78
HU	6.73	2.89	35.05	29.35	9.90	11.68	0.91	0.91
LT	4.42	13.19	29.88	22.59	12.91	9.58	0.07	-0.07
LV	4.97	7.30	42.56	30.16	13.47	10.60	0.83	-0.13
PL	3.94	2.87	16.05	20.10	11.82	13.12	1.41	1.44
RO	4.70	4.24	34.98	30.73	18.21	13.01	0.96	0.74
SI	5.76	3.51	21.19	16.95	9.35	7.79	0.74	0.31
SK	5.31	6.42	39.55	30.13	21.12	10.15	0.39	0.85
Total	4.04	4.79	31.17	26.29	14.05	11.93	0.79	0.90

Table 3.8: Comparison of bank controls across years and ownership

	Size DOM	Size FGN	Liquidity DOM	Liquidity FGN	Capitalization DOM	Capitalization FGN	Profitability DOM	Profitability FGN
1998	5.89	4.78	38.09	42.69	16.88	12.05	0.14	0.93
1999	5.87	4.59	37.43	42.02	16.75	14.32	1.09	0.83
2000	5.83	4.62	41.97	40.54	17.73	13.27	1.22	1.12
2001	5.67	5.42	46.40	40.42	16.36	12.74	0.98	1.07
2002	5.18	5.75	42.12	38.20	15.45	13.05	1.48	1.65
2003	3.88	5.76	38.18	34.25	14.38	12.59	1.13	1.47
2004	3.50	5.30	33.59	31.66	13.26	12.74	1.60	1.46
2005	3.26	4.69	32.71	30.27	13.50	11.20	1.63	1.39
2006	3.09	4.82	30.27	28.23	13.03	11.48	1.41	1.20
2007	3.08	4.83	26.19	24.93	13.11	10.95	1.54	1.30
2008	2.84	4.50	21.46	19.42	13.81	11.11	0.53	0.89
2009	2.98	4.28	20.96	17.68	12.72	10.99	0.16	-0.16
2010	2.91	4.33	22.49	17.13	11.37	11.63	-0.23	0.24
2011	3.08	4.48	22.31	17.15	10.62	11.77	-0.81	0.40
2012	3.37	5.27	22.03	16.38	11.11	12.13	0.02	0.36
Total	4.16	4.88	32.35	27.87	14.21	12.02	0.79	0.92

3.6.2 Data coverage

Table 3.9: Data coverage by country

	Number of bank-years		Sample coverage (in %)	
	ownership	net loans	in # of bank-years	in volume of net loans
BG	353	288	95.83	99.31
CZ	430	381	88.19	91.00
EE	114	97	91.75	99.25
HR	527	476	98.32	99.69
HU	448	455	84.40	98.50
LT	145	130	99.23	99.31
LV	310	229	98.69	98.76
PL	683	478	92.68	98.56
RO	437	344	92.44	99.57
SI	282	256	92.58	97.66
SK	279	246	93.09	95.49
Total	4008	3380	92.75	97.25

Table 3.10: Data coverage by year

	Number of bank-years		Sample coverage (in %)	
	ownership	net loans	in # of bank-years	in volume of net loans
1998	242	163	93.87	88.34
1999	242	168	91.67	89.22
2000	252	183	88.52	89.78
2001	244	176	86.93	87.29
2002	251	179	90.50	90.40
2003	266	188	94.68	93.31
2004	271	223	94.62	96.95
2005	282	251	95.22	96.70
2006	268	249	95.18	96.75
2007	266	253	93.28	96.95
2008	289	267	95.13	99.73
2009	282	283	91.52	98.43
2010	284	286	91.61	99.03
2011	284	272	93.75	97.65
2012	285	239	92.05	98.43
Total	4008	3380	92.75	97.25

3.6.3 Estimation results: robustness checks

Table 3.11: Determinants of bank lending, accounting for different monetary policy regimes

	(1)	(2)	(3)	(4)	(5)
FGN	-0.557	-1.280	3.059	-1.650	3.647
	(2.131)	(2.301)	(3.124)	(2.143)	(3.671)
MP	-1.816***	-1.578***	-1.677***	-1.688***	-1.629***
	(0.323)	(0.276)	(0.401)	(0.204)	(0.404)
FGN*MP	1.166***	1.138***	0.921***	1.103***	0.850***
	(0.326)	(0.344)	(0.228)	(0.264)	(0.237)
Size	-0.0734	-0.0374	-0.00511	-0.0462	0.0339
	(0.0503)	(0.0608)	(0.292)	(0.0577)	(0.251)
Liq	-0.147**	-0.0697	-0.349***	-0.0749	-0.360***
	(0.0558)	(0.0471)	(0.0621)	(0.0495)	(0.0650)
Cap	-0.253*	-0.236**	-0.665***	-0.265**	-0.649**
	(0.124)	(0.0923)	(0.201)	(0.0972)	(0.225)
Prof	1.315**	1.566***	1.590***	1.603***	1.539***
	(0.429)	(0.457)	(0.428)	(0.473)	(0.394)
GDP	1.310***	2.204***	1.147***	2.126***	1.412***
	(0.160)	(0.305)	(0.151)	(0.259)	(0.313)
Pi	-0.981***	-0.385	-1.112***	-0.125	-0.914***
	(0.139)	(0.239)	(0.145)	(0.206)	(0.196)
Independent MP		0.478	-3.636		
		(1.562)	(2.362)		
Change in EUR x-rate				-0.388**	-0.267
				(0.140)	(0.146)
Time Fixed Effects	Yes	No	Yes	No	Yes
Country Fixed Effects	Yes	No	No	No	No
Bank Fixed Effects	Yes	No	Yes	No	Yes
Observations	2403	2403	2403	2361	2361
R^2	0.244	0.165	0.305	0.172	0.308

Standard errors in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.010

Table 3.12: Determinants of bank lending- government banks

	OLS	FE	GMM
FGN	-1.809	0.345	0.0313
	(2.303)	(4.687)	(4.056)
GOV	-2.188	-7.680	-5.464
	(1.610)	(7.237)	(3.457)
MP	-1.777***	-1.676**	-1.474**
	(0.525)	(0.577)	(0.523)
FGN*MP	1.340***	0.879**	1.313*
	(0.284)	(0.272)	(0.668)
GOV*MP	0.588	-0.303	0.0828
	(0.860)	(0.943)	(0.777)
Size	-0.0288	0.0113	2.296**
	(0.0579)	(0.320)	(1.006)
Liq	-0.0639	-0.353***	-0.705***
	(0.0484)	(0.0609)	(0.118)
Cap	-0.226**	-0.655**	-2.084***
	(0.0968)	(0.208)	(0.424)
Prof	1.558***	1.539***	1.702***
	(0.456)	(0.415)	(0.249)
GDP	2.201***	1.143***	0.864***
	(0.301)	(0.166)	(0.258)
Pi	-0.384	-1.118***	-1.014***
	(0.236)	(0.156)	(0.173)
L.Delta Net Loans			0.212***
			(0.0270)
Observations	2403	2403	2001

Standard errors in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.010

3.6.4   DSGE model

Households   Standard intra-temporal condition for labor supply:

$$\frac{1}{c_t^H(i)} = \frac{l_t^H(i)^\phi}{w_t}, \tag{3.6.1}$$

and an inter-temporal condition for consumption choice:

$$\frac{1}{c_t^H(i)} = \beta_H \left(1 + r_t^d\right) \mathbb{E}_t \left[\frac{1}{c_{t+1}^H(i)}\right]. \tag{3.6.2}$$

Given those two conditions, deposits are determined via budget constraint that holds with equality:

$$c_t^H(i) + d_t^H(i) = W_t l_t^H(i) + \left(1 + r_{t-1}^d\right) d_{t-1}^H(i) + T_t^H. \tag{3.6.3}$$

Table 3.13: Determinants of bank lending - without ownership change banks

	OLS	FE	GMM
MP	-1.827***	-1.909***	-1.502**
	(0.249)	(0.535)	(0.562)
FGN*MP	1.567***	1.105**	1.399***
	(0.417)	(0.421)	(0.423)
Size	0.0994	-0.156	1.976
	(0.0782)	(0.533)	(1.236)
Liq	-0.0630	-0.271***	-0.673***
	(0.0577)	(0.0816)	(0.152)
Cap	-0.246**	-0.591**	-2.113***
	(0.102)	(0.243)	(0.454)
Prof	1.348**	1.444***	2.096***
	(0.502)	(0.418)	(0.347)
GDP	2.285***	1.145***	0.997***
	(0.281)	(0.211)	(0.303)
Pi	-0.364	-1.099***	-0.994***
	(0.214)	(0.170)	(0.235)
L.Delta Net Loans			0.210***
			(0.0357)
Observations	1825	1825	1502

Standard errors in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.010

Entrepreneurs

$$\frac{1}{c_t^E(i)} - \zeta_t^E(i) = \beta_E \mathbb{E}\frac{1+r_t^b}{c_{t+1}^E(i)} \tag{3.6.4}$$

$$\mathbb{E}\left[\frac{\zeta_t^E(i)\, m^E q_{t+1}^k (1-\delta^k)}{1+r_t^b} + \frac{\beta_E}{c_{t+1}^E(i)}\left(q_{t+1}^k\left(1-\delta^k\right)+r_{t+1}^k\right)\right] = \frac{q_t^k}{c_t^E(i)} \tag{3.6.5}$$

$$\frac{(1-\alpha)\,y_t^E(i)}{l_t^d(i)\,x_t} = w_t \tag{3.6.6}$$

$$r_t^k \equiv \frac{\frac{\partial y_t^E(i)}{\partial k_t(i)}}{x_t} \tag{3.6.7}$$

Banks - aggregation of loans   The problem of entrepreneur i choosing his total loans $b_E(i)$ facing a continuum of banks indexed with j to allocate these loans among the continuum of banks is a standard cost-minimization problem:

$$\min_{b_E(i,j)} \int_0^1 r_b(j)\, b_E(i,j)\, dj \tag{3.6.8}$$

$$\text{subject to: } \left[\int_0^1 b_E(i,j)^{\frac{\varepsilon-1}{\varepsilon}}\, dj\right]^{\frac{\varepsilon}{\varepsilon-1}} = b_E(i) \tag{3.6.9}$$

For a given aggregate price r_b the entrepreneur optimally chooses the total amount of loans and its partition among monopolistically competitive banks. Note, we can write:

$$\left[\int_0^1 b_E\left(i,j\right)^{\frac{\varepsilon-1}{\varepsilon}} dj\right] = b_E\left(i\right)^{\frac{\varepsilon-1}{\varepsilon}}. \tag{3.6.10}$$

The first order condition of retail branch j gives the demand for loans at bank j charging $r_{bE}\left(j\right)$, given aggregate price for loans r_{bE}:

$$b_E\left(i,j\right) = \left(\frac{r_{bE}\left(j\right)}{r_{bE}}\right)^{-\varepsilon} b_E\left(i\right) \tag{3.6.11}$$

which we integrate on the both sides wrt to i to get:

$$b_E\left(j\right) = \left(\frac{r_{bE}\left(j\right)}{r_{bE}}\right)^{-\varepsilon} b_E. \tag{3.6.12}$$

With $r_{bE} = \left[\int_0^1 r_{bE}\left(j\right)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}}$ being the price index. Now, we have the two following equations (the first one is postulated to reflect the monopolistic competition assumption, the other follows):

$$b_E\left(i\right) = \left[\int_0^1 b_E\left(i,j\right)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{3.6.13}$$

$$r = \left[\int_0^1 r\left(j\right)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}}. \tag{3.6.14}$$

Let us assume a within-ownership symmetric equilibrium such that a measure of foreign banks μ chooses $r_{f,bE}$ and a measure of domestic banks $1-\mu$ chooses $r_{h,bE}$. Without loss of generality we say the banks with $j \in [0,\mu)$ set $r_{f,bE}$. We than have that:

$$r_{bE} = \left[\int_0^1 r_{bE}\left(j\right)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}} = \left[\mu r_{f,bE}^{1-\varepsilon} + \left(1-\mu\right) r_{h,bE}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{3.6.15}$$

Now, we use the demand equations to derive the index of quantities, by differentiating equation (3.6.12) with respect to j which yields:

$$b_E = \left(\mu b_{f,E}^{\frac{\varepsilon-1}{\varepsilon}} + \left(1-\mu\right) b_{h,E}^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}. \tag{3.6.16}$$

The last two equations are used in aggregation of individual demands and prices to aggregate demands and prices in the loans market.

Retailers Retail good producers buy the good produced by entrepreneurs, aggregate them to the final good and sell it with a markup subject to Rotemberg type of adjustment costs. The first equation is the definition of retailer profits, κ_p is the parameter governing the inertia of the aggregate price level. The second equation is the first order condition of the optimal pricing problem, can be thought of as a Philips curve.

$$J_t^R = y_t \left(1 - \frac{1}{x_t} - \frac{\kappa_p}{2} \left(\pi_t - \left(\pi_{t-1}^{\zeta_p} \bar{\pi}^{1-\zeta_p} \right) \right)^2 \right) \tag{3.6.17}$$

$$1 = \varepsilon_t^y + \frac{\varepsilon_t^y}{x_t} - \kappa_p \left(\pi_t - \left(\pi_{t-1}^{\zeta_p} \bar{\pi}^{1-\zeta_p} \right) \right) \pi_t + \tag{3.6.18}$$

$$\beta^P \mathbb{E}_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_p \left(\pi_{t+1} - \left(\pi_t^{\zeta_p} \bar{\pi}^{1-\zeta_p} \right) \pi_{t+1} \right) \frac{y_{t+1}}{y_t} \right]$$

Capital good producers The role the capital good producers play in the model is twofold. First, their presence encapsulates the economy-wide investment equation and capital accumulation. Without loss of generality, this decision could be placed at the firm level as well. Next, and more importantly, it is a way of introducing the price of capital to the model hence facilitating the use of the collateral constraint on capital in a meaningful way.

$$k_t = (1 - \delta_k) k_{t-1} + i_t \left(1 - \frac{\kappa_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right) \tag{3.6.19}$$

$$1 = q_k \left(1 - \frac{\kappa_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right) + \beta^E \mathbb{E}_t \left[\frac{\zeta_{t+1}^E q_{t+1}^k}{\zeta_t^E} \kappa_i \left(\frac{i_{t+1}}{i_t} - 1 \right) \left(\frac{i_{t+1}}{i_t} \right)^2 \right]. \tag{3.6.20}$$

Aggregation The aggregation conditions read:

$$Y_t = C_t + q_t^k \left(K_t - \left(1 - \delta^k \right) K_{t-1} \right) + \frac{\delta^b K_{t-1}^b}{\pi_t} \tag{3.6.21}$$

$$B_t = D_t + K_t^b \tag{3.6.22}$$

$$C_t = \int c_t^H (i) + c_t^E (i) \, di \tag{3.6.23}$$

$$B_t = b_{E,t} \tag{3.6.24}$$

$$D_t = d_t \tag{3.6.25}$$

$$K_t = k_t^e \tag{3.6.26}$$

$$Y_t = y_t^e \tag{3.6.27}$$

$$l_t^d = l_t^p. \tag{3.6.28}$$

3.6.5   Calibration

In this section we discuss calibration of the model parameters. We calibrate the model using standard values for yearly data as this is the frequency micro data is reported in Bankscope. Let us start with the discussion of our calibration targets.

First, observe that the central bank rate pins down the rate of return on bonds. Thus, we wish to replicate a 6% p.a. value here, higher than the standard US value of 4% by two percentage points. This assumption determines the household discount factor β^H. We pick entrepreneurs patience to be captured by $\beta^E =$. We pick the inverse of the Frisch elasticity to be equal to 1. The capital share in the production function is set at $\alpha = 0.3$. The depreciation rate of physical capital is $\delta_k = 0.02$. The LTV ratio m^E is postulated to be equal to 0.35. We assume a markup in the goods market at 15% and the markup on the interbank rate to be about 40%. The monetary policy inertia we set at 0.8. The cost for managing bank capital is determined in the equilibrium to assure that the banks achieve their target balance structure. The multiplier on the quadratic cost of deviations from the optimal balance sheet structure κ_b is put at 10.The price stickiness parameter is set κ_p to 30. The elasticity of loans is equal to 4.

For the internal market hypothesis we increased the penalty multiplier κ_b in foreign banks to 100, we also postulate the target leverage to be $\nu_{fgn} = 0.045$ in foreign-owned banks while the domestic banks have it on $\nu_{dom} = 0.09$. The segmentation market hypothesis has $\varepsilon_l^H = 7$ and ε_l^L follows to map the steady state banking variables for the homogeneous elasticities baseline case. We set the country size parameter η to match the ratio of GDP of the Eurozone and Poland. Other parameters we keep symmetric apart from the markup on the interbank market to be half of the one used for the Home country. We pick the penalty parameter κ_ω to allow for up to 10% deviations in the stream of the dividends in the policy simulations experiments.