Universitat Autònoma de Barcelona

Essays on Macroeconomic Policy over the Business Cycle

Daniela Stefanie Hauser

UNIVERSITAT AUTÒNOMA DE BARCELONA
DEPARTMENT OF ECONOMICS AND ECONOMIC HISTORY
INTERNATIONAL DOCTORATE IN ECONOMIC ANALYSIS

DOCTORAL THESIS

APRIL 2013

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Author:
Daniela Stefanie HAUSER

Supervisor:
Dr. Evi PAPPA

Daniela Stefanie Hauser

Evi Pappa

April 18, 2013

Acknowledgements

Many people have contributed, directly and indirectly, to the completion of this thesis. Foremost, I would like to thank my supervisor, Evi Pappa, for her help and guidance during the creation of this thesis. She managed to direct me onto the right path and helped in shaping me as an economist. It was a real pleasure working with you, Evi!

Second, many faculty members and colleagues contributed to one or several chapters of this thesis. In particular I would like to acknowledge the help of Luca Gambetti, Albert Marcet and Jordi Caballé, who offered me great advice. Special thanks go to Luisa Lambertini for her support and for welcoming me warmly to the Chair of International Finance at EPFL Lausanne.

Third, I would like to thank my sister for her unconditional support, her stubborn belief in my abilities as a researcher, and for her love. I am equally and deeply thankful to my mother, who, with her strength, ambition and love made the path that lead to this thesis possible.

Last, but by no means least, a very special thanks goes to Stefano. Thank you for your professional support to finish this thesis. And thank you for providing the fertile grounds on which, over the years, our joint happiness has grown to a solid tree.

Barcelona, April 2013 Daniela Hauser

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Introduction

This thesis consists of three loosely connected chapters, each of them analyzing a particular question of interest to macroeconomic policymakers concerned with business cycle fluctuations.

The first Chapter generalizes the baseline small open economy New-Keynesian model to allow for endogenous dollarization, i.e. the use of a stable foreign currency as a substitute for some of the monetary services of the official, domestic currency. Defining dollarization endogenously gives rise to an additional policy trade-off between stabilization and the control of the degree of dollarization, with the latter depending on variables controlled by the monetary authority. Monetary policy therefore has an impact on the degree of dollarization, which in turn affects monetary policy trade-offs. Our model suggests that a positive degree of dollarization not only feeds back on the economy's steady state allocation but also affects the economy's dynamics after different economically relevant shocks. Temporary monetary policy shocks, for example, affect the cost-benefit relation of the two currencies in circulation and thus have permanent real effects. Whether the shock induces an increase or a fall in the use of the foreign currency depends on the economy's initial degree of dollarization. When considering positive technology shocks, the magnitude and persistence of the small open economy's responses depend on the degree of dollarization. Finally, comparing two different monetary policy regimes, aiming at stabilizing either domestic- or CPI-inflation, leads to the conclusion that stabilizing domestic inflation generally induces more volatility in all macroeconomic variables but output. But the differences in the dynamic adjustment of the small open economy across the two monetary policy regimes under consideration become smaller with higher degrees of dollarization.

In the second Chapter we study the role of labor mobility an adjustment mechanism to asymmetric shocks. In particular, we provide evidence on the dynamic behavior of net labor flows across US states in response to a positive technology shock. Technology shocks are identified as disturbances that increase relative state productivity in the long run for 226 state pairs encompassing 80 percent of labor flows across US states in the period 1976 - 2008. The data suggest heterogeneous responses of both employment and net labor flows across states conditional on a positive technology shock. We build a two region dynamic stochastic general equilibrium (DSGE) model with endogenous labor mobility and region-specific shocks accounting for this evidence. We calibrate the model economy consistently with the observed differences in the degree of nominal rigidities across states, and show that we replicate the different patterns of the responses in employment and net labor flows across states following a technology shock.

In the third Chapter we argue that explicitly modelling a home production sector as an alternative option to market work is crucial for understanding the propagation of exogenous changes in public spending to macroeconomic variables. In fact, the substitutability between market and home produced goods is an important driver of the labor supply response to government expenditure shocks and, as a consequence, is key to explain the magnitude of fiscal multipliers, as well as the behavior of private market consumption after a fiscal expansion. We build an otherwise standard New-Keynesian model that encompasses a home production sector and we use both micro- and macroeconomic evidence to validate our predictions. If the elasticity of substitution between home and market goods is chosen in line with the microeconomic estimates our model delivers impulse response functions to government expenditure shocks that match the VAR evidence.

To my father.

Chapter 1

Monetary Policy in presence of endogenous dollarization

1.1 Introduction

This first Chapter studies monetary policy in presence of unofficial dollarization. Unofficial, partial or de facto dollarization occurs when individuals and firms voluntarily choose to use a foreign currency (often the US Dollar) as a substitute for some of the monetary services of the domestic currency. The definition of a dollarized economy has become quite elusive in the relevant literature, where competing definitions of dollarization and a general lack of data have prevented the emergence of anything resembling a consensus. In general, dollarized countries are understood as economic systems where a foreign currency circulates alongside the local currency and gradually takes over one or several of the basic functions of money. Dollarization is considered to be official or full when a nation adopts de jure the currency of a foreign nation to wholly replace its domestic currency, as for instance Panama since 1904 and Ecuador since 2000. Currency substitution is the use of a foreign currency as a unit of account or means of payment for transactions; and asset- or liability substitution is the use of foreign currency denominated assets as a store of value. The focus of this Chapter is on currency substitution, which, in a country that starts to become partially dollarized, is generally observed first and thus before asset- or liability substitution[1]. By focusing explicitly on currency substitution we abstract from different phenomenon directly linked to the presence of asset substitution, without wanting to negate their importance[2].

The degree and incidence of dollarization has increased notably in developing and emerging economies since the early 1980s. The empirical literature on dollarization struggles with the fact that the use of a foreign currency for transactions hardly ever leaves a paper trail such that accurate or even systematic data are available to a very limited extent. The literature has been largely restricted to foreign currency deposits as an indicator of dollarization[3]. The growing body of empirical evidence suggests that currency substitution is a widespread phenomenon that has been observed extensively in Latin America, but also in the Middle East, in Africa and Asia, and in several transition economies in Eastern Europe[4]. Hence, dollarization in a broad sense must be considered increasingly as a defining characteristics of developing and emerging market economies and must be taken into account explicitly in defining adequate stabilization policies.

Specifically, the shocks affecting a dollarized economy might be different from those

[1]In this study, no formal distinction is made between dollarization and currency substitution and the two terms are used interchangeably. Furthermore, dollarization is understood as a generic term used to characterize any currency that effectively serves as a replacement for the national currency, i.e., the substitute currency need not be the U.S. Dollar.

[2]We abstract from a possible limited availability of financial assets in the domestic currency, which is reflecting the degree of development of the domestic financial- and banking system. We are therefore not addressing issues of lacking stability or credibility of the domestic financial sector. Moreover, whenever asset substitution is studied problems linked to currency mismatch have to be addressed specifically. Furthermore, default and/or bank runs are phenomena that have been observed together with asset substitution and therefore deserve a thorough analysis.

[3]A few papers have gone beyond this, including Feige (2003), and Reinhart, Rogoff and Savastano (2003) who propose two alternative indices of dollarization.

[4]For example Judson and Porter (1996), Feige, Faulend, Sonje and Sosic (2002), Gulde, Hoelscher, Ize, Marston and De Nicolé (2004), Isakova (2010) study groups of countries in Latin America, Central and Eastern Europe, and in the former Soviet republics and provide evidence that macroeconomic instability, in particular high devaluation- and inflation rates, are major reasons for dollarization in these economies.

affecting the economy related to the foreign currency in use, which possibly causes further macroeconomic instability. In this context Broda (2004) shows that dollarized economies differ systematically in their response to macroeconomic shocks from non-dollarized economies. Moreover, dollarization has important impacts on the effectiveness of monetary policy: Dollarized countries relinquish their ability to conduct a cyclical monetary policy, which results in a reduced ability to accommodate shocks. A view widely held among economists and policymakers is that dollarization makes monetary policy more complex and less effective. Schmitt-Grohé and Uribe (2001) have contributed to the debate analyzing the costs of full or official dollarization. In a small open economy model calibrated to the Mexican economy, the welfare costs of economic fluctuations under alternative monetary policies, with full dollarization defined as a fixed exchange rate, are compared. The existing trade-off between fixed and flexible exchange rate is shown to define an explicit welfare cost of dollarization. Schmitt-Grohé and Uribe (2001) conclude that official dollarization is welfare inferior to all alternative policies considered. In particular, dollarization is inferior to an independent monetary policy regime which seeks to stabilize inflation and output volatility. In a more recent contribution Castillo, Montoro and Tuesta (2012) show in a model calibrated to the case of Peru that in an economy characterized by currency substitution an active exchange rate management is welfare improving.

However, in both Schmitt-Grohé and Uribe (2001) and Castillo et al. (2012) dollarization is defined exogenously, while Uribe (1997) shows that the degree of dollarization is affected by both inflation- and exchange rate volatility, variables controlled by the monetary authority. Monetary policy therefore affects the degree of dollarization, which in turn affects monetary policy trade-offs. Hence, there is a direct interaction between stabilization and the degree of dollarization, which, by applying standard prescriptions for the conduct of monetary policy, gives rise to an additional policy trade-off. In general, monetary authorities in small open economies face a trade-off between the stabilization of both the nominal and real exchange rates, on the one hand, and the stabilization of inflation and the output gap on the other[5]. Defining dollarization exogenously abstracts from an additional policy trade-off between stabilization and the degree of dollarization and makes the phenomenon easily reversible once the relative rates of return on the domestic currency are changed. However, this implied reversibility stands in stark contrast with the persistently high degree of dollarization that has been observed in many dollarized countries, even during periods with low fluctuations in inflation-, devaluation- and interest rates[6]. One prominent explanation for this observed persistence of dollarization rates is the fact that once individuals have accumulated a certain knowledge in using the foreign currency as a means of transactions they are reluctant to switch back to the domestic currency. In particular, the marginal cost of using the foreign currency might have reached a level much lower than the one associated to the use of the domestic currency. Once these transaction costs are lower than the costs of switching back to the local currency a threshold level of dollarization is achieved, after which currency substitution becomes hardly reversible. Consequentially, even in periods of stabilized devaluation- and/or inflation rates the foreign currency remains a prominent medium of exchange. Accounting for these so called network externalities in using the foreign currency makes dollarization a history dependent process and has thus further important implications on the effectiveness of monetary policy.

Our economic environment generalizes the baseline small open economy model in Galí and Monacelli (2005) to allow for endogenous dollarization. We assume perfect means of payment substitutability, with households being able to purchase goods with either the domestic or the foreign currency. Purchases of goods in the foreign currency

[5]See Galí and Monacelli (2005) for a survey on monetary policy in small open economies.

[6]See Dell'Erba and Saldías-Zambrana (2006) who document a persistently high degree of dollarization long after stabilization of inflation rates in Bolivia. Furthermore, Stix (2008) studies the reasons for the observed persistence in the use of foreign currencies in Croatia, Slovenia and Slovakia even after their economies have stabilized.

are subject to an additional variety-specific transaction cost, assumed to decline in the aggregate knowledge of the economy in using the foreign currency as a medium of exchange. We follow the literature in recognizing that dollarization results from a decision of economic agents reacting to a particular economic environment characterized by an increased volatility in the purchasing power of the local currency and consequentially an eroding confidence in the domestic currency[7]. This economic environment leads agents to substitute the domestic currency with a given foreign currency for transactions. The benefit of carrying out transactions in the foreign currency consist in the possibility of circumventing fluctuations in the value of the domestic currency, which are costly for both domestic and importing firms. Domestic firms have their production costs denominated in the domestic currency, such that by falling back on the foreign currency they insure themselves against fluctuations in their revenues. In particular, a devaluation of the domestic currency induces an increase in the benefit attached to the use of the foreign currency and provides an incentive to domestic firms to sell their goods in the foreign currency. Importing firms, on the other hand, have their production costs denominated in the foreign currency and therefore find it costly to sell in the domestic currency, whenever the value of the latter is volatile. The cost in using the domestic currency (or alternatively, the benefit in using the foreign currency) is therefore defined by changes in the nominal exchange rate, which influence firms' pricing behavior. The presence of network externalities implies future transaction costs in using the foreign currency as a means of transaction to decrease whenever the economy as a whole falls back increasingly on the foreign currency. The respective costs in using either of the two currencies, and ultimately the degree of dollarization, are thus defined by both the volatility of the exchange rate and by the variety-specific transaction costs which incur whenever a given good is purchased in the foreign currency, and which are

[7] There are cases of currency substitution, usually at very low levels, based not on lack of confidence but on ease of transactions. Canada, Switzerland, and other small advanced and stable economies with fairly open trade and financial borders have always exhibited holdings and use of neighbouring currencies for transaction purpose.

directly affected by the presence of network effects. In the present setup the endogenously defined degree of dollarization gives rise to a multiplicity of steady states where each of them depends on initial conditions and where the degree of dollarization feeds back on the steady state allocation. In this setup a temporary high cost in using the domestic currency triggers a dollarization process which can only be reversed with an important decline in devaluation rates. This suggests that unofficial dollarization may take place rapidly in the aftermath of a monetary crisis, and once attained is costly to reverse.

The present Chapter closes the existing gap between modern monetary policy in small open economies and the phenomenon of endogenous dollarization, as it has first been addressed in Uribe (1997). The analysis presented in this Chapter is a first step towards a full-fledged definition of optimal monetary policy in presence of dollarization. The remainder of the Chapter is organized as follows: Section 2 describes the model economy, and Section 3 defines the equilibrium. In Section 4 we provide a characterization of the multiple steady states and analyze the feedback effects of dollarization on the steady state allocation. We analyze the macroeconomic implications of alternative monetary policy regimes to different shocks in Section 5, and Section 6 concludes.

1.2 A small open economy model

We consider a small open economy model which is inhabited by a large number of identical and infinitely lived households, by domestic firms producing a differentiated good, and by a continuum of importing firms that operate as price setters in the local market. The specification of the small open economy developed in this Chapter is based on Galí and Monacelli (2005), which is adapted in order to allow for endogenous dollarization. The two intrinsically useless currencies are considered ex-ante perfect substitutes, but using either currency as a means of transaction entails different costs, respectively benefits. All goods available in the small open economy are tradeable and can be purchased in either the domestic or the foreign currency, but no variety is purchased in both currencies at the same time. Firms set optimal prices in both currencies at the beginning of every period, such as to be indifferent between selling in either one. Households then define the set of goods purchased in both currencies, given the prices set by firms, and given the associated costs in using the respective currency. Domestic dollarization, i.e. the share of domestic goods purchased with the foreign currency, is thus optimally chosen by households. The degree of dollarization of foreign goods, i.e. the share of imported goods purchased with the foreign currency, under some simplifying assumptions on the price setting of importing firms, coincides with the degree of dollarization of domestically produced goods. After setting optimal prices, firms observe households' choices, which define both the currency of transaction for the variety produced by a given firm and the amount of labor employed by the latter[8].

1.2.1 Households

The small open economy is inhabited by a representative household who consumes Dixit-Stiglitz aggregates of domestic and imported goods, who seeks to maximize

$$U_o = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right] \tag{1.1}$$

where N_t denotes hours of labor, and C_t is a composite consumption index defined by

$$C_t = \frac{C_{H,t}^{1-\alpha} C_{F,t}^{\alpha}}{(1-\alpha)^{(1-\alpha)} \alpha^{\alpha}}$$

with $C_{H,t}$ and $C_{F,t}$ being indices of consumption of domestic and foreign goods, assuming the elasticity of substitution between domestic and foreign goods to be equal to

[8]Note, that letting firms define the degree of dollarization yields the exact same definition of the degree of dollarization as the one resulting from the present set-up. Furthermore, having domestic firms denominated part of their production costs in the foreign currency would not fundamentally change the results. The advantage of the present modelling choice is the clear-cut separation of costs and benefits attached to the use of the foreign currency.

one. Goods are assumed to be merchandised either in the domestic currency (henceforth referred to as *Peso*) or in the foreign currency (henceforth denoted as *Dollar*). The index of consumption of domestic and foreign goods is given by the following constant elasticity of substitution (CES) aggregators of the quantities consumed of each type of good:

$$\begin{aligned} C_{j,t} &= \left[\int_0^1 C_{j,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} = \left[\int_0^{\theta_t^j} C_{j,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di + \int_{\theta_t^j}^1 C_{j,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \\ \text{for } j &= H, F \end{aligned}$$

θ_t^j defines the cut-off good, i.e. the first good being purchased in Pesos. The representative household takes prices as given and chooses the set of goods purchased in Dollars, $i \in \left[0, \theta_t^j\right)$, and Pesos, $i \in \left[\theta_t^j, 1\right]$, respectively[9]. Households are allowed to convert one currency into another anytime in a given period at the nominal exchange rate ε_t. Purchases of goods are therefore made in a continuous fashion during a given period t. Notice, that σ is the coefficient of relative risk aversion. The elasticity of substitution among goods within each category is given by $\varepsilon > 1$, which is assumed to be independent of the currency of transaction of a particular variety i. Parameter α can be interpreted as a measure of openness of the small open economy, while $(1-\alpha)$ is referred to as home-bias.

Purchasing one unit of good i in Dollars implies households to bear an additional, proportional, and variety-specific transaction cost of

$$\Phi(i, K_t) \equiv [(1-i)K_t]^{-\alpha_2} \tag{1.2}$$

where K_t stands for the economy's accumulated knowledge (up to period t) in using Dollars as a means of payment, henceforth referred to as the stock of dollarization capital. Households are assumed to take the path of K_t as given, but the aggregate level

[9] As we will discuss in detail in Section 2 of the present Chapter, under some simplifying assumptions on the price setting of foreign firms, we have $\theta_t^H = \theta_t^F = \theta_t$ for all t, such that θ_t serves as a natural measure for the degree of dollarization in the small open economy.

of K_t is determined endogenously. The proportional transaction costs on purchases in Dollars are bigger than one, twice continuously differentiable, strictly convex, strictly increasing in i, and strictly decreasing in the latent variable K_t[10]. The latter assumption is motivated by the empirical evidence on the presence of network effects, i.e. the fact that more people using the foreign currency as a means of transactions makes it less costly. Furthermore, in order to account for the empirical evidence that the foreign currency never completely takes over the role as means of transaction in a not officially dollarized economy, we assume that as i converges to 1 the transaction cost tends to infinity. Note, that the parameter α_2 defines the speed of augmentation of transaction costs across varieties, with lower values of α_2 corresponding to a flatter transaction cost function. Finally, we assume these transaction costs to be equal for domestically and imported goods.

The maximization of (1.1) is subject to a sequence of budget constraints of the form:

$$\int_0^{\theta_t^H} \left[P_{H,t}^D(i)\Phi(i,K_t)\right] C_{H,t}(i)di + \int_{\theta_t^H}^1 \frac{P_{H,t}^P(i)}{\varepsilon_t} C_{H,t}(i)di + \\ + \int_0^{\theta_t^F} \left[P_{F,t}^D(i)\Phi(i,K_t)\right] C_{F,t}(i)di + \int_{\theta_t^F}^1 \frac{P_{F,t}^P(i)}{\varepsilon_t} C_{F,t}(i)di + \\ + E_t\left\{\frac{Q_{t,t+1}B_{t+1}}{\varepsilon_{t+1}}\right\} \leq \frac{B_t}{\varepsilon_t} + \frac{W_t}{\varepsilon_t}N_t + \frac{T_t}{\varepsilon_t}$$

for $t = 0, 1, 2, ...$, where $P_{H,t}^D(i)$ and $P_{F,t}^D(i)$ denote Dollar-prices, and $P_{H,t}^P(i)$ and $P_{F,t}^P(i)$ denote Peso-prices for domestic and foreign good i, respectively. B_{t+1} is the nominal payoff in period $t+1$ of the portfolio held at the end of period t, and $Q_{t,t+1}$ defines the stochastic discount factor for nominal payoffs. We assume households to have access to a complete set of contingent claims, denominated in the domestic currency, which are traded internationally. W_t is the nominal wage, and T_t denotes lump-sum transfers or taxes, both denominated in Pesos. Notice, that all variables are expressed in units of

[10]We borrow these assumptions from Uribe (1997).

Dollars, with ε_t being the period's nominal exchange rate, i.e. the price of one Dollar in terms of Pesos[11].

While we model frictionless financial markets in this Chapter, this is not to say that market imperfections are unimportant or absent. Assuming financial markets to be complete implies the present distortions to be undone at the aggregate level, but not within the two sectors, i.e. within the set of firms selling in a given currency. We think of financial frictions in reduced form, to manifest themselves as shocks to domestic productivity. The simplifying assumption of absence of financial frictions is based on two grounds: First, by focusing on currency substitution as particular form of dollarization we are interested in isolating its effects, without modeling financial- or asset dollarization. By assuming financial markets to be incomplete we would capture dynamics strictly related to financial- or asset-dollarization. Second, we want to avoid agents to engage in precautionary savings, again for the purpose of isolating the particular form of dollarization we are concerned about. Hence, in focusing on currency substitution assuming financial markets to be complete is helpful.

The optimal allocation of any given level of expenditure within each category of goods yields households' demand function for domestic and imported goods

$$\begin{aligned} C_{j,t}(i) &= C_{j,t}\left(\frac{P_{j,t}(i)}{P_{j,t}}\right)^{-\varepsilon} \text{ with } P_{j,t}(i) = \begin{cases} P_{j,t}^{D}(i)\Phi(i,K_t) \text{ for } i \in \left[0,\theta_t^j\right) \\ \frac{P_{j,t}^{P}(i)}{\varepsilon_t} \text{ for } i \in \left[\theta_t^j,1\right] \end{cases} \\ \text{for } j &= H,F \end{aligned} \tag{1.3}$$

where

$$\begin{aligned} P_{j,t} &\equiv \left[\int_0^1 P_{j,t}(i)^{1-\varepsilon}di\right]^{\frac{1}{1-\varepsilon}} \\ &= \left[\int_0^{\theta_t^j}\left(P_{j,t}^{D}(i)\Phi(i,K_t)\right)^{1-\varepsilon}di + \int_{\theta_t^j}^1\left(\frac{P_{j,t}^{P}(i)}{\varepsilon_t}\right)^{1-\varepsilon}di\right]^{\frac{1}{1-\varepsilon}} \text{ for } j = H,F \end{aligned} \tag{1.4}$$

[11]Note, that in the present context we are interested in the particular case where $\varepsilon_t > 1$ for all t, i.e. the foreign currency used for transactions is stronger than the domestic currency.

is the price index (expressed in terms of Dollars) of all domestic and imported goods purchased in either Dollars or Pesos. The household's total consumption expenditures consist thus of four parts, consumption expenditures of domestic and imported goods in both Pesos and Dollars. Note, that given $P^P_{j,t}(i) = P^P_{j,t}(\theta^j_t)$ for all $i \in \left[\theta^j_t, 1\right]$ in equilibrium, household's demand across goods (both domestically produced and imported) which are purchased in Pesos are constant and thus equal to the consumption of the respective cut-off good, θ^j_t. Demand schedules for goods purchased in Dollars are decreasing in i given transaction costs to be increasing in i. Transaction costs thus mark the difference between the price households pay for a given i being purchased in Dollars, and the price firms' receive for selling one unit of the same i in Dollars.

The optimal allocation of expenditures between domestically produced and imported goods is given by

$$C_{H,t} = (1-\alpha)\left(\frac{P_t}{P_{H,t}}\right)C_t;\ C_{F,t} = \alpha\left(\frac{P_t}{P_{F,t}}\right)C_t$$

where

$$P_t \equiv (P_{H,t})^{1-\alpha}(P_{F,t})^{\alpha} \tag{1.5}$$

defines the consumer price index (CPI). Once we account for the above optimality conditions, the intertemporal budget constraint can be rewritten as:

$$P_tC_t + E_t\left\{\frac{Q_{t,t+1}B_{t+1}}{\varepsilon_{t+1}}\right\} \leq \frac{B_t}{\varepsilon_t} + \frac{W_t}{\varepsilon_t}N_t + \frac{T_t}{\varepsilon_t} \tag{1.6}$$

The remaining optimality conditions for the household's problem, which consists in maximizing (1.1) subject to (1.6), state as follows:

$$\beta R_t E_t\left\{\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\left(\frac{\varepsilon_t}{\varepsilon_{t+1}}\right)\right\} = 1 \tag{1.7}$$

where $R_t^{-1} = E_t\{Q_{t,t+1}\}$ is the price of a riskless one-period bond, and therefore R_t its gross return. Equation (1.7) is a conventional stochastic Euler equation.

$$\frac{W_t}{P_t\varepsilon_t} = N_t^{\varphi}C_t^{\sigma}$$

defines a standard intratemporal optimality condition, which can be understood as a competitive labor supply schedule, determining the quantity of labor supplied as a function of the real wage (expressed in terms of Dollars), given the marginal utility of consumption.

$$P^D_{j,t}(\theta^j_t)\Phi(\theta^j_t, K_t) = \frac{P^P_{j,t}(\theta^j_t)}{\varepsilon_t} \quad \text{for } j = H, F \tag{1.8}$$

defines both the home- and the foreign cut-off good as the good for which the cost of purchasing it in Dollars is exactly equal to the cost of purchasing it in Pesos. By definition this particular variety is purchased in Pesos.

In the rest of the world a representative household faces a standard problem. Unlike in the small open economy households in the rest of the world can purchase goods only in the foreign currency, i.e. in Dollars. As in Galí and Monacelli (2005) we assume the size of the small open economy to be negligible relative to the rest of the world, an assumption that allows to treat the latter as if it was a closed economy. The small open economy representation prevents domestic policy from affecting the rest of the world and permits us to abstract from strategic interactions between countries. Henceforth, a star denotes foreign variables.

Terms of trade, Law of one Price and Real Exchange Rate

We define the effective bilateral terms of trade, i.e. the relative price of imports, between the domestic economy and the rest of the world as

$$S_t \equiv \frac{P_{F,t}}{P_{H,t}} = \left(\frac{P_t}{P_{H,t}}\right)^{\frac{1}{\alpha}}$$

where the second equality follows from the definition of the CPI-price index, as defined in (1.5)[12].

Treating the rest of the world as an approximately closed economy, with the goods

[12]Note, that both price indices are a function of the respective cut-off good, such that the terms of trade of the small open economy are indirectly affected by the degree of dollarization.

being produced in the small open economy representing a negligible fraction of the rest of the world's consumption basket, allows us to treat the foreign price index, P_t^*, and the foreign currency prices of imported goods, $P_{F,t}^*$, as equivalent. This implies $\pi_t^* = \pi_{F,t}^*$, for all t, i.e. an equivalence between domestic and CPI-inflation in the rest of the world.

We assume throughout the law of one price to hold for exports but not for imports[13], such that we discard implicitly that domestic firms can price-discriminate across countries. For analytical convenience we assume domestic firms to export their goods in the same currency as they sell them in the small open economy. This assumption implies that some of the exporting firms apply consumer currency pricing (and therefore set prices in the foreign currency) and some practice producer currency pricing (and thus set prices in the domestic currency). Whenever a given variety i is sold in the rest of the world (in Dollars), the foreign consumer is assumed to bear the additional transaction cost. This assumption can be rationalized by the presence of an intermediate trader buying the good from the producers and exporting it to the rest of the world. Exporting a given domestically produced good therefore implies at least some transactions within the small open economy. Whenever these transactions are made in the foreign currency the arising transaction costs are thus shifted by the trader to the final foreign consumer. As a consequence the law of one price holds for exports.

For varieties produced in the rest of the world and imported into the small open economy transaction costs arise solely for the set of varieties purchased in Dollars. As for domestic firms we assume that foreign firms in all countries in the rest of the world set export prices with respect to the small open economy in both the domestic and the foreign currency in use. We abstract from exchange rate frictions between a given country's domestic currency and the Dollar. Foreign firms thus set prices in the

[13]In this model, we observe two sources of deviations from aggregate purchasing power parity: First, heterogeneity in the consumption baskets between the small open economy and the rest of the world. And second, deviations in the law of one price captured by movements of the gap in the law of one price.

same way as domestic firms in the small open economy, with one difference: While domestic firms face frictions in setting prices in Dollars for their production costs to be denominated in Pesos, foreign firms face this same friction for setting prices in Pesos, given that foreign firms' production costs are denominated in Dollars. Contrary to Peso-prices for domestically produced goods, import prices set in Pesos fluctuate with the nominal exchange rate, i.e. they increase whenever the Peso depreciates, whereas import prices set in Dollars are not affected by fluctuations in the nominal exchange rate. Consequentially, the degree of dollarization for imports is defined in the exact same way as the degree of dollarization of domestically produced goods (both in the equilibrium and in the steady state), such that $\theta_t^H = \theta_t^F = \theta_t$.

Given that consumers in the rest of the world do not face any transaction costs for locally produced varieties, the law of one price does not hold for imports. More precisely, the gap in the law of one price (l.o.p. gap henceforth) represents the gap between foreign and domestic prices for imports purchased in Dollars, due to the presence of transaction costs in the small open economy[14]:

$$
\begin{aligned}
P_{F,t} &= \left[\int_0^{\theta_t^F} \left(P_{F,t}^D(i)\Phi(i,K_t)\right)^{1-\varepsilon} di + \int_{\theta_t^F}^1 \left(\frac{P_{F,t}^P(i)}{\varepsilon_t}\right)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \\
&= \Lambda_t \left[\int_0^1 \left(P_{F,t}^*(i)\right)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} = \Lambda_t P_{F,t}^* = \Lambda_t P_t^*
\end{aligned}
$$

with Λ_t being the l.o.p. gap, which is a function of the aggregate transaction costs paid for Dollar purchases, the period's nominal exchange rate and the foreign cut-off good. Given the functional form for the transaction costs, as specified in (1.2), the l.o.p. gap

[14]The l.o.p. gap can be interpreted as the relative price of purchasing imports in Dollars with respect to the overall import price index, and thus serves as a measure of the cost-benefit relation in using the foreign currency for purchases of imports. More broadly, the l.o.p. gap can be interpreted as an exchange rate friction related to international trade.

states as follows:

$$\Lambda_t = \left\{ K_t^{\alpha_2(\varepsilon-1)} \left(\frac{1-(1-\theta_t^F)^{\alpha_2(\varepsilon-1)+1}}{\alpha_2(\varepsilon-1)+1} \right) + (1-\theta_t^F)\varepsilon_t^{(\psi-1)(1-\varepsilon)} \right\}^{\frac{1}{1-\varepsilon}}$$

In Monacelli (2005) where incomplete exchange rate pass-through on import prices gives rise to a l.o.p. gap, the latter depends on the nominal exchange rate, the world- and the domestic currency price of imports. In the present model with endogenous dollarization we furthermore have both the degree of dollarization and the period's stock of dollarization capital affecting the l.o.p. gap. This is due to the fact that transaction costs incurred for imports purchased in Dollars are the only source for a positive l.o.p. gap in the present setup. Consequentially, the l.o.p. gap is increasing in the degree of dollarization, and positive (and bigger than one) whenever the degree of dollarization of the small open economy is positive.

Next, let us derive the relationship between the terms of trade and the real exchange rate. We define the real exchange rate as $Q_t \equiv \frac{P_t^*}{P_t}$, i.e. the ratio of CPIs (both expressed in Dollars). Under our assumptions it follows that

$$Q_t = \frac{S_t^{1-\alpha}}{\Lambda_t} \tag{1.9}$$

The real exchange rate is therefore proportional to the terms of trade, with the proportionality coefficient being an inverse function of the degree of openness. In order to stabilize the real exchange rate, stabilization of both the terms of trade and the l.o.p. gap are required. Whenever the monetary authority (strictly) targets consumer price inflation such that, without loss of generality, we have $P_t = P_t^*$ for all t, we have a stable real exchange rate, $Q_t = 1$ for all t. The terms of trade and the l.o.p. gap therefore move proportionally:

$$S_t = \Lambda_t^{\frac{1}{1-\alpha}}$$

For domestic inflation to be the target of the monetary authority, the terms of trade and the l.o.p. gap move one-to-one, $S_t = \Lambda_t$. The real exchange rate and the terms of trade are then negatively correlated:

$$Q_t = S_t^{-\alpha} \tag{1.10}$$

International risk-sharing

Assuming complete international financial markets, a first order condition analogous to (1.7) must also hold for households in the rest of the world:

$$\beta R_t^* E_t \left\{ \left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\sigma} \left(\frac{P_t^*}{P_{t+1}^*} \right) \right\} = 1 \tag{1.11}$$

Combining (1.7) and (1.11), together with the real exchange rate yields the following standard relationship linking consumption in the small open economy to consumption in the rest of the world:

$$C_t = \upsilon C_t^* Q_t^{\frac{1}{\sigma}}$$

for all t, where υ is a constant that depends on initial conditions.

Uncovered interest parity

The assumption of complete international financial markets furthermore requires the equilibrium price of the riskless bond in the small open economy to be equal to the price of a riskless bond sold in the rest of the world and thus denominated in Dollars. Combining the pricing equations of the two bonds yields a version of the uncovered interest parity condition:

$$E_t \left\{ Q_{t,t+1} \left[R_t \left(\frac{\varepsilon_{t+1}}{\varepsilon_t} \right) - R_t^* \right] \right\} = 0$$

1.2.2 Firms

Technology

Consider a continuum of firms within the small open economy, indexed by $i \in [0, 1]$. Each firm produces a differentiated good, but they all use an identical constant returns to scale technology, represented by the production function

$$Y_t(i) = A_t N_t(i) \tag{1.12}$$

where A_t represents the country-wide level of technology, assumed to be common to all firms and to evolve exogenously over time, according to the following AR(1) process

$$a_t = \rho_a a_{t-1} + \epsilon_t^a$$

where $a_t \equiv \log A_t$ and $\{\epsilon_t^a\}$ is white noise. We assume that all firms face a common factor market, such that all firms pay the same nominal wage, W_t, denoted in Pesos. We define an index for aggregate (domestic) output, analogous to the one introduced for consumption:

$$Y_t \equiv \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} = \left[\int_0^{\theta_t} Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di + \int_{\theta_t}^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{1.13}$$

where domestic firms are assumed to take the cut-off good (θ_t) as given.

Firms in the rest of the world are assumed to have access to an identical technology, with (log) productivity following an AR(1) process defined as $a_t^* = \rho_a^* a_{t-1}^* + \epsilon_t^*$. As firms in the small open economy firms in the rest of the world selling their goods in the small open economy take the cut-off good as given.

Price setting with flexible prices

A useful benchmark is given by the situation where goods prices are fully flexible. All varieties of goods are not perfect substitutes, such that firms can set prices, subject to the demand for their good. We assume that firms set Peso- and Dollar-prices for a given good i at the beginning of each period t, as to maximize profits for sales in both currencies. Households observe these prices and choose the cut-off good optimally. Firms, in turn, observe this choice, which defines both the currency of transaction for the variety produced by a given firm and the amount of labor employed by the latter[15]. All firms face the following demand schedule:

$$Y_t(i) = C_{H,t}(i) + C^*_{H,t}(i)$$
$$= \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon}\left[(1-\alpha)\left(\frac{P_t}{P_{H,t}}\right)C_t + \alpha\left(\frac{P^*_t}{P_{H,t}}\right)C^*_t\right] \quad (1.14)$$

where $C_{H,t}(i)$ is defined according to (1.3) and $C^*_{H,t}(i)$ denotes foreign demand for domestically produced goods. In order to set optimal Peso-prices, firms maximize Peso-profits in each period t

$$P^P_{H,t}(i)Y_t(i) - W_tN_t(i)$$

subject to the common technology (1.12) and to their demand schedule (1.14). The optimal Peso-price to charge for one unit of a given good i is defined as $P^P_{H,t}(i) = \left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{W_t}{A_t}$ such that $P^P_{H,t}(i) = P^P_{H,t}$ for all $i \in \left[\theta^H_t, 1\right]$, i.e. the optimal Peso-price set by firms is independent of a given variety i. We define the relative Peso-price (i.e. the optimal Peso-price set by firms relative to the domestic price index) as follows:

$$S^P_{H,t} \equiv \frac{P^P_{H,t}}{\varepsilon_t P_{H,t}} = \left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{W_t}{\varepsilon_t A_t P_t}S^\alpha_t \quad (1.15)$$
$$= \left(\frac{\varepsilon}{\varepsilon-1}\right)MC^P_t$$

where $MC^P_t = \frac{W_t}{\varepsilon_t A_t P_t}S^\alpha_t$ defines the real marginal cost of production for firms selling the periods production in Pesos. We assume the fiscal authority in both the small open economy and the rest of the word to fully neutralize distortions associated with firms' market power by means of a constant employment subsidy τ. Consequentially, assuming perfectly flexible prices firms' marginal cost of production, MC^P_t, is exactly equal to the relative Peso-price, $S^P_{H,t}$.

[15]Note, that firms know how households choose the cut-off good, but given the large number of producers firms ignore the impact of their pricing decisions on both the choice of the cut-off good and on the aggregate price indices.

Price setting of Dollar-prices is more complex, as it raises the issue of how Dollar-prices react to exchange rate movements. Domestic firms have their production costs denominated entirely in Pesos and therefore take into account changes in the nominal exchange rate when setting optimal Dollar-prices. Furthermore, firms have to set prices before observing the period's nominal exchange rate (or alternatively, facing the risk that the nominal exchange rate changes within the period). Therefore, firms adjust the predetermined component once they observe the exchange rate and explicitly take into account the possibility of falling back on the Dollar in order to circumvent fluctuations in the domestic currency. The most natural way of modeling this friction is in the form of an assumed imperfect pass-through of variations in the nominal exchange rate to the optimal Dollar-price set by firms. In the baseline partial equilibrium cash-in-advance model in Uribe (1997) the cost of using Pesos is introduced indirectly by the assumed timing of markets. Firms are allowed to convert Dollar-earnings of a given period t only in the financial market in period $t+1$, such that (expected) devaluation of the nominal exchange rate enters the pricing-rule. In particular, Dollar-prices for all goods are assumed to be constant and equal to one Dollar, whereas Peso-prices are a function of the expected nominal exchange rate. Consequentially, in the partial equilibrium model in Uribe (1997) the relative Peso-to-Dollar price is equal to the expected nominal exchange rate. As we show in Appendix A this modelling assumption implies a unique steady state with zero dollarization. Alternatively, in the present general equilibrium setup the cost-benefit relation among the two parallel currencies in the economy follows the basic idea presented in Uribe (1997), but allows for positive steady state degrees of dollarization. Following Corsetti and Pesenti (2005), firms, by maximizing Dollar-profits subject to the common technology (1.12) and to their demand schedule (1.14), predetermine the optimal, frictionless Dollar-price,

$$\tilde{P}^D_{H,t}(i) = \left(\frac{\varepsilon}{\varepsilon - 1}\right)\frac{W_t}{\varepsilon_t A_t} = \tilde{P}^D_{H,t} \quad \text{for all } i \in \left[0, \theta^H_t\right)$$

which is then adjusted to variations of the exchange rate during the period

$$P_{H,t}^{D}(i) = \frac{\tilde{P}_{H,t}^{D}(i)}{\varepsilon_t^{\psi}}$$

with

$$\psi \equiv \frac{\partial \ln P_{H,t}^{D}}{\partial \ln(1/\varepsilon_t)}$$

being a measure of sensitivity of the optimal Dollar-price set by firms with respect to variations in the nominal exchange rate, taking the predetermined frictionless Dollar-price, $\tilde{P}_{H,t}^{D}(i)$, as given. We henceforth refer to pass-through elasticity when referring to variations of Dollar-prices set by firms due to variations in the nominal exchange rate[16]. The more the Peso depreciates the lower is the optimal Dollar-price and thus the bigger the benefits in using the Dollar for transactions. We assume ψ being constant over time, which implies that agent's sensitivity with respect to changes in the nominal exchange rate does not substantially change within a given period of time. It is surely reasonable to consider the exchange rate pass-through as a decision variable of firms, given that the determinants of the latter clearly include some of the variables considered in the present model. But it may reasonably depend on other factors, as for instance, in the context of partially dollarized economies, a general lack of confidence in the domestic currency. By assuming the pass-through elasticity to be constant over time, we focus on economies where agents are lacking confidence in the Peso and where they do not regain full trust in the domestic currency in the short run. As a consequence agents (potentially) resort to the Dollar for transactions.

Empirically, we know little about exchange rate pass-through on prices in general. We know that it varies across types of goods, sectors and countries, but on average it is far from being perfect. For the particular case of partially dollarized economies, Reinhart et al. (2003) document that the pass-through from exchange rates to domestic

[16] In general, pass-through elasticity measures the reaction of either import- or export prices to exchange rate movements, whereas in the present model we are concerned with the reaction of domestic prices set in the foreign currency.

prices are relatively high, and clearly not one-to-one. In models where the pass-through elasticity measures the reaction of import- and/or export prices to movements in the nominal exchange rate, the value of the pass-through elasticity is between zero and one, implying that variations in the nominal exchange rate translate to prices at most one-to-one. For example, in Corsetti and Pesenti (2005) movements in the nominal exchange rate affect the final consumer price, but not the earnings of domestic firms. By contrast, in the present model the optimal Dollar-price set by firms, and consequentially the respective incomes, react to variations in the nominal exchange rate. In particular, we are interested in the case where firms "overreact" to variations in the nominal exchange rate and therefore consider values higher than one for the pass-through elasticity.

The present setup with an assumed imperfect reaction of domestic prices set in Dollars with respect to the Dollar exchange rate results in the following problem all firms solve when setting optimal Dollar-prices:

$$\max_{P_{H,t}^D(i)} P_{H,t}^D(i) Y_t(i) - \frac{W_t}{\varepsilon_t^{\psi} A_t} Y_t(i)$$

subject to the common technology (1.12) and to their demand schedule (1.14). The optimal Dollar-price charged for one unit of a given good i sold in the foreign currency is defined as $P_{H,t}^D(i) = \left(\frac{\varepsilon}{\varepsilon-1}\right) \frac{W_t}{\varepsilon_t^{\psi} A_t} = P_{H,t}^D$ for all $i \in \left[0, \theta_t^H\right)$.

The relative Dollar-price, the optimal Dollar-price set by firms relative to the domestic price index, is defined as follows:

$$\begin{aligned} S_{H,t}^D \equiv \frac{P_{H,t}^D}{P_{H,t}} &= \left(\frac{\varepsilon}{\varepsilon-1}\right) \frac{W_t}{\varepsilon_t^{\psi} A_t P_t} S_t^{\alpha} \\ &= \left(\frac{\varepsilon}{\varepsilon-1}\right) MC_t^D \end{aligned} \tag{1.16}$$

where $MC_t^D = \frac{W_t}{\varepsilon_t^{\psi} A_t P_t} S_t^{\alpha}$ denotes real marginal cost of production of firms selling the period's production in Dollars. Having assumed constant returns to scale technology the marginal cost of production is independent of the level of production and is equal across firms selling in the same currency. We can think of this economy as having two sectors, the Peso- and the Dollar-sector, with the same technology, but facing different marginal costs of production for selling in different currencies. Consequentially, equilibrium markups are different across sectors, i.e. across firms selling in either Pesos or Dollars[17]. Whenever the small open economy displays a positive degree of dollarization, the marginal cost of production of firms selling in Dollars is lower than the one of firms selling in Pesos. This, in turn, implies Dollar-prices to be set at a lower level than Peso-prices such that households optimally decide to purchase some varieties $i \in [0, \theta_t)$ in Dollars. The exact size of the set of varieties purchased in the foreign currency depends on the variety-specific transaction costs.

The assumed price setting of domestic firms implies that agents eventually start using the foreign currency as a means of transactions, but not to what extent. In particular, higher values of ψ reflect a world in which agents are more reluctant to the domestic currency such that the benefits in using the foreign currency for transactions are potentially higher. But how big these benefits are does depend on both the period's nominal exchange, ε_t, and the pass–through elasticity, ψ[18]. Having defined both optimal Peso- and Dollar-prices for the case of full price flexibility we can establish the following relationship[19]:

$$\frac{P^P_{H,t}}{P^D_{H,t}} = \varepsilon_t^{\psi} \tag{1.17}$$

defining the wedge between optimal Peso- and optimal Dollar-prices as a function of the period's nominal exchange rate and the pass-through elasticity. Note, that we focus

[17]Note, that for $\psi = 1$, i.e. no frictions for firms in setting prices in different currencies, firms in both sectors face the same marginal cost of production and thus set the same prices.

[18]For $\psi = 1$ there are no benefits attached to the use of the Dollar and households optimally choose to purchase all goods in Pesos. Moreover the transaction cost households face in buying a given good in Dollars does not affect firms' price-setting behavior, such that the stock of dollarization capital does not have any effect on optimal Dollar-prices when assuming prices being perfectly flexible.

[19]In a world with perfectly flexible prices the relative price between optimal Dollar- and Peso-prices is equal to ε_t^{ψ}, for both foreign and domestic firms. This, in turn, implies that the degree of dollarization for imports is defined in the exact same way as the degree of dollarization of domestically produced goods (both in the equilibrium and in the steady state), i.e. $\theta_t^H = \theta_t^F = \theta_t$.

on the particular case where $\varepsilon_t > 1$ for all t, and $\psi > 1$, i.e. the foreign currency is stronger than the domestic currency and Dollar-prices react by more than one-to-one with respect to changes in the nominal exchange rate. It is therefore beyond the goals of this Chapter to explicitly model how a process of dollarization is triggered. Rather we are interested in the macroeconomic implications of different monetary policy regimes in the particular situation where agents, characterized by a certain distrust in the domestic currency and thus a relative sensitivity with respect to exchange rate fluctuations, consider falling back on the foreign currency for certain transactions in the goods market.

Price setting with sticky prices

Additional to the benchmark scenario of perfectly flexible prices we consider the case of nominal price rigidities. In addition to the price setting mechanism specified previously, firms face a quadratic cost of nominal price adjustments based on the specification in Rotemberg (1982). Specifically, each firm pays an increasing and convex cost measured in terms of aggregate output when the size of its price increase deviates from the steady state inflation rate. The adjustment cost for a firm selling variety i in Pesos is given by the following equation:

$$\frac{\lambda}{2}\left(\frac{P^P_{H,t}(i)}{\Pi^P_{SS}P^P_{H,t-1}(i)}\frac{\varepsilon_{t-1}}{\varepsilon_t}-1\right)^2 Y_t$$

where $\lambda \geq 0$ measures the degree of the price adjustment cost and π^P_{SS} denotes steady state inflation of Peso-prices. Higher values of λ indicate greater price stickiness, while $\lambda = 0$ refers to the benchmark case of perfectly flexible prices. In order to set optimal Peso-prices, firms maximize Peso-profits, taking into account adjustment costs:

$$E_t\sum_{s=0}^{\infty}Q_{t,t+s}\left\{\frac{P^P_{H,t+s}(i)}{\varepsilon_{t+s}}Y_{t+s}(i)-\frac{W_{t+s}}{\varepsilon_{t+s}A_{t+s}}Y_{t+s}(i)-\frac{\lambda}{2}\left(\frac{P^P_{H,t+s}(i)}{\Pi^P_{SS}P^P_{H,t+s-1}(i)}\frac{\varepsilon_{t+s-1}}{\varepsilon_{t+s}}-1\right)^2 Y_{t+s}\right\}$$

subject to the common technology (1.12) and to their demand schedule (1.14). Assuming $\Pi^P_{SS} = 1$ and using the fact that $Q_{t,t+s} = \beta^s \left(\frac{C_{t+s}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+s}}\right) \left(\frac{\varepsilon_t}{\varepsilon_{t+s}}\right)$ the log-linearized first order condition defining the optimal Peso-price with adjustment costs yields the Peso-Phillips curve:

$$\pi^P_{H,t} = \beta E_t \left\{\pi^P_{H,t+1} - d_{t+1}\right\} + d_t + \eta_1 mc^P_t + \eta_2 s^P_{H,t} + \eta_3$$

where $\eta_1 \equiv \left(\frac{\varepsilon}{\lambda}\right)(S^P)^{-\varepsilon} MC^P$, $\eta_2 \equiv \left(\frac{1-2\varepsilon}{\lambda}\right)(S^P)^{1-\varepsilon}$, and η_3 is a convolution of parameters. Peso-inflation, in log deviations from the steady state, is defined as $\pi^P_{H,t} \equiv p^P_{H,t} - p^P_{H,t-1}$[20], and Peso-devaluation, in log deviations of the steady state, is given by $d_t \equiv e_t - e_{t-1}$. The log-linear version of the marginal cost of production of firms selling in Pesos is given by

$$mc^P_t = \sigma y^*_t + \varphi y_t + \left(\frac{1}{1-\alpha}\right) q_t - (1+\varphi) a_t - \left(\frac{\alpha}{1-\alpha}\right) \lambda_t$$

where

$$\lambda_t = \eta_4 k_t + \eta_5 \nu_t + \eta_6 e_t + \eta_7$$

defines the l.o.p. gap, which in turn depends on the stock of dollarization capital, k_t, the degree of dollarization in the small open economy, $\nu_t = log(1-\theta_t)$, and the nominal exchange rate, e_t[21].

Firms selling in the foreign currency face a slightly different adjustment cost, defined as follows:

$$\frac{\lambda}{2} \Phi(i, K_t)^{-\varepsilon} \left(\frac{P^D_{H,t}(i)}{\Pi^D_{SS} P^D_{H,t-1}(i)} - 1\right)^2 Y_t$$

where Π^D_{SS} denotes steady state inflation of Dollar-prices and with $\Phi(i, K_t)^{-\varepsilon}$ the transaction costs paid by consumers for a given variety i. Note, that the transaction costs mark the difference between the producer- and the consumer price paid for a given variety i, and therefore measure the gap between the optimal price set by firms and

[20]Note, that lower case letters denote log deviations of the variables from their steady state value.
[21]η_4, η_5, η_6 and η_7 depend both on steady state and parameter values.

the final price paid by consumers. In order for the transaction cost not to introduce an additional distortion on firms pricing behavior with respect to the foreign currency when considering costly price adjustments, firms take the transaction costs paid by consumers into account in the above specified way. In particular, knowing that transaction costs are strictly increasing in variety i, with $\varepsilon > 1$ representing the elasticity of substitution among varieties, the price adjustment cost incurred by firms is lower for varieties with higher transaction costs.

Firms facing price adjustment costs readjust Dollar-prices of the same tenure as under the benchmark case of flexible prices. In particular, firms selling their varieties in the foreign currency solve the following maximization problem:

$$E_t \sum_{s=0}^{\infty} Q_{t,t+s} \left\{ P^D_{H,t+s}(i) Y_{t+s}(i) - \frac{W_{t+s}}{\varepsilon^{\psi}_{t+s} A_{t+s}} Y_{t+s}(i) - \frac{\lambda}{2} \Phi(i, K_{t+s})^{-\varepsilon} \left(\frac{P^D_{H,t+s}(i)}{\Pi^D_{SS} P^D_{H,t+s-1}(i)} - 1 \right)^2 Y_{t+s} \right\}$$

subject to the common technology (1.12) and to their demand schedule (1.14). Assuming $\Pi^D_{SS} = 1$ and using the definition of the stochastic discount factor we derive the following log-linearized Dollar-Phillips curve:

$$\pi^D_{H,t} = \beta E_t \left\{ \pi^D_{H,t+1} \right\} + \eta_8 mc^D_t + \eta_9 s^D_{H,t} + \eta_{10} \tag{1.18}$$

where $\eta_8 \equiv \left(\frac{\varepsilon}{\lambda}\right) (S^D)^{-\varepsilon} MC^D$, $\eta_9 \equiv \left(\frac{1-2\varepsilon}{\lambda}\right) (S^D)^{1-\varepsilon}$, and η_{10} is a convolution of parameters. $\pi^D_{H,t} = p^D_{H,t} - p^D_{H,t-1}$ defines the evolution of optimal Dollar-prices set by firms, which does not account for the transaction costs paid by consumers for varieties purchased in Dollars. On the contrary, domestic inflation captures changes in consumer prices for domestically produced goods and therefore includes transaction costs paid on all purchases carried out in the foreign currency. The log-linear version of the marginal cost of production of firms selling in Dollars is given by

$$\begin{aligned} mc^D_t &= \sigma y^*_t + \varphi y_t + \left(\frac{1}{1-\alpha}\right) q_t - (1+\varphi) a_t - \left(\frac{\alpha}{1-\alpha}\right) \lambda_t + (1+\psi) e_t \\ &= mc^P_t + (1+\psi) e_t \end{aligned}$$

Degree of dollarization

We define the degree of dollarization of the small open economy as the share of goods purchased in Dollars. Assuming prices to be perfectly flexible together with the relationship between the optimal Peso- and Dollar-price defined by (1.17) and the definition of both the home- and the foreign cut-off good (1.8) yields

$$\Phi(\theta_t^j, K_t) = \varepsilon_t^{\psi-1} \tag{1.19}$$

for $j \in [H, F]$. The left-hand side of equation (1.19) defines households' marginal cost in purchasing one more variety in Dollars, and the right-hand side captures the benefits for firms to price a given variety in Dollars, relative to pricing in Pesos. Hence, the cut-off good in the small open economy is defined by the variety for which, when purchased in the foreign currency, the economy-wide costs equalize the benefits. It is interesting to note that assuming firms to optimally choose the currency of transaction and thus to bear the additional cost on all transactions made in Dollars would lead to the exact same definition of the cut-off good as in (1.19). According to Uribe (1997) we define the degree of dollarization of the small open economy with flexible prices as follows:

$$\theta_t(K_t, \varepsilon_t, \psi) = \begin{cases} 0 & \text{if } \Phi(0, K_t) \geq \varepsilon_t^{\psi-1} \\ \theta_t^H = \theta_t^F & \text{if } \Phi(\theta_t^H, K_t) = \varepsilon_t^{\psi-1} \end{cases} \tag{1.20}$$

When the degree of dollarization for a given period t is positive, it is given by the cut-off good for both domestically produced and imported goods, whose cost is the same whether it is bought with the domestic or the foreign currency[22]. The degree of dollarization of the small open economy depends on the stock of dollarization capital, K_t, on the period's nominal exchange rate, ε_t, and on the pass-through elasticity, ψ.

Assuming price adjustments to be costly does not alter the definition of the cut-off good according to households optimality condition, (1.8), but instead affects the

[22]Note, that given our assumptions on the price-setting of foreign firms we have the foreign cut-off good, θ_t^F, to coincide with the home cut-off good, θ_t^H, i.e. the share of domestically produced goods purchased in Dollars is the same as the share of imported goods purchased in the foreign currency.

relationship between the optimal Peso- and Dollar-price which is no longer defined by (1.17). Consequentially, the definition of the degree of dollarization is no longer as clear cut as in the case of perfectly flexible prices.

We define the law of motion of the stock of dollarization capital, similar to Uribe (1997), as follows:

$$K_{t+1} = (1-\delta)K_t + e^{\alpha_1 \theta_t} K^N + \Xi_t$$

Today's stock of dollarization capital is strictly increasing in the last period's degree of dollarization, capturing the social learning in adopting the foreign currency as a means of transaction. In particular, α_1 defines how today's degree of dollarization affects tomorrow's stock of dollarization capital. Higher values of α_1 imply agents to learn faster in using the Dollar actively as a means of transactions, which makes the stock of dollarization capital to grow faster. Faster learning, in turn, makes transaction costs to fall faster (for a given level of the nominal exchange rate), which, in turn, induces a more rapid increase in the degree of dollarization. When the Dollar is no longer used as a means of payment, i.e. when $\theta_t = 0$ for many consecutive periods, the stock of dollarization capital gradually decreases at a constant depreciation rate of $\delta \in [0,1]$ and the economy as a whole forgets how to use the foreign currency to purchase goods. Finally, K^N defines the natural stock of knowledge in dealing with the foreign currency, and Ξ_t evolves exogenously over time, according to the following AR(1) process

$$\xi_t = \rho_k \xi_{t-1} + \epsilon_t^k \tag{1.21}$$

where $\xi_t \equiv \log \Xi_t$ and $\left\{\epsilon_t^k\right\}$ is white noise.

According to our assumptions on firms price setting behavior, and as it becomes evident from the definition of the degree of dollarization in (1.20), fluctuations in the nominal exchange rate translate into fluctuations in the degree of dollarization. The immediate effect of a Peso-devaluation consists in an increase in the cost of using Pesos for transactions which is reflected in relatively higher Peso- to Dollar-prices.

Consequentially, households optimally decide to purchase more goods in Dollars, such that the degree of dollarization increases. Households are thus able to soften the impact of a Peso-devaluation on the domestic price-level, by resorting to the foreign currency. The increase in the degree of dollarization triggered by a Peso-devaluation induces an increase in the stock of dollarization capital of the following period, K_{t+1}, which in turn leads to lower costs in using the Dollar as a means of transaction. The respective costs in using either of the two currencies, and ultimately the degree of dollarization, are thus defined by both the volatility in the nominal exchange rate and by the stock of dollarization capital. Finally, and as it already becomes evident from (1.4) the degree of dollarization is a defining variable for the equilibrium price level and thus for the equilibrium inflation rate.

1.3 Market clearing and equilibrium

1.3.1 Consumption and output in the small open economy

Domestic Demand for domestically produced goods

Households' demand functions for domestically produced goods purchased in Pesos, in log-linear form, can be expressed as follows:

$$\begin{aligned} c_{H,t}(i) &= c_t + \alpha s_t - \varepsilon s^P_{H,t} \\ &= c_t + \left(\frac{\alpha}{1-\alpha}\right)(q_t - \lambda_t) - \varepsilon s^P_{H,t} \end{aligned}$$

for all $i \in [\theta_t, 1]$, where the last equality follows from (1.9). Equivalently, households' demand functions for all domestically produced varieties $i \in [0, \theta_t)$ purchased in Dollars is defined by:

$$\begin{aligned} c_{H,t}(i) &= c_t + \alpha s_t - \varepsilon(s^D_{H,t} - \alpha_2 K_t) \\ &= c_t + \left(\frac{\alpha}{1-\alpha}\right)(q_t - \lambda_t) - \varepsilon(s^D_{H,t} - \alpha_2 K_t) \end{aligned}$$

Both demand functions are increasing in aggregate consumption and in the terms of trade, and decreasing in the respective relative price. The positive correlation between demand and the terms of trade gives rise to an expenditure switching effect from foreign to domestically produced goods, whenever we observe an increase in the terms of trade. The magnitude of the effect, as in the benchmark small open economy defined in Galí and Monacelli (2005), depends on the openness of the small open economy, measured by α. But contrary to the benchmark small open economy the l.o.p. gap, λ_t, affects demand in both sectors negatively. Finally, for the Dollar-sector we have an additional term affecting demand, which stems from the transaction costs: The higher the economy's knowledge in using the foreign currency for purchases, K_t, and the faster the social learning in using the foreign currency (higher values for α_2), the higher is the demand for goods purchased in Dollars[23].

Domestic demand for imported goods

Equivalently to demand for domestically produced goods, demand for all varieties $i \in [\theta_t, 1]$ imported from the rest of the world and purchased in Pesos, state as follows:

$$\begin{aligned} c_{F,t}(i) &= c_t + (\alpha - 1)s_t - \varepsilon s^P_{F,t} \\ &= c_t + \lambda_t - q_t - \varepsilon s^P_{F,t} \end{aligned}$$

Households' demand functions for all imported varieties $i \in [0, \theta_t)$ purchased in Dollars is defined by:

$$\begin{aligned} c^D_{F,t}(i) &= c_t + (\alpha - 1)s_t - \varepsilon(s^D_{F,t} - \alpha_2 K_t) \\ &= c_t + \lambda_t - q_t - \varepsilon(s^D_{F,t} - \alpha_2 K_t) \end{aligned}$$

[23]Note, that for higher values of α_2 demand for goods purchased in Dollars is more sensitive with respect to changes in K_t. In particular, a moderate increase in K_t can provoke an important rise in the demand for goods purchased in Dollars. This is due to the fact that in an economy characterized by higher α_2, agents are able to adapt to the new currency faster, such that both higher values of K_t and α_2, via a reduction in transaction costs on Dollar-purchases, affect final consumer prices in the foreign currency negatively.

with $s^D_{F,t} = p^D_{F,t} - p_{F,t}$ denoting the relative Dollar-price for imports, and $s^P_{F,t} = p^P_{F,t} - p_{F,t}$ the relative Peso-price for imports. The degree of openness of the small open economy, α, affects demand for imports positively. The more open the small open economy, the bigger the share of imported goods in aggregate consumption, and thus the higher demand for imported goods. Furthermore, demand for imports are negatively related to the terms of trade[24].

Foreign demand for domestically produced goods

Foreign demand for domestically produced goods, i.e. exports from the small open economy to the rest of the world, in log linearized form are defined as:

$$c^*_{H,t}(i) = y^*_t - \varepsilon s^P_{H,t}$$

for all $i \in [\theta_t, 1]$, and

$$c^*_{H,t}(i) = y^*_t - \varepsilon(s^D_{H,t} - \alpha_2 K_t)$$

for all $i \in [0, \theta_t)$. Remind that in the small open economy the law of one price holds for exports such that the l.o.p. gap does not affect foreign demand for domestic products, contrary to the setup with a positive l.o.p. gap in Monacelli (2005).

Goods market clearing

Market clearing in the small open economy requires

$$\begin{aligned} Y_t(i) &= C_{H,t}(i) + C^*_{H,t}(i) \\ &= \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} \left[(1-\alpha)\left(\frac{P_t}{P_{H,t}}\right) C_t + \alpha \left(\frac{P^*_t}{P_{H,t}}\right) C^*_t\right] \end{aligned} \tag{1.22}$$

[24]Given the positive correlation between the terms of trade and the l.o.p. gap defined by equation (1.9), the negative correlation between imports and the terms of trade can also be interpreted differently. The bigger the l.o.p. gap, the bigger the wedge between import prices and prices in the rest of the world (the more costly are imports relative to domestically produced goods), and thus the smaller the demand for imports.

Plugging (1.22) into the definition of aggregate output (1.13) we obtain

$$Y_t = Y_t^* \left(\frac{S_t}{\Lambda_t}\right) \left[(1-\alpha)(Q_t)^{\frac{1-\sigma}{\sigma}} + \alpha\right] \tag{1.23}$$

which corresponds to the standard expression linking domestic and foreign production, except for Λ_t representing the l.o.p. gap, which dampens the effect of the terms of trade on domestic output.

For the case of interest where the monetary authority (perfectly) stabilizes consumer price inflation the above equation simplifies to:

$$Y_t = Y_t^* S_t^\alpha$$

Domestic output in this case is increasing in both output in the rest of the world and the terms of trade. In equilibrium, any movement in relative output of the small open economy with respect to the rest of the world therefore requires an adjustment in the terms of trade.

In case the monetary authority seeks to (perfectly) stabilize domestic inflation (1.23) simplifies to:

$$Y_t = Y_t^* \left[(1-\alpha)(Q_t)^{\frac{1-\sigma}{\sigma}} + \alpha\right]$$

Contrary to the case of consumer price inflation stabilization, movements in relative output of the small open economy with respect to the rest of the world require an adjustment of the real exchange rate.

In what follows, we assume the exogenous driving forces in the rest of the world to be described in form of an exogenous AR(1) process for foreign output:

$$y_t^* = \rho_{y^*} y_{t-1}^* + \epsilon_t^{y^*}$$

1.3.2 Aggregate employment and price dispersion

Having defined aggregate domestic production as (1.13) we define the following relationship for aggregate employment, using equation (1.22):

$$
\begin{aligned}
N_t &\equiv \int_0^1 N_t(i)di = \frac{1}{A_t}\int_0^1 Y_t(i)di \\
&= \frac{Y_t}{A_t}\int_0^1 \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} di
\end{aligned}
$$

We define price- and output dispersion across domestic firms as follows:

$$
\begin{aligned}
\Omega_t &\equiv \int_0^{\theta_t} \left(\frac{P^D_{H,t}(i)\Phi(i,K_t)}{P_{H,t}}\right)^{-\varepsilon} di + \int_{\theta_t}^1 \left(\frac{P^P_{H,t}(i)}{\varepsilon_t P_{H,t}}\right)^{-\varepsilon} di \\
&= \left(S^D_{H,t}\right)^{-\varepsilon} \left(\frac{K_t^{\alpha_2\varepsilon}\left[1-(1-\theta_t)^{\alpha_2\varepsilon+1}\right]}{\alpha_2\varepsilon+1}\right) + (1-\theta_t)\left(S^P_{H,t}\right)^{-\varepsilon}
\end{aligned}
$$

where $\left(\frac{P^D_{H,t}(i)}{P_{H,t}}\right) \equiv S^D_t(i) = S^D_t$ for all $i \in [0,\theta_t)$ and $\left(\frac{P^P_{H,t}(i)}{\varepsilon_t P_{H,t}}\right) \equiv S^P_t(i) = S^P_t$ for all $i \in [\theta_t, 1]$. Aggregate employment in the small open economy, in log-linear form, is thus defined as follows:

$$
n_t = y_t - a_t + \omega_t \tag{1.24}
$$

where

$$
\omega_t = \eta_{11}k_t - \eta_{12}s^D_t - \eta_{13}s^P_t + \eta_{14}\nu_t + \eta_{15}
$$

defines price dispersion, which depends on the stock of dollarization capital, the degree of dollarization, $\nu_t = log(1-\theta_t)$, and both the relative Dollar- and Peso-price[25]. Normally, price dispersion is interpreted as the variation in prices across sellers of the same good, whereas in the present setup the interpretation is slightly different. In particular, price dispersion captures two things: First, the difference between Peso- and Dollar-prices for a given variety i, due to the present frictions related to the use of the two currencies. And second, the consumer price dispersion within the set of goods

[25] η_{11}, η_{12}, η_{13}, η_{14} and η_{15} depend both on steady state and parameter values.

purchased in Dollars, due to the variety-specific transaction costs. As a consequence, a positive degree of dollarization goes together with a positive price dispersion. Given our assumptions, price dispersion provides information about the interplay between the costs and the benefits attached to the use of the foreign currency. In order to be able to interpret price dispersion in a correct way, it is helpful to remind the difference in the price indices used: $P_{H,t}^{D}$ being the Dollar-price set equally by all firms selling in Dollars, which is affected by the volatility of the nominal exchange rate, for a given exchange rate pass-through elasticity, $\psi > 1$, but not by the transaction costs, which by assumption are paid by consumers. $P_{H,t}$ on the other hand, stands for the consumer price index, expressed in terms of Dollars. $P_{H,t}$ contains the transaction costs due for all purchases in Dollars such that this index is affected by both frictions, the imperfect exchange rate pass-through and the transaction cost. Price dispersion is inefficient in the standard sense, i.e. it raises the aggregate labor hours needed to produce a given level of output. Hence, for positive degrees of dollarization we observe higher levels of employment than the one prevailing in an economy where no foreign currency is used for transactions. Theoretically the monetary authority is able to directly affect the benefits in using the foreign currency for transactions, via the period's nominal exchange rate, but not the costs. Given the presence of variety-specific transaction costs, for any (non-zero) degree of dollarization, price dispersion is always positive. Hence, the monetary authority is no longer able to completely offset price dispersion, unless the monetary policy in place permanently stabilizes the degree of dollarization of the small open economy to zero. Furthermore, in case the monetary authority wanted to stabilize price dispersion at its lowest possible level, the knowledge of the exact degree of dollarization prevailing in the small open economy is crucial for such a policy to be successful.

1.3.3 Monetary policy

We analyze two possible monetary policy regimes, consumer price inflation targeting (CPIT) and domestic inflation targeting (DIT). The monetary authority sets interest rates according to the following Taylor-rule:

$$R_t = \beta^{-1} \left(\frac{\Pi_t}{\Pi^{SS}} \right)^{\Phi_\pi} \left(\frac{\Pi_{H,t}}{\Pi_H^{SS}} \right)^{\Phi_{\pi_H}} \upsilon_t$$

with Π^{SS} being the steady state CPI-inflation rate and Π_H^{SS} the steady state domestic inflation rate. The monetary policy shock, υ_t, follows the law of motion:

$$\upsilon_t = \rho_\upsilon \upsilon_{t-1} + \epsilon_t^\upsilon$$

Assuming the monetary authority to target CPI-inflation implies $\Phi_{\pi_H} = 0$, whereas assuming domestic inflation targeting implies $\Phi_\pi = 0$. In both cases we assume the world monetary authority to fully stabilize world prices[26].

1.4 Characterization of the steady state

The present model, characterized by an endogenous degree of dollarization, displays multiplicity of steady states where each of them depends on initial conditions and where the degree of dollarization feeds back on the economy's steady state allocation. In particular, for a given pass-through elasticity, ψ, the initial level of the nominal exchange rate of the economy defines the respective steady state degree of dollarization[27].

[26]Note, that considering a hybrid monetary policy rule including devaluation of the exchange rate or deviation of the real exchange rate from its steady state level, as for instance in Wang (2009), yields more volatility in the exchange rate, via the uncovered interest rate parity. Hence, there is no apparent advantage of targeting devaluation rates explicitly. Overall, the difference between the rules considered here and hybrid rules is rather small, independently of the degree of dollarization.

[27]In other words, in the present model we have a unit root in the nominal exchange rate. As it has been highlighted by Schmitt-Grohé and Uribe (2003), when domestic residents have only access to a risk-free bond whose rate of return is exogenously determined abroad, the steady state of the model depends on initial conditions. In the present model, even for the different cases considered in

Furthermore, the steady state depends on the monetary policy regime in place. A positive steady state degree of dollarization brings about several distortions, compared to a steady state characterized by zero degree of dollarization, with the two most important distortions being a positive level of price dispersion and a positive l.o.p. gap. Depending on the assumed monetary policy regime, the l.o.p. gap affects the terms of trade and/or the real exchange rate: Assuming strict CPIT implies automatic stabilization of the real exchange rate such that the l.o.p. gap absorbs an important part of the distortions linked to a positive degree of dollarization, which in turn affects the behavior of the terms of trade. Assuming strict DIT, on the other hand, makes both the l.o.p. gap and the real exchange rate to partially absorb the distortions linked to a positive degree of dollarization, such that neither the terms of trade nor the real exchange rate are fully stabilized.

In this section we characterize the perfect foresight, zero inflation steady states of our small open economy mode for the two different monetary policy regimes, consumer price inflation targeting (CPIT) and domestic inflation targeting (DIT), considering different levels of the steady state degree of dollarization.

1.4.1 Consumer Price Inflation Targeting (CPIT)

Figure 1.1 summarizes the continuum of steady states, assuming the monetary authority to fully stabilize CPI-inflation. By stabilizing CPI-inflation the monetary authority fully stabilizes the real exchange rate, which in turn implies steady state aggregate consumption in the small open economy, C, to be constant for any initial value of the nominal exchange rate and thus independently of the steady state degree of dollarization. However, the composition of aggregate consumption changes across the different steady states, in the sense that different shares of aggregate consumption are purchased

Schmitt-Grohé and Uribe (2003) we have dependency on initial conditions. Note, that dependency on the initial nominal exchange rate is equivalent to dependency on the initial level of the stock of dollarization capital, K_0, as in Uribe (1997).

in Pesos and in Dollars. The lower the steady state value of the Peso with respect to the foreign currency (and thus the higher the steady state level of the nominal exchange rate), the more beneficial is it for firms to sell their production in Dollars. Consequentially we observe the relative Dollar-price to fall (and the relative Peso-price to increase) with the steady state degree of dollarization, which brings about an increase in the share of goods purchased in Dollars (and a fall in the share of goods purchased in the domestic currency).

Moreover, we observe an increase in both the l.o.p. gap and in the terms of trade for low to moderate degrees of dollarization, and a gradual decline in both variables for higher degrees of dollarization[28]. The steady state l.o.p. gap reflects the cost-benefit relation in using the foreign currency for purchases of imported goods. For low degrees of steady state dollarization the l.o.p. gap is increasing given the growing difference between the relative Peso- and the relative Dollar-price. For higher degrees of dollarization the variety-specific transaction costs dampen the difference between the consumer prices in both currencies, which results in a reduction in the aggregate price dispersion.

Price dispersion is increasing in the degree of dollarization, for a more and more important difference in Peso- and Dollar-prices and for higher transaction costs which widen the difference for Dollar-prices of different varieties. Steady state employment is increasing with the degree of dollarization for two reasons: First, a higher level of price- and output dispersion makes domestic production more labor intensive. We therefore observe an outward shift of firms' labor demand which results in higher steady state wages, with the latter to be increasing in the steady state degree of dollarization. And second, a higher degree of dollarization yields a higher steady state employment because of a higher level of domestic output, which is mainly due to an expenditure switching effect of imported to domestically produced goods.

[28]Note, that an increase in the terms of trade implies domestically produced goods to become relatively less expensive than imports. Hence, for steady state degrees of dollarization up to 0.7 an increase in the use of the foreign currency for transactions implies an increase in domestic absorption (at the steady state and conditional on strict CPIT).

Steady state output in the present setup generally depends negatively on price dispersion and the l.o.p. gap. The terms of trade and the nominal exchange rate, on the other hand, are positively correlated with steady state output. An increase in the steady state terms of trade results in both an expenditure switching effect from imports to domestically produced goods, as well as a higher demand for exports from the rest of the world, and therefore in an increase in domestic production. For the particular case of $\sigma = 1$, we have steady state output to be independent of the terms of trade and of the l.o.p. gap. The positive relation between output and the nominal exchange rate is stronger for high degrees of dollarization. This fact can be interpreted as an increase in the overall stability of the economy as more and more goods are purchased in the stable foreign currency, allowing firms to set lower prices, which in turn stimulates demand. Hence, the more pronounced the devaluation of the domestic currency, the greater are the benefits of falling back on the foreign currency for transactions, and the more important is the increase in demand and ultimately in output. In this sense, the nominal exchange rate is a measure of the benefits in using the Dollar as a means of transactions. The positive correlation between the steady state degree of dollarization and the level of domestic output, as predicted by the model, is consistent with the empirical evidence: countries experiencing periods of dollarization have higher output in periods of higher dollarization[29].

Economies that are characterized by higher pass-through elasticities of Dollar-prices with respect to variations in the nominal exchange rate, ψ, experience a faster increase in the degree of dollarization, due to a more pronounced reaction of relative prices. As a result, more variety-specific transaction costs distort both prices and output, which yields higher levels of price dispersion. The benefits attached to the use of the foreign currency in such an environment are bigger, such that the increase in domestic output (for a given increase in the steady state degree of dollarization) is more pronounced.

[29] See for example Dell'Erba and Saldías-Zambrana (2006) for the case of Bolivia.

Finally, higher price dispersion and higher levels of domestic output lead to higher levels of employment. The same is true for economies that display either a faster learning in using the foreign currency for transactions (higher values of α_1), or a flatter transaction cost function (lower values of α_2). On the one hand, faster learning induces the transaction costs on Dollar-purchases to be lower (for a given degree of dollarization), which in turn yields a more pronounced growth in the degree of dollarization. On the other hand, a transaction cost function that increases more gradually in the varieties purchased in Dollars yields lower aggregate transaction costs and therefore also leads to a faster increase in the degree of dollarization.

1.4.2 Domestic Inflation Targeting (DIT)

Figure 1.1 summarizes the continuum of steady states when the monetary authority targets domestic inflation. Domestic Inflation Targeting (DIT) implies both domestic and world inflation to be zero, i.e. $\pi_{H,t} = \pi_t^* = 0$, for all t. Two are the main differences with respect to the steady state allocation assuming CPIT: First, steady state aggregate consumption in the small open economy is no longer independent of the steady state degree of dollarization. And second, as we have already underlined, both the terms of trade and the real exchange rate are affected by the distortions linked to a positive steady state degree of dollarization.

Aggregate steady state consumption co-moves with the real exchange rate, which, under the regime analyzed here, is declining in the steady state degree of dollarization. The decline in the aggregate consumption, for a given increase in the steady state degree of dollarization, is more important in more open economies, which becomes evident by the international risk sharing condition together with equation (1.10). Assuming DIT implies the terms of trade to move one-to-one with the l.o.p. gap. Overall, the increase in the terms of trade in the steady state degree of dollarization is smaller under DIT, given that the real exchange rate absorbs part of the steady state effects linked to a positive degree of dollarization. Finally, steady state output behaves equally as under CPIT, given that for the case of interest steady state output is independent of both the terms of trade and the l.o.p. gap.

1.5 Simple Monetary Policy Rules for the Small Open Economy

In the present section we analyze the macroeconomic implications of the two above discussed monetary policy regimes for the small open economy with endogenous dollarization for both the case with prices being perfectly flexible and for price adjustments to be costly. We discuss the dynamic effects of different shocks on a number of macroeconomic variables and compare the results to the relevant literature. We present some quantitative results based on a parametrized version of our model economy. The main assumptions underlying our baseline parametrization are in line with the relevant literature. We choose parameter values, as defined in Table 1.1, to mimic the structure of the economy of the United States. Some comments with respect to the calibration are in order: We interpret a period as one quarter. We set σ to unity, which corresponds to a log-utility specification. We assume a labor supply elasticity of $\frac{1}{3}$. The steady state markup of the monopolistic firms is assumed to be equal to 20 percent, which implies the elasticity of substitution between differentiated goods (ε) to take value 6. We assume $\beta = 0.99$, which implies a riskless annual return of about 4 percent at the steady state. A baseline value for α, the degree of openness, is set at 0.4. The calibration of the interest rate rules follows the original Taylor calibration and sets Φ_π and Φ_{π_H} respectively equal to 1.5. For the calibration of the stochastic properties of the exogenous driving force, according to Galí (2008), we set $\rho_a = 0.95$, $\rho_v = 0.5$ and $\rho_{y^*} = 0.86$. When considering the case of costly price adjustments we set the price adjustment cost, λ, to 50. All previous parameters are assumed to take identical values in the small open economy and the world economy.

The parameter capturing firms' sensitivity with respect to variability in the exchange rate, ψ, is set to 1.15. The agents' learning in using the foreign currency is set to $\alpha_1 = 0.5$, which implies that for a one percent increase in the steady state degree of dollarization the stock of dollarization capital raises by 0.5. Finally, α_2 is set to 0.3, which implies a moderate increase in the transaction costs over varieties. We provide extensive sensitivity analysis for these three key parameters. Given the presence of multiplicity of steady states we restrict our attention to two different steady state degrees of dollarization, a relatively low degree of dollarization (corresponding to 20% of all transactions carried out in the foreign currency) and a relatively high degree of dollarization (60% of transactions in the foreign currency)[30].

1.5.1 Dynamic Effects of a Monetary Policy Shock

In this section we analyze the dynamics of the model after a contractionary monetary policy shock, which corresponds to an increase of 25 basis points in the exogenous component of the nominal interest rate, ϵ_t^v. The Euler equation (1.7) combined with the market clearing (1.23), yields the equilibrium condition

$$y_t = E_t\left\{y_{t+1}\right\} - \frac{1}{\sigma}\left[r_t - E_t\left\{\pi_{t+1}\right\} - E_t\left\{d_{t+1}\right\} - \rho + E_t\left\{\triangle\omega_{t+1}\right\}\right] + \zeta_{\sigma,\alpha}E_t\left\{\triangle s_{t+1}\right\} \tag{1.25}$$

[30]Remember that for the high dollarization steady state we have a higher share of domestic consumption purchased in Dollars and thus a lower share of domestic consumption purchased in Pesos, due to a lower relative Dollar-price and a higher relative Peso-price. Moreover, the high dollarization steady state displays a higher level of both domestic output and employment, and a higher level of price dispersion.

with $\zeta_{\sigma,\alpha} = \left(\frac{1-\alpha}{\sigma} - \alpha\right)$[31] and where $r_t - E_t\{\pi_{t+1}\}$ defines the real interest rate of period t. Compared to the corresponding expression in a standard small open economy New Keynesian framework, tomorrow's expected variation in price dispersion, $E_t\{\triangle\omega_{t+1}\}$, enters the equilibrium condition stated above. Solving (1.25) forward yields

$$y_t = -\frac{1}{\sigma}\sum_{k=0}^{\infty} E_t\{r_{t+k} - \pi_{t+k+1} - d_{t+k+1} - \rho + \triangle\omega_{t+k+1} + \omega_{\sigma,\alpha} \triangle s_{t+k+1}\}$$

In the present model exogenous interventions by the monetary authority have an effect on output only to the extent they influence current or future expected short term real interest rates, price dispersion or changes in the terms of trade. In the following sections we analyze the effect of an exogenous monetary policy shock in both the flexible and sticky price environment.

CPIT with perfectly flexible prices

Figure 1.2 describes the impulse response functions of the partially dollarized small open economy when prices are perfectly flexible, and assuming the monetary authority to target CPI-inflation. The contractionary monetary policy shock induces an increase in the real interest rate and a fall in both CPI- and domestic inflation, as in a classical model without dollarization. The magnitude of the responses of nominal variables are equal for both the low and the high dollarization steady state, and therefore unaffected by the small open economy's degree of dollarization. Given that in the limiting case of perfect price flexibility the cyclical dynamics of a New Keynesian model resemble those of a RBC model, monetary policy only affects nominal variables. As a consequence, on

[31] Note, that assuming log-utilities implies $\omega_{\sigma,\alpha}$ to take positive values for $\alpha < 0.5$ and negative values for $\alpha > 0.5$. The underlying intuition is the following: For countries with relatively lower shares of imports, an increase in the terms of trade from t to $t+1$, triggers an expenditure switching effect from imported to domestically produced goods, and thus has a positive effect on both domestic consumption and production. For countries with relatively high shares of imports (α above 0.5), the expenditure-switching effect is still present but since imports are a big share of domestic consumption not all of it can be substituted by domestically produced goods. Therefore, the overall cost of consumption is increasing which dampens domestic consumption and ultimately domestic production.

impact, all real variables in the present partially dollarized small open economy remain unaffected by the contractionary monetary policy shock.

Note, that as it is standard in flexible price economies, the contractionary monetary policy shock yields a counterfactual fall in the nominal interest rate, due to the missing liquidity effect[32]. For a temporary reduction in the nominal interest rate, given the constant nominal interest rate in the rest of the world, the uncovered interest rate parity implies a depreciation of the nominal exchange rate, which causes a transition to a new steady state with a higher degree of dollarization. Hence, unlike in a standard, non-dollarized small open economy with flexible prices, an exogenous monetary policy shock causing a temporary depreciation of the domestic currency yields permanent effects on real variables in a partially dollarized small open economy. In particular, the devaluation of the local currency makes the use of Dollars beneficial, in the sense that it provides firms an incentive to set lower Dollar-prices. The optimal Peso-price is not directly affected by the shock, but given the fall in optimal Dollar-prices it becomes relatively more expensive to purchase goods in Pesos. Consequentially, the demand for goods purchased in Dollars gradually rises, whereas it falls for goods purchased in the domestic currency. Hence, both for imports and domestically produced goods the set of goods purchased in Dollars enlarges such that the degree of dollarization of the small open economy gradually increases in response to the shock. The resulting increase in the degree of dollarization is slightly less important for economies starting off with a higher degree of dollarization. This is due to the presence of increasing transaction costs on Dollar-purchases, which make the rise in the degree of dollarization more and more costly. Consequentially, the increase in the l.o.p. gap and in the level of price dispersion is more important for the highly dollarized economy, where the increase in

[32]According to the liquidity effect in response to a contractionary monetary policy shock the nominal interest rate should increase. This effect is rationalized by the fact that a contractionary monetary policy shock can be thought of as a contraction of the monetary base, and therefore a reduction in the economy's overall liquidity, which should induce an increase in the cost of money, i.e. an increase in the nominal interest rate.

the latter is caused by both of its determinants: First, the gap between Dollar- and Peso-prices set by firms is widening with the degree of dollarization to become larger. And second, the increase of the share of goods purchased in Dollars causes a rise in the aggregate good specific transactions costs. For the l.o.p. gap to be increasing in the degree of dollarization we have its increase in the wake of the shock to be of bigger magnitude for higher degrees of dollarization. The reaction of the terms of trade are proportional to the l.o.p. gap, with the increase in the terms of trade yielding an expenditure switching effect from imported to domestically produced goods, which is more pronounced for higher degrees of dollarization.

The positive reaction of domestic output is, as it is the case for all real variables, not directly provoked by the shock but a result of the transition to a new steady state with a higher degree of dollarization. During this transition domestic output is positively affected by the expenditure switching effect from imported to domestically produced goods, and by the increase in demand of Dollar-purchases. The positive effect of an increase in the terms of trade is nevertheless dampened by the l.o.p. gap which enlarges with the degree of dollarization. Employment rises during the transition to the new steady state, both due to the increase in domestic output in the small open economy and due to the higher level of price dispersion.

To sum up: For the economy to start off at a higher degree of dollarization the response of nominal variables is independent of the degree of dollarization, unlike the reaction of relative prices to the temporary increase in the nominal interest rate. In an economy with a higher level of initial dollarization the domestic currency's value vis-a-vis the Dollar is lower, i.e. the steady state nominal exchange rate is higher. Therefore, the devaluation of the Peso, resulting from the monetary policy shock, makes the relative Dollar-price to fall by more for higher degrees of dollarization. Nevertheless, for the presence of increasing transaction costs the degree of dollarization, which is permanently affected by these changes in the relative prices, increases by less for economies with a higher initial degree of dollarization. Real variables in the present flexible price setup are thus not affected by the monetary policy shock directly, but gradually react during the transition to a new steady state. A temporary contractionary monetary policy shock in an economy with a positive degree of dollarization thus has permanent real effects, given that the shock makes the economy converge to a new steady state with a higher level of dollarization.

CPIT with sticky prices

Figures 1.3 and 1.4 display the impulse response functions after a contractionary monetary policy shock in a small open economy, with high and low degree of dollarization, respectively. In a partially dollarized economy where price adjustments are costly a contractionary monetary policy shock has two effects: First, we observe that even with price adjustments being costly there is no liquidity effect. Second, the degree of dollarization falls on impact, and then gradually increases until the economy reaches its new steady state. As we have seen for the case of perfectly flexible prices, for any positive degree of dollarization the devaluation of the domestic currency, resulting from the monetary policy shock, and its impact on relative prices are the driving forces of the model's dynamics.

In a standard small open economy with nominal rigidities, as in Galí and Monacelli (2005), a contractionary monetary policy shock triggers an increase in the nominal interest rate and a fall in both CPI- and domestic inflation rates. But we know from Galí (2008) that even in a basic New Keynesian framework, depending on the calibration, the liquidity effect might be absent. The present model does not predict any liquidity effect under any reasonable parametrization. The intuition for the missing liquidity effect is fairly straightforward: In a partially dollarized economy with nominal rigidities, changes in the share of goods purchased in either currency, and thus changes in the degree of dollarization, act as an alternative adjustment mechanism to shocks. This becomes evident by the dynamic behavior of both domestic- and CPI-inflation rates, whose dynamics are exactly the same as under perfect price flexibility. Hence, even though prices are rigid within both the Peso- and the Dollar-sector, the possibility of shifting consumption among the two sectors makes aggregate price levels and thus inflation rates to behave as if prices fully adjust[33].

The initial decrease in both CPI- and domestic inflation makes the overall purchasing power to increase. The initial fall in Dollar-prices is smaller when price adjustments are costly, with the fall being less pronounced than the overall fall in domestic prices, unlike in the flexible price setup. Moreover, the monetary policy shock does not have any reducing impact on the transaction costs due on purchases in Dollars. These two facts together make the use of the Dollar relatively more expensive and give rise to a fall in the degree of dollarization immediately after the shock. As prices adjust over time optimal Dollar-prices fall and the degree of dollarization of the small open economy gradually increases. The magnitude of the dynamic reaction of real variables are not very big, even in presence of price adjustment costs. This result underlines the generally held belief that monetary policy is less effective in presence of dollarization. As in the flexible price setup, the contractionary monetary policy shock, via its effect on the nominal exchange rate, provokes a transition to a new steady state with a different degree of dollarization.

Comparing the dynamics of two economies with costly price adjustment but with different degrees of dollarization leads to the following conclusions: For a lower degree of dollarization the difference between Dollar- and Peso-prices set by firms is smaller, such that the monetary policy shock brings about a more pronounced initial fall in the

[33]Alternatively, think of the following rational for the missing liquidity effect in a partially dollarized economy: In an economy where the monetary base consists of both a domestic and a foreign currency that are considered perfect substitutes by domestic agents, reducing the domestic part of the monetary base does not affect the price of money, i.e. the interest rate. Therefore, in the present model after a contractionary monetary policy shock the interest rate is moving with expected inflation, which ultimately results in a depreciation of the domestic currency.

degree of dollarization. Hence, the inability to perfectly downward-adjust Dollar-prices makes the domestic currency to become more attractive. The transition towards a new steady state caused by a contractionary monetary policy shock in an economy with a low degree of dollarization may thus be to a steady state with the same or even a lower degree of dollarization. As it becomes evident from Figure 1.4 for the case of an economy with 20% of all transactions carried out in the foreign currency a contractionary monetary policy shock yields a transition to a steady state with a strictly lower degree of dollarization. On the contrary, the transition in an economy with high degree of dollarization is always towards a steady state with a higher degree of dollarization.

To sum up, in dollarized economies where price adjustments are costly we observe similar transitional dynamics after a contractionary monetary policy shock as in an economy with perfectly flexible prices, with two main differences. First, nominal price rigidities affect the cost-benefit relation of the two currencies and induce a fall in the degree of dollarization on impact. And second, whether the shock induces an increase or a fall in the use of the foreign currency depends on the economy's initial degree of dollarization. As we know from the open economy literature[34] monetary policy in open economies faces a trade-off between the desire to smooth fluctuations in the real exchange rate and to allow flexibility in the nominal exchange rate for terms of trade adjustments. In targeting CPI-inflation the monetary authority in a partially dollarized economy is able to stabilize the real exchange rate but faces an additional trade-off between stabilizing the degree of dollarization, and allowing flexibility in the nominal exchange rate for terms of trade adjustments.

Domestic Inflation Targeting (DIT)

In this section we analyze the dynamics of the model after a contractionary monetary policy shock, assuming the monetary authority to stabilize domestic inflation ($\pi_{H,t}$).

[34] See for example Devereux and Engel (2007).

Figure 1.5 displays the impulse response functions to a contractionary monetary policy shock for a small open economy with a high steady state degree of dollarization and perfectly flexible prices. Comparing the economy's dynamics for the two monetary policy regimes under consideration we conclude the following: The dynamic responses of nominal variables are not affected by the monetary policy regime. In particular, as under CPIT also under DIT the liquidity effect is absent, independently of the degree of nominal price rigidities. The only qualitative difference with respect to the dynamic responses of real variables is the behavior of aggregate consumption and output. Contrary to the case where the monetary authority stabilizes CPI-inflation, targeting domestic inflation makes the real exchange rate to downward-adjust, such that aggregate consumption is falling, whereas domestic output remains roughly unaffected by the shock. As under a regime of CPIT also under DIT the magnitude of the reactions to the contractionary monetary policy shock are relatively smaller for higher degrees of dollarization. Furthermore, the differences in the dynamics between the two regimes under consideration become smaller for higher degrees of dollarization. These two results underline the conventional wisdom of monetary policy to become less effective with higher degrees of dollarization.

Sensitivity Analysis

To conclude this section we conduct a sensitivity analysis to the parametrization of our key parameters. Increasing the pass-through elasticity, ψ, increases firms' sensitivity with respect to fluctuations in the nominal exchange rate when setting optimal Dollar-prices. Hence, higher values for ψ make Dollar-prices to react more fiercely, such that demand for both Peso- and Dollar-purchases adjust by more. Overall, an economy that is more reluctant to the use of its domestic currency sees its degree of dollarization to increase faster and converges to a new steady state with a relatively higher degree of dollarization after a contractionary monetary policy shock.

Increasing the social learning in using the foreign currency for transactions, α_1, increases the speed of the dollarization process. A faster learning implies after all lower transaction costs to be paid on Dollar-purchases, such that the cost in using the foreign currency falls, which boosts demand for Dollar-purchases (and depresses demand for Peso-purchases). Hence, in an economy where agents learn faster to adapt the foreign currency as a means of payment, a depreciation of the domestic currency provokes a transition to a steady state with a relatively higher degree of dollarization.

α_2 captures the speed of augmentation of transaction costs over varieties i. For lower values of α_2 transaction costs are increasing at a slower rate in the share of varieties purchased in Dollars, which makes the benefits in using the foreign currency relatively bigger. Consequentially, the dollarization process is faster, in the sense that the degree of dollarization is more sensitive with respect to changes in the relative prices, for the dampening effect of transaction costs to be smaller. Hence, if purchases in Dollars become slightly less expensive we observe the degree of dollarization to increase by relatively more for lower values of α_2 such that the shift from Peso- to Dollar-purchases of domestic consumption is more pronounced. The economy thus converges to a new steady state with a relatively higher degree of dollarization after a monetary policy shock. The impact on the remaining real variables are negligibly small.

Overall, the above discussed dynamic responses after a contractionary monetary policy shock are robust with respect to the key parameters, i.e. changes in the parameter values only affect the dynamics quantitatively, but not qualitatively.

1.5.2 Dynamic Effects of a Domestic Productivity Shock

In this section we analyze the dynamics of the model after a positive shock on domestic productivity.

CPIT with perfectly flexible prices

Figure 1.6 describes the dynamic effects of a domestic productivity shock on a number of macroeconomic variables, for different steady state degrees of dollarization, assuming prices to be perfectly flexible. Interestingly the magnitude of the dynamic responses depend on the economy's initial degree of dollarization, whereas qualitatively the dynamics are not affected by the degree of dollarization. In particular, independently of the initial degree of dollarization, a unit innovation in a_t yields a temporary and protracted increase in the degree of dollarization, an increase in output and the terms of trade, and a temporary decrease in domestic inflation.

The positive shock in domestic productivity affects producer prices in both Dollars and Pesos negatively, such that the domestic price index is temporarily lower than its initial steady state level[35]. In general, in presence of imperfect pass-through of variations in the nominal exchange rate to the producer prices in Dollar ($\psi > 1$), Dollar-prices of all firms are (inefficiently) lower compared to Peso-prices, which yields a positive level of price dispersion. The temporary reduction of Dollar-prices is thus more important than the temporary reduction in Peso-prices, such that the shock ultimately brings about a modification in the cost-benefit relation between the two currencies. These changes in the relative prices makes transactions in Dollar more attractive, and despite the presence of transaction costs, the degree of dollarization increases. For the presence of network effects, this increase is rather long-lasting.

Unlike in a standard small open economy model with perfectly flexible prices, in our partially dollarized economy employment falls on impact, independently of the economy's degree of dollarization. The positive productivity shock induces a demand shift from the Peso-sector to the Dollar-sector. Firms selling in Dollars produce and sell

[35] Domestic inflation falls by more for lower degrees of dollarization, due to the aggregate transaction costs which are unaffected by the productivity shock and therefore dampening the reduction in the overall domestic price level. For lower degrees of dollarization the aggregate transaction costs paid in equilibrium are lower. Therefore, the negative impact on the domestic price level is more important for economies starting off at a low level of dollarization.

more with the same amount of labor, given the rise in productivity. Firms selling in the domestic currency, on the other hand, produce less and thus dismiss part of their labor force. It is noteworthy that the increase in domestic output is substantially smaller than in an economy without dollarization. This is mainly driven by the positive price dispersion, which by equation (1.24), dampens the impact of the increase in productivity on domestic output (for given employment). In other words, on aggregate the increase in employment provoked by both domestic output and price dispersion after a positive technology shock is smaller than the reduction in aggregate employment due to a higher domestic productivity, such that aggregate employment falls. The magnitude of this decrease depends on the degree of dollarization in the economy and is bigger for lower levels of dollarization. This is due to the fact that a bigger share of firms is affected by the decrease in demand for domestic goods purchased in Pesos. In the transition to the new steady state the technology shock fades out over time while the persistently high price dispersion yields an increase in the aggregate employment[36].

For the domestic price level to be at a lower level after the positive technology shock the terms of trade increase on impact. Imports become more costly which induces an expenditure switch from imported to domestically produced goods and therefore provide an additional upward pressure on domestic output. The terms of trade move with the l.o.p. gap, which increases in the degree of dollarization. The temporary increase in the terms of trade is therefore slightly smaller for higher steady state degrees of dollarization. This, in turn, makes the temporary increase in output slightly less pronounced for economies which are more dollarized. Hence, the magnitude of the impact of a positive productivity shock on real variables is smaller for higher steady state dollarization. This is due to the increasing transaction costs which require a more

[36]Employment plays the role of a buffer between domestic output and price dispersion. Domestic output stabilizes at its initial level much faster than price dispersion, since the latter inherits the persistence of the degree of dollarization. The higher the steady state degree of dollarization, the more important is price- and output dispersion and thus the bigger the increase in the aggregate employment during the transition to the new steady state.

and more important reduction in the optimal Dollar-price for a further increase in the degree of dollarization.

To sum up, a positive domestic technology shock affects the cost-benefit relation between the two currencies and makes the use of the Dollar more beneficial such that the degree of dollarization increases. This increase is relatively long lasting due to the history dependence of the dollarization process given agents' learning in using the foreign currency for transactions. The degree of dollarization affects the economy's response to a positive technology shock both in terms of magnitude and persistence. Contrary to the monetary policy shock domestic productivity shocks do not provoke a transition to a new steady state with a different degree of dollarization, given that the nominal exchange rate remains unaffected by the shock. However, in particular for low degrees of dollarization, the effects of the positive shock on domestic productivity take a very long time to fade out. For the given parametrization, in the low steady state economy the degree of dollarization takes more than 80 quarters to come back on its initial level.

CPIT with sticky prices

Figures 1.7 and 1.8 display impact response functions after a positive domestic productivity shock in a small open economy with a high and low degree of steady state dollarization, respectively. The positive domestic productivity shock reduces production costs and therefore the optimal prices set by firms in both sectors. For Dollar-prices to be (inefficiently) lower compared to Peso-prices, even in presence of costly price adjustments, the benefits of using the foreign currency for transactions increase. The initial increase in the degree of dollarization following a positive productivity shock is nevertheless smaller in presence of nominal price rigidities, since firms do no longer find it optimal to adjust prices immediately after the shock. Consequentially the initial impact on price dispersion is less pronounced compared to the flexible price setup.

Over time, alongside firms' gradual price adjustment, price dispersion increases until the degree of dollarization reaches its peak.

The initial fall in aggregate employment is more pronounced in presence of costly price adjustment. This is due to the fact that whenever price adjustments are costly firms fall back on employment as only alternative margin of adjustment. Unlike in a flexible price setup we therefore observe an impact fall in employment in both sectors. Over time domestic demand purchased in Dollars increases and thus stimulates aggregate labor demand.

Given the sluggish adjustment in prices the initial increase in the terms of trade is less important such that ultimately the increase in domestic output is even less pronounced than in the flexible price setup. As in the benchmark case of perfectly flexible prices the magnitude of the dynamics in response to a positive productivity shock depends on the economy's degree of dollarization and is generally smaller in economies where the share of transactions carried out in the foreign currency is higher.

Domestic Inflation Targeting (DIT)

In this section we analyze the dynamics in the small open economy after a positive shock to domestic productivity, assuming the monetary authority to fully stabilize domestic inflation ($\pi_{H,t}$). Figure 1.9 compares the impulse response functions after a positive productivity shock in a small open economy with a low steady state degree of dollarization and perfectly flexible prices. Comparing the economy's dynamics after a positive productivity shock for the two regimes under consideration confirms a previous finding: When the monetary authority targets domestic inflation the magnitude of the reaction to the shock is bigger for all variables, but output. Stabilizing domestic inflation brings about a bigger adjustment of relative prices after a shock, such that the degree of dollarization is more volatile than under CPIT. This, in turn, feeds back into higher volatility of most variables in the small open economy. Galí and Monacelli (2005) show that the optimal monetary policy in a standard small open economy consists in fully stabilizing domestic inflation. Based on the present analysis this result is likely not to carry over to a partially dollarized small open economy. The exact specification of the optimal monetary policy in the present setup is left for future research.

Sensitivity Analysis

As we have concluded for the monetary policy shock, we confirm the robustness of the qualitative dynamic reactions to the domestic productivity shock with respect to the key parameters. Hence, a different parametrization only affects the magnitude of the dynamic responses. In particular, for higher values of ψ the initial degree of dollarization is higher, such that the effects of a positive domestic productivity shock are smaller in magnitude. An economy which adapts faster to the use of a foreign currency (higher values of α_1) starts off at a higher initial degree of dollarization and therefore sees the benefits in using the foreign currency to raise by relatively less in response to a positive domestic productivity shock. Finally, for lower values of α_2 transaction costs increase at a slower rate in the share of varieties purchased in Dollars. A slower increase in the transaction costs makes the benefits in using the foreign currency bigger and therefore the increase in these benefits due to a domestic productivity shock relatively more important.

1.5.3 Other economically relevant shocks

Exogenous shock on transaction costs

In this section we consider the effects of an exogenous shock to the economy's aggregate knowledge in using the foreign currency for transactions, captured by the term ϵ_t^k in equation (1.21). We can think of this shock representing exogenous modifications in the transaction costs attached to the use of the Dollar for transactions. On one hand, a negative shock on K may represent some legal restrictions on the use of the foreign currency in transactions, imposed by the government at a given moment t. On the other hand, a positive shock could be the adoption of certain payment facilitating technologies attached to the foreign currency, as for instance credit card payments.

The dynamic responses after a positive shock to the economy's aggregate knowledge in using the Dollar as currency for transactions are of little surprise: The shock makes the use of the foreign currency relatively less costly, i.e. the transaction cost function is shifted downwards such that transaction costs are lower for all varieties i. This reduction in the cost of carrying out transactions in Dollars therefore yields an increase in the economy's degree of dollarization. A negative shock, by symmetry, has the opposite effects and thus leads to a reduction in the degree of dollarization. Hence, any credible and effective reduction in the economy's knowledge of using the foreign currency for transactions helps in reducing dollarization. The effect of such a policy will be bigger the lower the initial degree of dollarization, but of non-negligible size even for very high steady state degrees of dollarization. For example, in an economy with 60% of transactions carried out in the foreign currency, a negative unitary innovation in the law of motion of K leads to an impact reduction in the degree of dollarization of 1.8 percentage points.

Exogenous shock on world output

A positive shock to world output affects the respective marginal cost of production in both sectors and therefore alters the cost-benefit relation between the two currencies. Marginal costs of production in both sectors are positively affected by an increase in world output. For a positive degree of dollarization the marginal costs of production in the Dollar-sector are strictly lower than in the Peso-sector, such that the increase is relatively more important for firms selling in Dollars. This brings about an increase in the relative Dollar-price and thus a fall in the degree of dollarization.

An increase in world output always generates an improvement in the terms of trade, and therefore an expenditure switching effect from domestically produced to foreign produced goods. Consequentially, aggregate domestic economic activity is negatively affected by the shock to world output. International risk sharing implies aggregate domestic consumption to be affected positively. Depending on the assumed monetary policy regime, for the given parametrization, either domestic consumption (CPIT) or domestic output (DIT) moves together with world output. For the given parametrization the positive effect on consumption dominates the expenditure switching effect dampening domestic output, such that domestic production slightly increases.

The different dynamics across the two monetary policy regimes under consideration confirm previously found differences. A regime stabilizing domestic inflation causes more volatility, due to the more pronounced initial reaction of relative prices. Furthermore, the differences in the dynamic adjustment of the small open economy across the two monetary policy regimes under consideration become smaller with higher degrees of dollarization.

1.6 Conclusion

We have distinguished several effects of dollarization. First, dollarization leads to the emergence of an additional policy trade-off between stabilization and the control of the degree of dollarization. Monetary policy therefore has an impact on the degree of dollarization, which in turn affects monetary policy trade-offs. Second, the presence of network externalities makes the dollarization process history dependent and gives rise to feedback effects between the economy's steady state degree of dollarization and its allocation. Monetary policy shocks are shown to have permanent real effects via the induced transition of the economy to a different steady state. Furthermore, the model suggests that the dynamic response to economically relevant shocks are conditional on the degree of dollarization in the economy. Finally, comparing two different monetary policy regimes leads to the conclusion that stabilizing domestic inflation generally induces more volatility in all macroeconomic variables but output.

The proposed framework constitutes a first attempt to contribute to the rich debate on optimal monetary policy in open economies by endogenizing dollarization and thus accounting explicitly for the additional policy-trade-off emerging in presence of this phenomenon. The analysis presented is a first step towards the definition of optimal monetary policy in presence of dollarization and has to be extended in several directions. The welfare implications and ultimately the definition of the optimal monetary policy in the given set-up have to be established, in order to have a say to what extent dollarization affects the optimal monetary policy descriptions of a standard small open economy. As a further extension it would be interesting to account more accurately particularities of emerging countries' business cycle characteristics, in the lines of Aguiar and Gopinath (2007), Garcia-Cicco, Pancrazi and Uribe (2010), and others.

So far, the question of whether dollarization should be considered good or bad, and thus be either encouraged or prevented by the monetary authority has not been addressed explicitly. For doing so, the costs of dollarization, in particular the loss of seigniorage revenues or the inability of conducting an independent monetary policy would have to be taken into account, in a framework apt for a thorough welfare analysis.

Table 1.1: **Parameter Values**

Parameter	**Mnemonic**	**Value**
Elasticity of intertemporal substitution	σ	1
Labor Supply Elasticity	$\frac{1}{\varphi}$	$\frac{1}{3}$
Elasticity of Substitution among varieties	ε	6
Discount Factor	β	0.99
Price Adjustment Cost	λ	$\in [0; 50]$
Degree of Openness	α	0.4
Taylor Coefficient CPI-Inflation	Φ_{π}	$\in [0; 1.5]$
Taylor Coefficient domestic Inflation	Φ_{π_H}	$\in [0; 1.5]$
Persistence Monetary Policy Shock	ρ_{υ}	0.5
Persistence Technology Shock	ρ_a	0.95
Persistence World Output Shock	ρ_{y^*}	0.86
Exchange Rate Pass-Through Elasticity	ψ	1.15
Learning Parameter	α_1	0.5
Transaction Cost Parameter	α_2	0.3
Depreciation Rate Stock of Dollarization Capital	δ	0.05
Natural Stock of Dollarization Capital	$K^N = \delta$	0.05

Figure 1.1: Continuum of Steady States depending on initial conditions (ε_0): Comparison CPIT vs. DIT

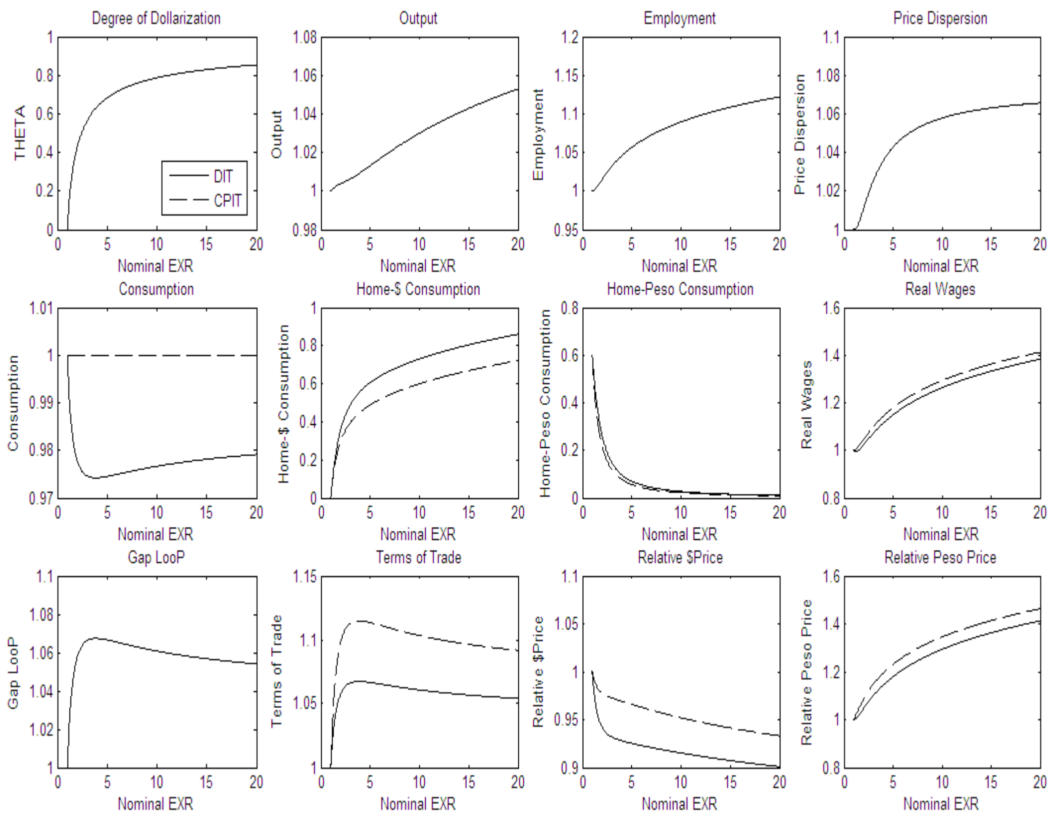


Figure 1.2: Impulse response functions to a contractionary monetary policy shock for different steady state degrees of dollarization, assuming perfectly flexible prices and the monetary authority to target CPI-Inflation (CPIT)

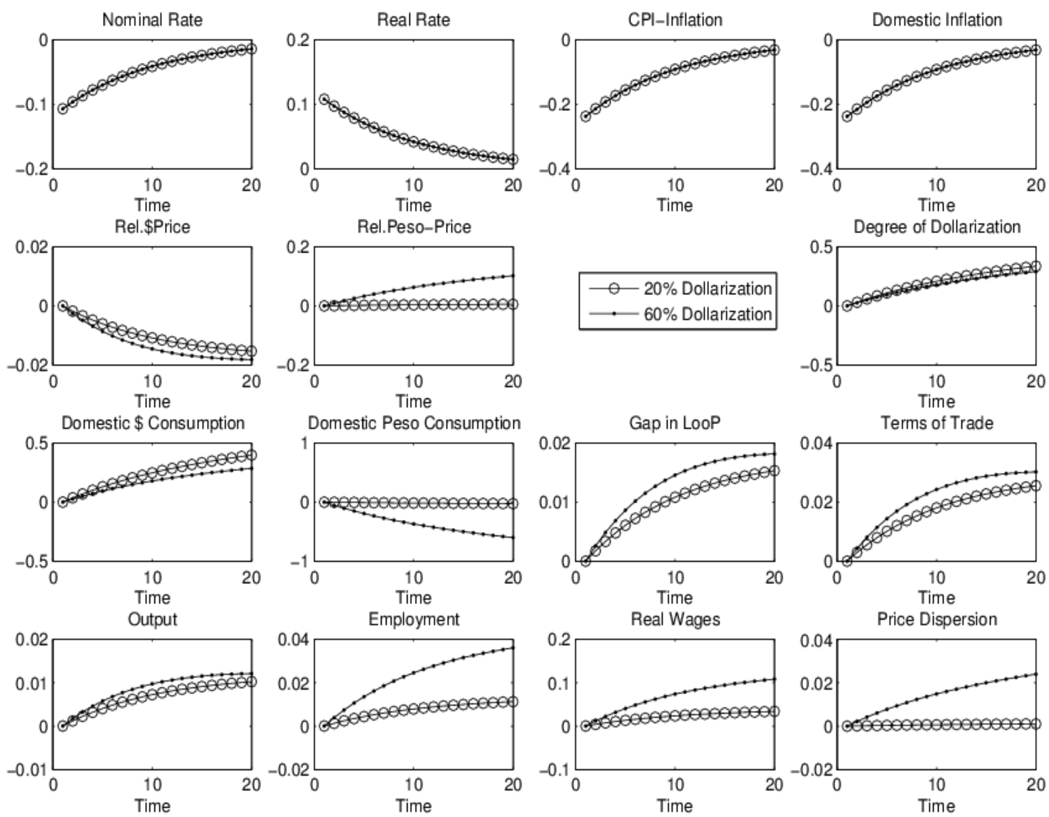


Figure 1.3: Impulse response functions to a contractionary monetary policy shock for high degrees of steady state dollarization, assuming the monetary authority to target CPI-Inflation (CPIT): Comparison flexible prices vs. costly price adjustment

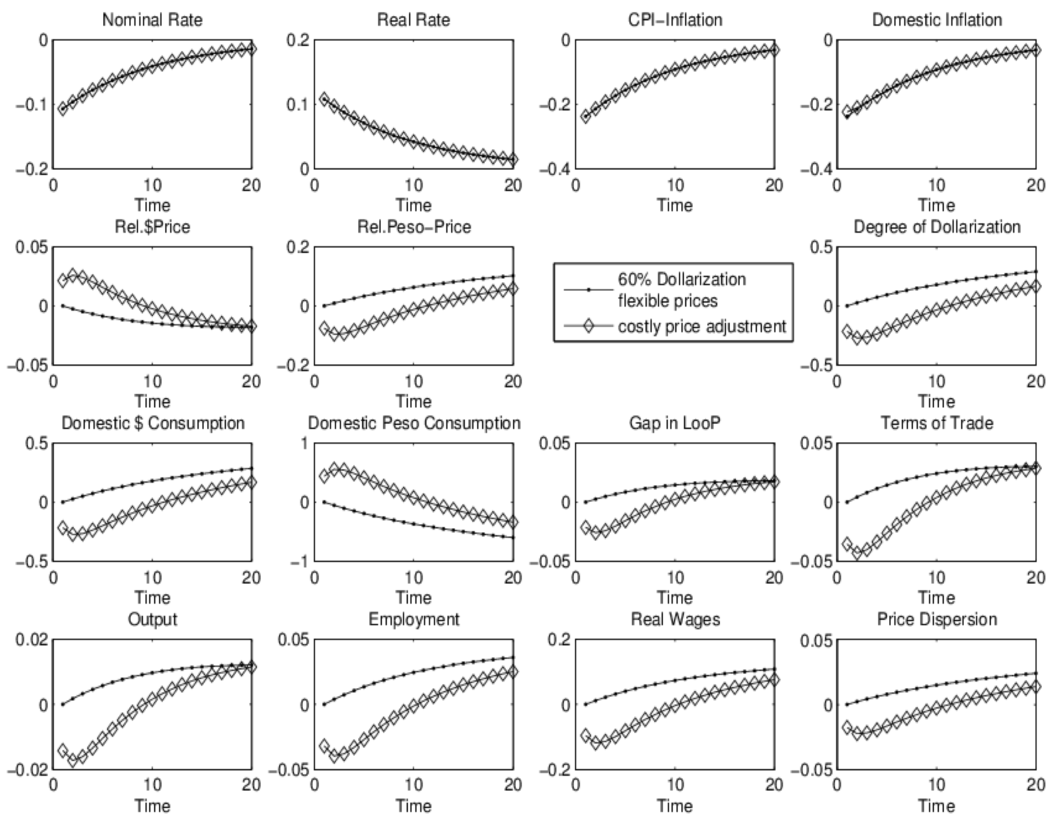


Figure 1.4: Impulse response functions to a contractionary monetary policy shock for low degrees of steady state dollarization, assuming the monetary authority to target CPI-Inflation (CPIT): Comparison flexible prices vs. costly price adjustment

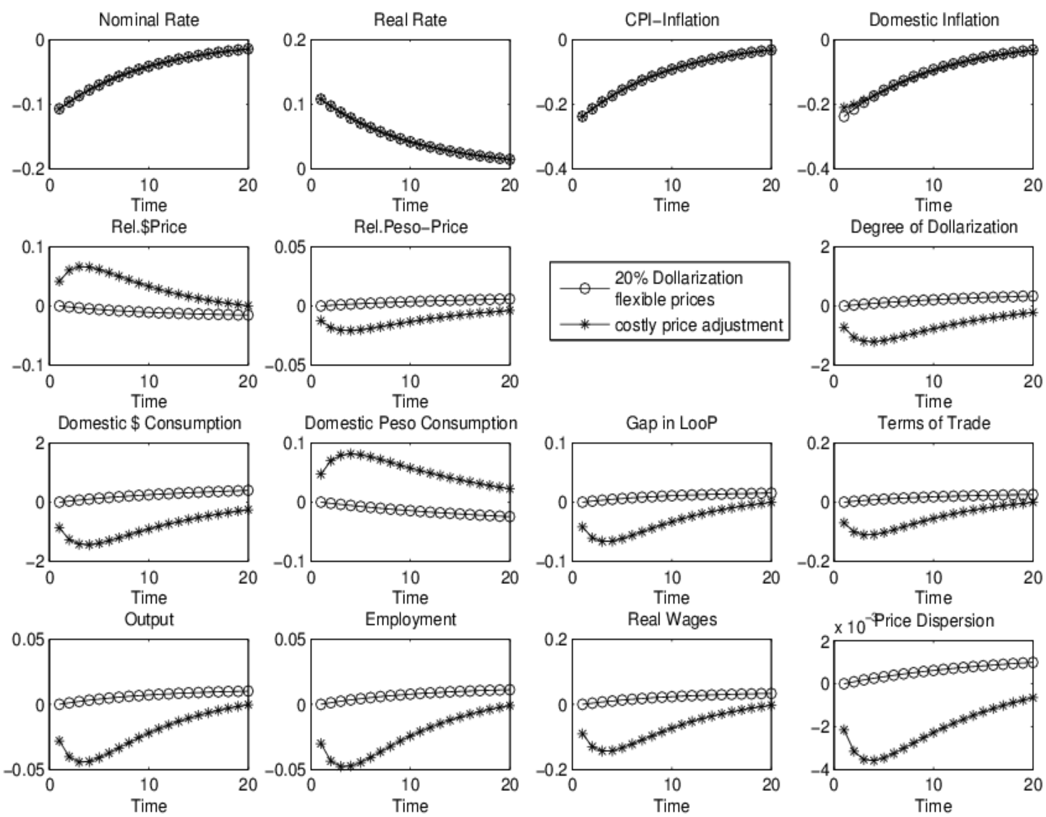


Figure 1.5: Impulse response functions to a contractionary monetary policy shock for high degrees of steady state dollarization, assuming prices to be flexible: Comparison CPIT vs. DIT

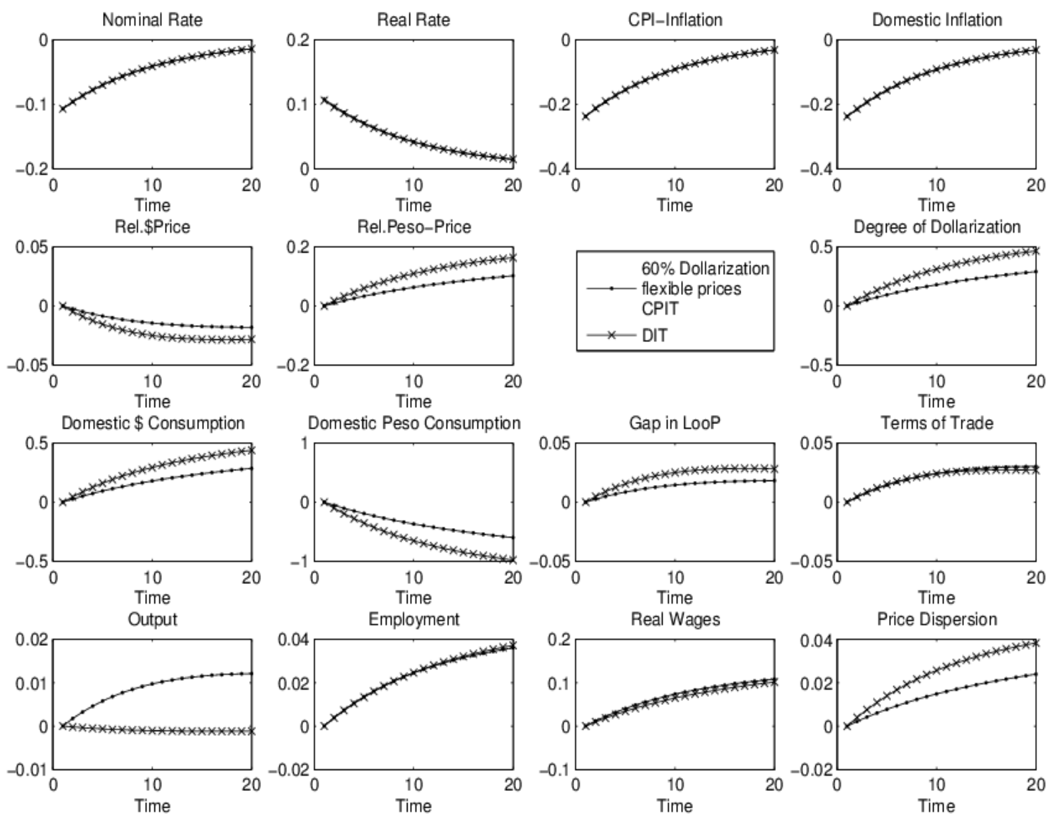


Figure 1.6: Impulse response functions to a positive domestic productivity shock for different steady state degrees of dollarization (CPIT)

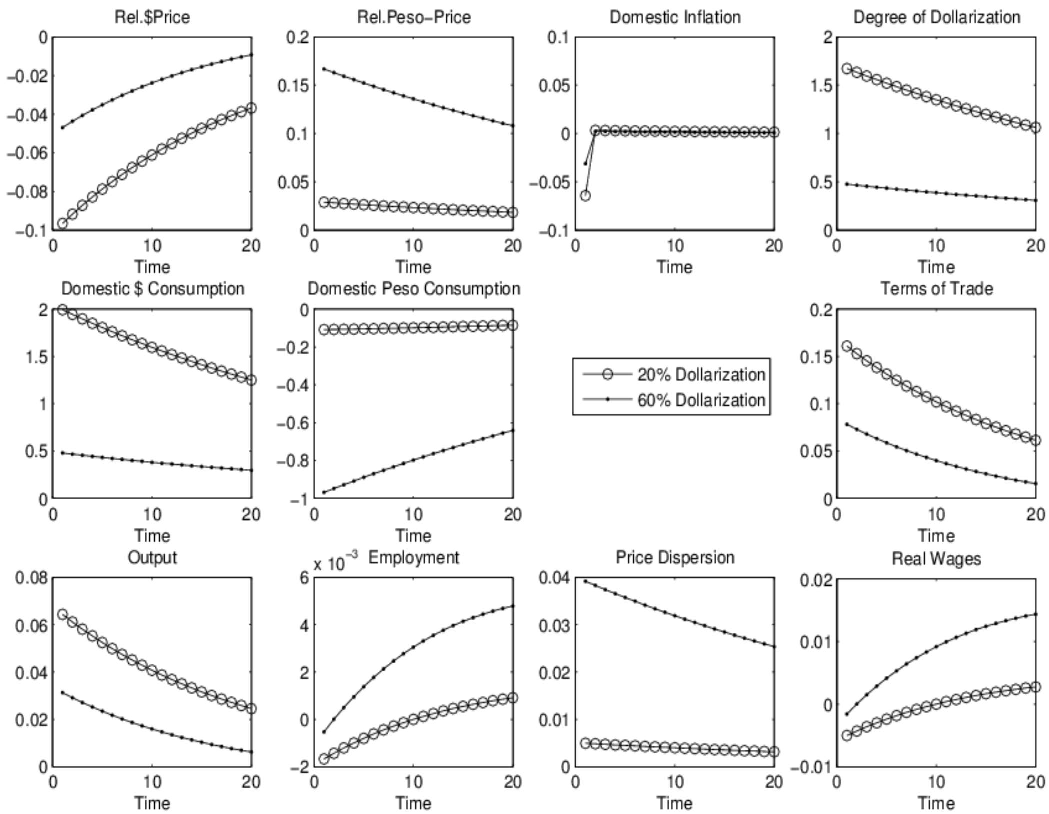


Figure 1.7: Impulse response functions to a positive domestic productivity shock in presence of costly price adjustment for a high dollarization steady state (CPIT)

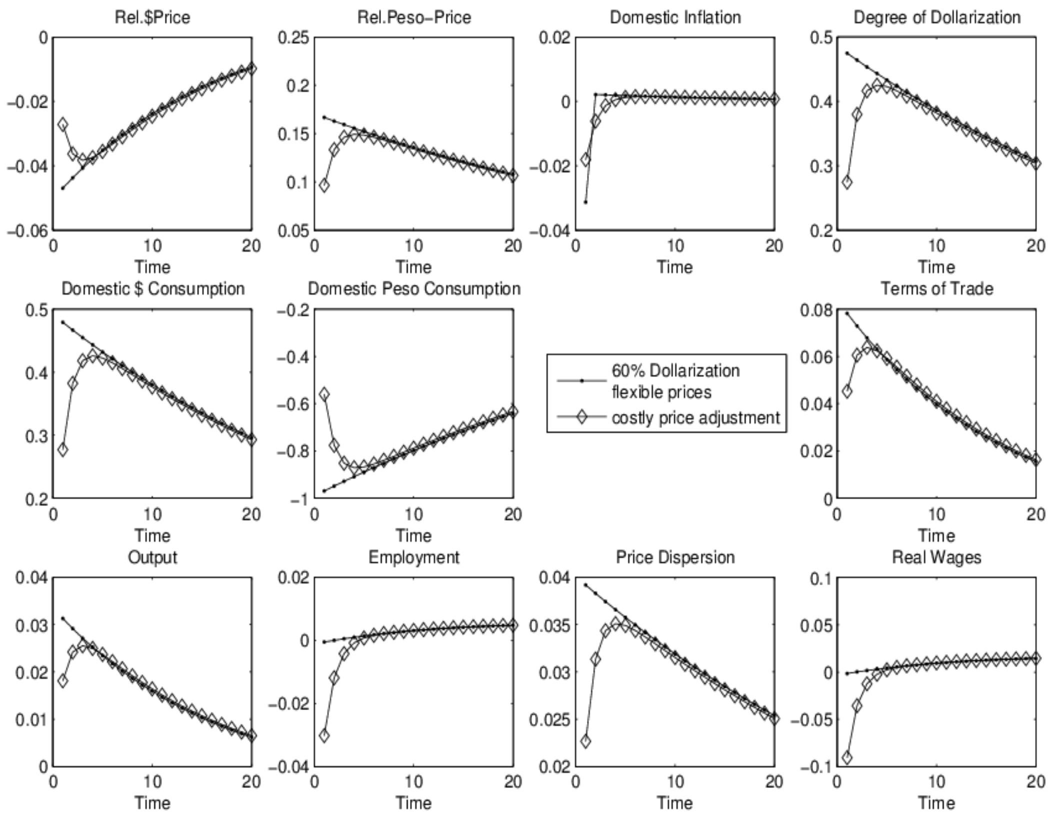


Figure 1.8: Impulse response functions to a positive domestic productivity shock in presence of costly price adjustment for a low dollarization steady state (CPIT)

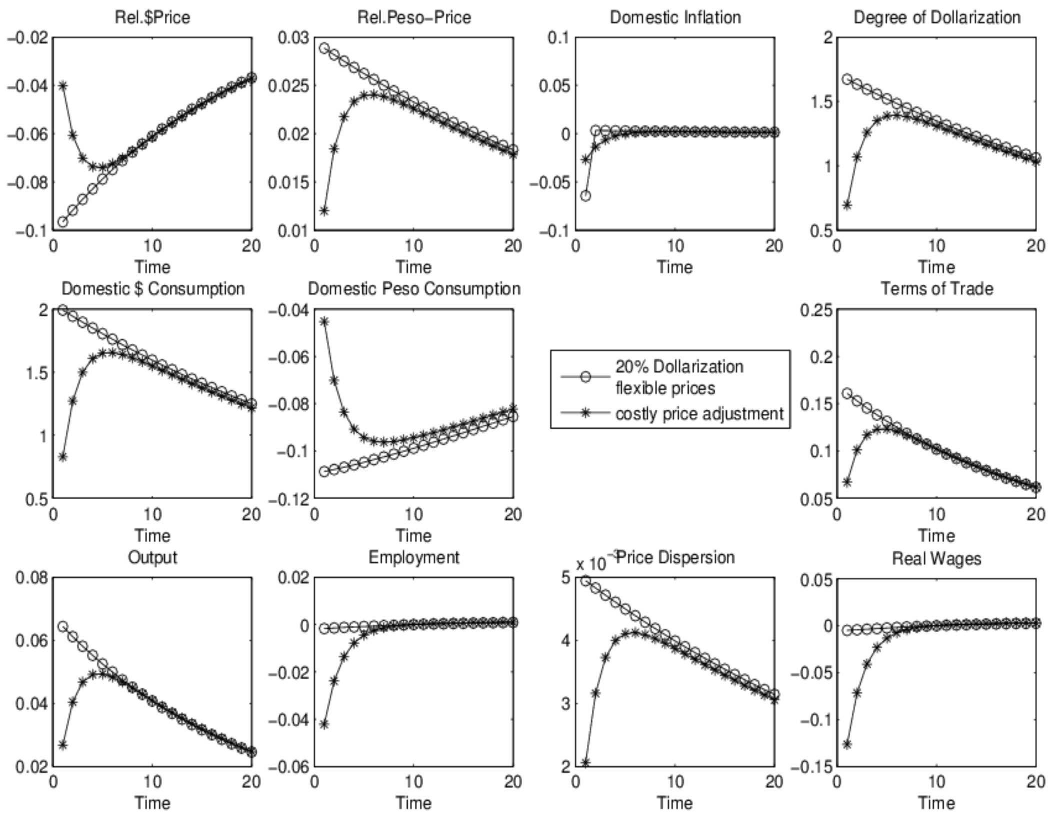
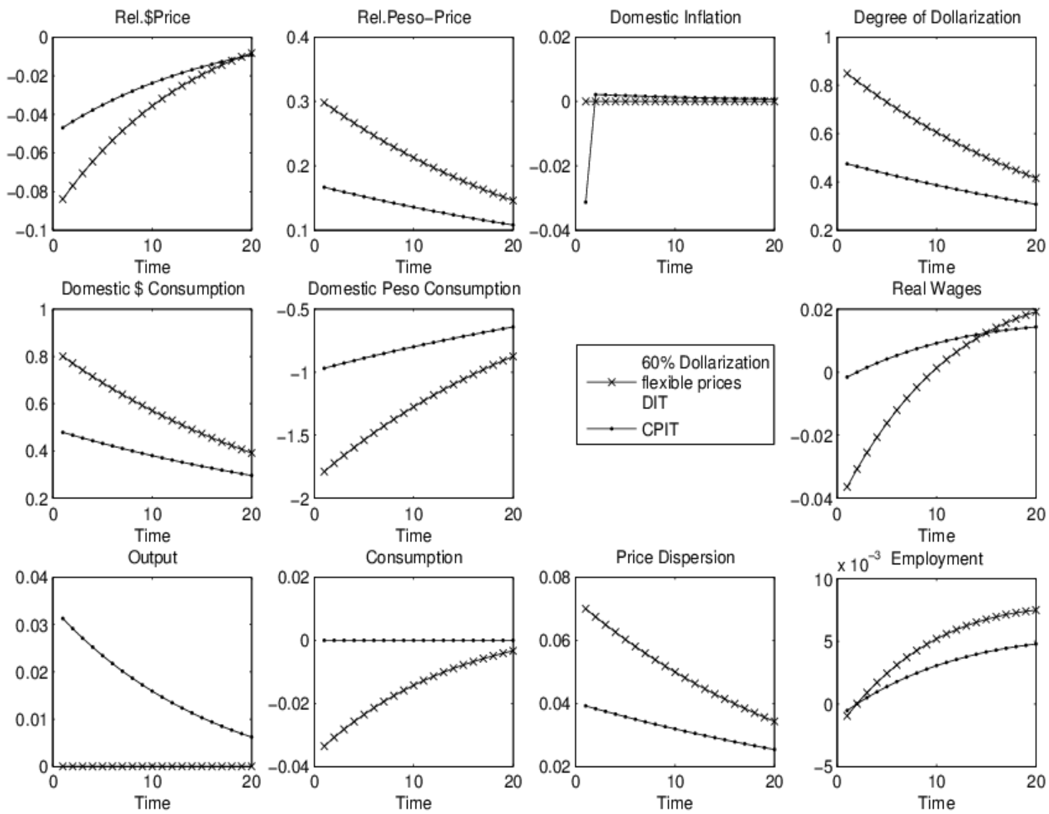


Figure 1.9: Impulse response functions to a positive domestic productivity shock for a low dollarization steady state (DIT vs. CPIT)



Chapter 2

Technology shocks, labor mobility and aggregate fluctuations

2.1 Introduction

Regional labor mobility within a country or labor flows across international borders do not play any role in most of the theories explaining cyclical fluctuations of macroeconomic variables. Yet according to a commonly held belief going back to Mundell (1961) labor mobility is an important mechanism of adjustment to asymmetric shocks, which are events that have diverse economic effects on different countries or on different regions within a given country. Labor mobility helps to balance the effects of asymmetric shocks in particular when conventional stabilization mechanisms are no longer available; for instance, in a monetary union with many regions and a single currency where monetary policy no longer serves as a stabilizing instrument for regional shocks. Only recently have some contributions emphasized that migration is not solely a long-run phenomenon. Rather, it is also relevant if one focuses on higher frequencies, typically between 6 and 34 quarters, which are commonly labeled as business cycle fluctuations. For example, Molloy and Wozniak (2011) show that internal migration rates within the US are strongly procyclical with respect to both the national and local business cycles. Moreover, from Herz and Van Rens (2011) we learn that labor mobility within the US is important in the sense that structural unemployment can not be explained by low levels of mobility of workers across regions, but rather by a mismatch between available workers and jobs. In a counterfactual exercise they show that removing the costs associated to workers' mobility would have reduced the 5%-point increase in unemployment in the Great Recession by only 0.1%-points. However, most of the evidence examines unconditional business cycle moments, and the literature is missing a conditional analysis that would provide information about the direction of labor mobility in response to specific shocks. Conditional moments are crucial in evaluating the role of labor mobility as an alternative adjustment mechanism to asymmetric shocks and in determining the shocks that explain the observed labor flows.

The contribution of this second Chapter to the literature is twofold: On one hand, we investigate the dynamic behavior of labor mobility conditional on state-specific labor productivity shocks. The empirical estimates of labor flows and employment, resulting from a structural vector autoregression (SVAR), exhibit important differences between conditional and unconditional moments, and furthermore indicate essential heterogeneity in conditional moments across US states. On the other hand, we build a two region dynamic stochastic general equilibrium (DSGE) model with endogenous labor mobility, accounting for this evidence. We calibrate the model economy consistently with the observed differences in the degree of nominal rigidities across states and show that we replicate the different patterns of the responses in employment and net labor flows across states following a technology shock. The focus on technology shocks comes as a natural choice, given the relative attention this particular shock has attracted in the literature. Internal mobility within the borders of the United States, as opposed to international labor movements, is very well documented, and the US is widely known for its mobile labor force. According to Census 2000, over 22 million people were internal migrants who changed their state of residence between 1995 and 2000 and over 40% of the US population lived in a state other than their state of birth.

For our SVAR specification we use available data on state-to-state migration in the US for the period 1976-2008 to identify a permanent shock to state-specific technology. We use long run restrictions, following Galí (1999), and assume technology shocks to be the only shocks having a permanent effect on the level of productivity in a given state. In particular, we estimate the dynamic behavior of labor flows between a given pair of US states in response to a shock to labor productivity in one of the two states. The SVAR includes four endogenous variables, namely labor productivity in both states of a given pair, labor input in the state hit by the shock and net labor flows, defined as the difference between inflows and outflows between a given pair of states. An appropriate ordering of the four endogenous variables allows the identification of a technology shock for a given state such that technology in the other state remains unaffected. The SVAR exercise provides two interesting results: First, labor mobility exhibits significant dynamics in response to technology shocks. Technology shocks thus induce people to reallocate geographically, in a way that is different from unconditional labor mobility. And second, the conditional dynamic behavior of net labor flows and employment differs across US states. We distinguish between three groups of state pairs: (a) Repelling states display a fall in both employment and net labor flows, (b) magnet states display the opposite (i.e. an increase in employment and labor flows), and (c) hybrid states exhibit an increase in net labor flows that go along with a decline in employment. We show that state pairs of a given group (repelling, magnet or hybrid states) do not display differences in business cycle moments; they do not belong to a specific region of the US, and they do not differ in terms of the distance between the states of a given pair. Rather the observed heterogeneity has to be seen in the context of state economies differing in their sectoral composition[1] and in the light of the ample empirical evidence for differences in the frequency of price adjustments

[1]See for example Bernard and Jones (1996), U.S. Department of Labor (2011)

across sectors in the US economy[2]. In a simple empirical exercise we show that the three groups of state pairs differ in their degree of nominal rigidities. In particular, we show that repelling (magnet) states display a high (low) average price duration, whereas hybrid state pairs are composed of states characterized by asymmetric degrees of price stickiness.

We develop a two region DSGE model, in the vein of Clarida, Galí and Gertler (2002), with endogenous labor mobility that replicates the observed heterogeneity in the dynamic behavior of labor flows and employment. We allow for labor mobility in the production sector assuming that firms hire both native and migrant workers, which are aggregated with a CES-function to total effective labor input for production. We assume that the representative household in each region consists of a continuum of family members, which can work in either one of the labor markets in the two regions. Households have a relative preference to work in the labor market of their region of nativity, such that working in the two regions entails different utility costs. Households in both regions take wages as given and optimally choose the composition of the aggregate labor supply, i.e. how many members to send to work in the domestic and the foreign labor market. The model predicts the dynamic behavior of labor mobility in response to region-specific technology shocks to depend crucially on the presence of nominal rigidities. This is essentially due to the respective differences in the adjustment of both the terms of trade and employment in the region hit by the productivity shock. When the shock occurs in a region where prices immediately adjust, the terms of trade depreciate such that demand for the region's products increases. This, in turn, induces firms to increase employment, triggering a net inflow of workers. On the contrary, in the case of a shock hitting a region characterized by sticky prices, the terms of trade and therefore the demand schedules adjust only slowly over time. Firms therefore fall back on the only alternative margin of adjustment and reduce employment. Conse-

[2]See for example Blinder, Canetti, Lebow and Rudd (1998), Bils and Klenow (2004), Nakamura and Steinsson (2008)

quentially, workers flow out of the region hit by the shock.

Our model illustrates several interesting implications of labor mobility: Compared to a standard setup, allowing for labor mobility makes the Phillips curve of a given region to depend not only on its output gap but also on gaps related to labor markets in both regions. Hence, relaxing the assumption of a fixed labor force breaks the isomorphism between a closed and an open economy, and gives rise to a direct link between the two economies through the mobile labor force. The spill-over effect of the region-specific productivity shock on the other region depends crucially on the direction of the resulting labor flows: When the productivity increase provokes an outflow of workers from the region where the shock occurs, employment in the other region increases such that we refer to a positive spill-over. A negative spill-over explains the opposite situation, i.e. labor flowing into the region hit by the shock and therefore inducing a reduction in the number of available workers in the other region. In conclusion, labor mobility is in an important phenomenon to be taken into account for questions related to stabilization policies.

The present Chapter relates to several contributions in the field: Franco and Philippon (2007) consider firm level data, assuming that firm dynamics are driven by permanent stochastic improvements in technology, permanent changes in the composition of aggregate output, and transitory shocks. They show that in response to a permanent technology shock at the firm level, identified using long run restrictions in a structural VAR, impact responses of employment are negative for 81% of firms and positive for the remaining 19% of firms[3]. Chang and Hong (2003) further investigate whether the finding of technology shocks reducing total hours worked in the short run is robust at a more disaggregate level, considering 458 four-digit US manufacturing industries for the time period 1958-1996. They find that in response to a favorable technology shock 13

[3]Marchetti and Nucci (2005), in a similar exercise using data of Italian manufacturing firms for the period 1984-1997 show that the contractionary effect of technology shocks is much stronger for firms with stickier prices.

industries exhibit a significant decrease in hours worked and 148 industries display a significant increase in employment. In a closed economy model Bentolila, Dolado and Jimeno (2008) study the implications of the presence of immigrants on the Phillips curve in Spain, assuming that native and migrant workers are assigned different labor market characteristics. They show that the presence of immigrants reduce labor costs which yields changes in both the slope and the intercept of the Phillips curve. In a more recent contribution Mandelman and Zlate (2012) examine the business cycle fluctuations of unskilled migration from Mexico to the US and the respective remittance flows, in a two-country DSGE model. Our work differs from those contributions in two respects: First, we explicitly study conditional business cycle moments. Second, a mobile labor force by nature has two ends such that a comprehensive understanding of labor mobility requires that in-depth attention be paid to both the origin and the destination locations in a general equilibrium approach. In our two-region model we therefore allow for labor flows in both directions. In line with the relevant migration literature differences in equilibrium wages are the key trigger for workers' mobility in our model: As it has been pointed out and empirically confirmed by many studies starting with Hicks (1932) and Greenwood (1975), respectively, differences in wages are key in explaining labor mobility.

The Chapter proceeds as follows: Section 2 presents the empirical evidence. In Section 3 we develop the theoretical model and we study its dynamics. We make concluding remarks in Section 4.

2.2 A structural VAR with labor mobility across US states

In this Section we provide empirical evidence on the dynamic effects of a labor productivity shock on labor mobility across states within the United States. We use available annual data on state-to-state migration in the US for the period 1976-2008 to identify a permanent shock to state-specific technology. Our long run identification scheme is based on Galí (1999). Specifically, we estimate the dynamic responses of net labor flows and employment for a given pair of US states after a shock to labor productivity in one of the two states.

2.2.1 Variable Definitions and Data

We specify the vector of observables for a given pair of states i and j as

$$Y_t = [\Delta x_{i,t}, \Delta x_{j,t}, \Delta n_{j,t}, \Delta net_{ji,t}]' \tag{2.1}$$

As will be discussed in further detail, we define all state-specific variables as logarithmic deviations from the respective aggregate US variable such that $\Delta x_{i,t}$ denotes the log-difference of labor productivity in state i at time t, $X_{i,t}$, relative to aggregate US labor productivity, $X_{US,t}$:

$$\Delta x_{i,t} = log\left(\frac{X_{i,t}}{X_{US,t}}\right) - log\left(\frac{X_{i,t-1}}{X_{US,t-1}}\right) = \Delta X_{i,t} - \Delta X_{US,t}$$

Equivalently, $\Delta x_{j,t}$ is the log-difference of labor productivity in state j relative to aggregate US labor productivity, $\Delta n_{j,t}$ stands for the log-difference of employment in state j relative to aggregate US employment and $\Delta net_{ji,t}$ is the log-difference of net labor flows from state i to state j. In particular, $\Delta net_{ji,t}$ is defined as follows[4]:

$$\Delta net_{ji,t} = \Delta log\left(\frac{Inflows_{ji,t}}{Outflows_{ji,t}}\right)$$

Our data[5] includes 48 states in the United States, excluding Alaska, the District of Columbia and Hawaii. The baseline series for labor productivity are constructed by subtracting the log of employment from the log of the gross state product for each

[4]Note, that aggregate inflows (over all states) are equal to aggregate outflows, such that there is no need to define net flows relative to US aggregate. The estimated dynamic responses are robust to an alternative definition of net flows defining them relative to the respective state population.

[5]See Appendix B.1 for a detailed discussion of data sources and definitions.

state. Data on gross state products and employment are taken from the Bureau of Economic Analysis (BEA). Data on net labor flows across US states are obtained from the Internal Revenue Service (IRS) and are based on year-to-year address changes reported on individual income tax returns filed with the IRS, available from 1976 onwards. Net flows for a given state are defined as the difference between inflows and outflows, where inflows measures the number of families (including the tax filer, its spouse and all dependants) who moved to a state and where they migrated from, and outflows the number of families leaving a state and where they went. Our data for migration flows provides information about net labor flows for all 1128 possible state pairs among the 48 states under consideration. We focus on 226 state pairs encompassing up to the 80th percentile of aggregate labor flows over all 48 states and for the entire period of interest, and show that our results are robust to accounting for all possible state pairs. For each of the 226 state pairs we identify a labor augmenting technology shock, separately in both states and study its effect on net labor flows, i.e. we consider 452 specifications.

The transformation of state-specific variables into logarithmic deviations from the aggregate value of the same variable relates to our identification strategy. In order to identify state-specific technology shocks we have to define state-specific variables in an appropriate way. As suggested in Blanchard, Katz, Hall and Eichengreen (1992) we assume state-specific variables to depend both on a common shock (related to the respective aggregate US variable) and on an idiosyncratic shock. Therefore, labor productivity in a given state i is defined as:

$$\Delta X_{i,t} = \alpha_i + \beta_i \Delta X_{US,t} + \upsilon_{i,t}$$

where $\Delta X_{i,t}$ is the log-difference of labor productivity in state i at time t (not the log-difference of relative labor productivity in state i, which we denoted $\Delta x_{i,t}$ earlier), $\Delta X_{US,t}$ is the log-difference of US labor productivity, and $\upsilon_{i,t}$ is an idiosyncratic disturbance term. This equation is estimated using annual data from 1976-2008, for each state under consideration in order to determine to what extent states differ in their elasticity to common shocks. The estimates for the coefficient β_i are significantly different from one for 10 out of 48 states, only[6]. Given that for most states we can not reject that $\beta_i = 1$ we use simple log-differences as a measure for state-specific variables.

2.2.2 Bilateral SVAR

Following Galí (1999) we identify labor productivity shocks assuming them to be the only shock having a permanent effect on the level of productivity in a given state. Consider the following structural VAR:

$$A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + \varepsilon_t \tag{2.2}$$

where Y_t is the vector of observables, as defined in (2.1), matrix A_0 captures contemporaneous relationships between the variables and ε_t is a vector of structural shocks which are uncorrelated across variables, such that the covariance matrix of ε_t is diagonal, i.e. $E_t(\varepsilon_t \varepsilon_t') = I$. We can rewrite the structural model, defined in (2.2), in a more general form:

$$A(L)Y_t = \varepsilon_t$$

where $A(L) = A_0 - A_1 L^1 - ... - A_p L^p$ is a polynomial in the lag-operator. Assuming that the vector of observables can be expressed as a (possibly infinite) distributed lag of all disturbances, the structural model can be written as an $MA(\infty)$

$$\begin{bmatrix} \Delta x_{i,t} \\ \Delta x_{j,t} \\ \Delta n_{j,t} \\ \Delta net_{ji,t} \end{bmatrix} = \begin{bmatrix} C^{11}(L) & C^{12}(L) & C^{13}(L) & C^{14}(L) \\ C^{21}(L) & C^{22}(L) & C^{23}(L) & C^{24}(L) \\ C^{31}(L) & C^{32}(L) & C^{33}(L) & C^{34}(L) \\ C^{41}(L) & C^{42}(L) & C^{43}(L) & C^{44}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_t^1 \\ \varepsilon_t^2 \\ \varepsilon_t^3 \\ \varepsilon_t^4 \end{bmatrix} = C(L)\varepsilon_t$$

[6] We consider the same regression for employment, $N_{i,t}$ and the gross state product, $Y_{i,t}$ and confirm the finding that the elasticity to common shocks in most of the states is not significantly different from one (at the 5% level). It is worth mentioning that even though we are considering a different time period, our results for employment are very similar to the ones reported in Blanchard et al. (1992)

where $\{\varepsilon_t^1\}$ and $\{\varepsilon_t^2\}$ denote, respectively, the sequence of technology shocks in the two states of a given pair. Our identification restriction is that the structural shocks ε_t^3 and ε_t^4 do not have permanent effects on labor productivity, employment and net flows which implies the matrix of long run multipliers, $C(1)$, to be lower triangular, i.e. $C^{12}(1) = C^{13}(1) = C^{14}(1) = C^{23}(1) = C^{24}(1) = C^{34}(1) = 0$[7]. Note, that given the ordering of the variables the technology shock in state i, ε_t^1, affects both labor productivity in state i, $\Delta x_{j,t}$, and in state j, $\Delta x_{j,t}$[8]. By contrast, ε_t^2 only affects labor productivity in state j and leaves labor productivity in state i unaffected in the long run. We therefore use the long run restrictions to identify a technology shock in state j, ε_t^2, for each state pair. Note that our previously discussed definition of state-specific variables, as log-differences from the respective aggregate variable, excludes the possibility that the structural shock is driven by movements related to the aggregate US economy.

We impose the long run identification restrictions in a standard way: First we define the reduced form model corresponding to our structural VAR. Assuming the matrix of contemporaneous relationships, A_0, to be invertible allows to pre-multiply both sides of the structural VAR model defined by (2.2) with A_0^{-1}:

$$Y_t = A_0^{-1}A_1Y_{t-1} + A_0^{-1}A_2Y_{t-2} + ... + A_0^{-1}A_pY_{t-p} + A_0^{-1}\varepsilon_t$$

[7]The specification of our structural VAR is based on the assumption that labor productivity is integrated of order one, so that first-differencing is necessary to achieve stationarity. That assumption is motivated by the outcome of standard augmented Dickey Fuller tests which do not reject the null of a unit root in the levels, but do reject the same null when applied to the first-differences (at the 5-percent significance level).

[8]We test for cointegration of labor productivity in state i and j for each state pair under consideration. We use both the Johansen Test and the Engle-Granger test. 3 out of 226 state pairs are tested positively for cointegration of $x_{i,t}$ and $x_{j,t}$ using Johansens' Test; 1 out of 225 state pair is tested positively for cointegration of $x_{i,t}$ and $x_{j,t}$ using the Engler-Granger test. Only one state pair displays cointegration of labor productivities for both tests. We thus conclude that generally cointegration between $x_{i,t}$ and $x_{j,t}$ is not an issue.

Defining $\phi_i = A_0^{-1} A_i$ for all $i \in [1, p]$ and establishing the relationship between structural and reduced form shocks, $A_0^{-1}\varepsilon_t = u_t$, we define our reduced form model:

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + ... + \phi_p Y_{t-p} + u_t$$

Second, we orthogonalize the reduced form shocks by Cholesky decomposition, i.e. $\left(A_0^{-1}\right)\left(A_0^{-1}\right)' = E_t(u_t u_t')$. According to the standard information criterion[9] the optimal number of lags is equal to one, such that we set $p = 1$. We estimate the reduced form model by ordinary least squares (OLS) in order to get consistent estimates for the coefficient ϕ_1 and the variance-covariance matrix of the reduced form error terms. The long run effect of a given reduced form shock u_t is defined by

$$\begin{aligned} E\left[\sum_{s=0}^{\infty} Y_t \mid u_t\right] &= \left[1 + \phi_1 + \phi_1^2 + ... + \phi_1^{\infty}\right] u_t \\ &= (I - \phi_1)^{-1} u_t \end{aligned}$$

Using the relation between structural and reduced form shocks we recover the matrix of long run multipliers corresponding to the vector of structural shocks on which we impose our identifying assumptions:

$$C(1) = (I - \phi_1)^{-1} A_0^{-1}$$

Our results are robust to changing the order of employment and net labor flows. Furthermore, we consider an alternative vector of observables including employment of the other state of a given pair. We therefore augment the four variable structural VAR with an additional variable measuring employment in state i for each state pair under consideration. This alternative specification allows the study of the effects on a labor productivity shocks of a given state j on employment in state i. More details about the augmented SVAR can be found in Appendix B.2.

[9]We test the appropriate lag length using the Akaike information criterion, the Schwarz/Bayesian criterion and the Hannan-Quinn information criterion. All three criteria suggest $p = 1$ to be the optimal number of lags.

2.2.3 Results

Table 2.1 reports estimates of aggregate unconditional correlations between employment, the gross state product (GSP), labor productivity and net labor flows. We compute aggregate unconditional correlations as simple average over correlations for all 48 states. All correlations are significant at the 5% level for all states under consideration. The signs of the estimated correlations are consistent with the relevant empirical literature, as for instance Molloy and Wozniak (2011). In particular we confirm the finding of internal migration being procyclical, i.e. net labor flows tend to be lower during downturns in a given state's economy.

Table 2.2 reports correlations between employment, the gross state product (GSP), labor productivity and net labor flows conditional on labor productivity shocks. Conditional correlations are computed as weighted average over all 452 specifications, where the weight is given by the respective share in aggregate labor flows of a given state pair (but using the simple average gives almost identical results). For 418 out of 452 specifications under consideration we have all conditional correlations to be significant at the 5% level. Aggregate conditional moments of employment and labor productivity are consistent with the findings in Galí (1999), i.e. the conditional correlation between labor productivity and employment are large and negative[10]. Interestingly, when considering conditional moments we have net labor flows across US states to be negatively correlated with both GSP and labor productivity. This implies that after a technology shock net labor flows tend to be lower, such that we observe relatively more outflows and relatively less inflows compared to normal times. Hence, comparing conditional with unconditional moments yields the exact opposite picture of labor flows.

Even though Table 2.2 apparently provides a uniform picture for the aggregate conditional moments across US states we observe important heterogeneity in the estimated

[10]Note, that our state level data is consistent with the findings in Galí (1999). In particular, aggregating our state level data and running the same bivariate SVAR as in Galí (1999) yields almost identical results, even though the time period considered in this Chapter is different.

impulse response functions at the state pair level. In particular, we distinguish three patterns for the estimated impact behavior of both net flows and employment to a positive technology shock: First, 133 state pairs representing 34%[11] of aggregate labor flows across all 48 states between 1976 and 2008 display a negative impact reaction of both net flows and employment. The second pattern we identify is an estimated positive impact reaction of both net flows and employment, which we observe in 155 state pairs capturing 15% of aggregate labor flows. The third pattern in the estimated dynamic behavior consists in a positive impact reaction of net flows and a negative impact reaction of employment. 123 state pairs encompassing 26% of aggregate labor flows across all 48 states between 1976 and 2008 display these dynamics[12].

As we have mentioned before the focus on all state pairs within the 80th percentile of aggregate state-to-state labor flows is not affecting the results. In particular, the relative size of the groups, measured either in terms of the number of state pairs or in terms of aggregate labor flows, remains unaffected when enlarging the analysis to all possible state pairs. The 226 state pairs under consideration are therefore to be considered a good representation of the state-to-state labor flows in the United States between 1976 and 2008.

The insights we gain from the structural VAR exercise lead to two conclusions: First, labor mobility exhibits significant dynamics in response to technology shocks. Technology shocks thus induce people to reallocate geographically, in a way that is

[11]For each state pair we have data on the total number of net moves, such that we can compute the share of labor flows of a given state pair to the total number of moves. For example, the state pair Florida - New York captures 1.73% of total aggregate labor flows for the period 1976-2008. Summing up the shares of all state pairs displaying the same pattern yields the total share of aggregate labor flows for the period 1976-2008.

[12]For the remaining 41 state pairs capturing less than 5% of aggregate labor flows in the period of interest, the estimated impact responses to a technology shock are positive for employment and negative for net flows. Along with the small number of state pairs belonging to this group we have none out of the 41 state pairs displaying significant impact reactions of both employment and net flows. This fourth group can therefore be considered negligible both quantitatively and qualitatively, such that we abstract from it for the rest of this second Chapter.

different from unconditional labor mobility. And second, the conditional dynamic behavior of net labor flows and employment differs across US states. In what follows we analyze in further detail the impact response of employment and net flows for each of the three identified patterns, exemplified through the respective state pair with the biggest fraction in aggregate labor flows.

Repelling States

For 133 state pairs we estimate a fall in both employment and net labor flows in the state hit by the productivity shock. The productivity shock repels workers form the labor market in the state where the shock is observed such that inflows decrease and/or outflows increase. The impulse responses to the identified labor productivity shock for the state pair Florida - New York are illustrated in Figure 2.1. We show the impact of one standard error increase in labor productivity in New York relative to aggregate US labor productivity along with 68% bootstrapped confidence intervals for a horizon of 10 years. Migration between Florida and New York consists in the largest state-to-state migration flow between 1976 and 2008, amounting to 1.73% of aggregate labor flows for the same period. In response to a positive technology shock in New York labor productivity increases by 1.2 percent[13], eventually stabilizing at a level somewhat higher than before the shock. Output also experiences a permanent increase, with the initial increase of 1.1 percent to be more gradual than that of productivity. The gap between the initial increase in labor productivity and the smaller increase in output is reflected in a significant fall in employment (-0.1 on impact). The fall in employment in New York goes along with a significant fall in net flows between Florida and New York of 4.36 percent on impact. The technology shock in New York thus implies a fall

[13]Note, that given our specification of state-level variables relative to the US aggregate, impulse response functions have to be interpreted as the reaction of the state-specific variable relative to the US aggregate. In the present example, labor productivity in New York relative to aggregate US labor productivity increases by 1.2 percent in response to a one standard deviation shock to relative labor productivity in New York.

of 4.36 percent in the ratio of inflows to outflows from New York to Florida, which can be interpreted as a fall in inflows and/or an increase in outflows.

Considering the estimated dynamics of the augmented SVAR discussed in Appendix B.2 allows to draw conclusions about the spill-over effect of the technology shock identified in a given state j on employment in state i. Figure 2.2 shows the estimated impulse response functions of the augmented SVAR for the state pair New York - Florida. The spill-over effect of the technology shock in New York on employment in Florida is significantly positive. Over all state pairs classified as repelling states 71% display a positive spill-over effect to state j's employment.

The group of repelling states consists in the most important group in terms of total significant impact responses of net flows and employment (73 out of 133), as shown in Table 2.4. Furthermore, with 34% in aggregate labor flows repelling states represent an important part of state-to-state migration in our sample period.

Magnet States

Opposite to repelling states where we observe a fall in both labor input and net flows, for 155 state pairs we estimate an increase in both employment and net labor flows in the state for which we identify the shock. The productivity shock attracts workers to the labor market of the state hit by the technology shock such that inflows increase and/or outflows decline. Figure 2.3 displays the estimated impulse responses for the state pair Texas - Ohio, which constitutes the 14th largest state-to-state migration flow between 1976 and 2008, accounting for 0.72% of aggregate labor flows. In response to a positive technology shock labor productivity in Ohio increases by 1.65 percent on impact. Output also increases, with the impact response of 1.84 percent to be slightly more persistent than the one of labor productivity. The difference between the two impact responses is due to an increase in employment of 0.19 percent on impact. Alongside the persistent increase in employment in Ohio net flows with Texas increase by 3.24 percent on impact. After a positive technology shock in Ohio we thus observe an increase in the ratio between inflows and outflows with Texas of 3.24 percent, which can be interpreted as an increase in inflows and/or a fall in outflows.

According to the augmented SVAR the spill-over of the technology shock in a given state j on employment in the other state (i) of a given pair is negative for 72% of all state pairs classified as magnet states. Figure 2.4 shows a significantly negative spill-over effect of a positive productivity shock in Ohio on employment in Texas.

Even though the number of state pairs included in the group of magnet states is higher than the one of repelling states, magnet states account for a lower but still important share of aggregate state-to-state flows between 1976 and 2008 (15%). As indicated in Table 2.5 out of 155 state pairs 63 display a significant impact response of both employment and labor flows, versus only 9 state pairs for which we estimate non-significant increases in both variables.

Hybrid States

Additionally to the previously discussed patterns where the impact response for employment and labor flows display the same sign we identify a third pattern where the dynamic reaction of employment and labor flows go in opposite directions. For 123 state pairs we estimate an increase in net labor flows and a fall in employment in the state experiencing a productivity shock. The significance of the impact responses of net flows and employment for all hybrid state pairs are summarized in Table 2.6. Despite a fall in employment the productivity shock attracts more workers, such that inflows rise and/or outflows decrease. Hence, states displaying these dynamics become relatively more attractive after the technology shock, even though employment is reduced. Figure 2.5 displays the estimated impulse responses for the state pair Texas - California, which with 1.70% of aggregate labor flows captures the second largest state-to-state migration flow between 1976 and 2008. After a positive technology shock in California labor productivity increases by 0.68 percent on impact. Output increases by slightly less, 0.51 percent on impact. The difference between the two impact responses is due to a fall in employment by -0.17 percent on impact. The ratio of inflows to outflows between California and Texas increases by 7.82 percent on impact.

In 85% of the cases of state pairs classified as hybrid the spill-over effect of a technology shock in state j on state i's employment is negative, according to the augmented SVAR. Figure 2.6 documents the significantly negative spill-over of a technology shock in California on employment in Texas.

2.2.4 Regional and Structural Differences as possible explanation for the observed heterogeneity

One possible explanation that naturally lends itself to account for the observed heterogeneity in labor flows are regional or structural differences causing economies of given states behaving differently across the business cycle and therefore also exhibiting different dynamics of labor flows. We therefore consider aggregate (unconditional) business cycle moments for each of the three groups of states (repelling, magnet and hybrid states) and show that they do not significantly differ in terms of business cycle moments: Table 2.3 shows that the three groups are not characterized by differences in volatilities. Table 2.7 summarizes unconditional business cycle moments for each of the groups. For all three groups we find a positive correlation between employment and net labor flows (ranging from 0.38 to 0.43), between employment and gross state product (ranging from 0.58 to 0.65) and between gross state product and net labor flows (ranging from 0.21 to 0.27). The correlation between productivity and GSP is positive and high for all three groups, whereas the correlation between productivity and net flows is positive but rather low. The only difference across groups lies in the correlation between productivity and employment, which is very small and slightly negative for repelling and hybrid states, respectively. For magnet states the unconditional correlation of labor input and productivity is small, but slightly positive. These values are in line with the near-zero correlation found in the literature. Overall we conclude that differences in business cycle moments do not explain the observed heterogeneity in the dynamics after a labor augmenting productivity shocks.

Figures 2.7, 2.8, and 2.9 provide a graphical summary of all state pairs belonging to the three groups defining the different dynamic reactions of a given state's economy after a labor augmenting productivity shock. This simple graphical exercise makes clear that states belonging to each of the three groups are spread over the entire United States, such that geographical differences can be ruled out as explanation for the observed heterogeneity in the dynamics after a technology shock. Moreover, we consider the proposed classification of states according to Blanchard et al. (1992) in order to further analyze the possibility of regional trends being the cause of the observed heterogeneity. In particular, we consider the following clusters of states[14]: New England, Middle Atlantic and coal countries, Rust Belt, Sun Belt, Farm States and Oil States. In addition, we consider states with a high level of defense dependency, according to Ellis, Barff and Markusen (1993). We find that all farm states are classified as magnet states. For all other state clusters under consideration we do not find any intersection with any of the three groups defining the differences in the dynamic behavior in response to a labor augmenting productivity shock.

Finally, distance plays an important role in migration decisions and is usually referred to as a serious deterrent to migration. In order to rule out different groups reflecting state pairs with larger or smaller distances between them we consider the share of state pairs within each group being neighbor states. We find that this share is remarkably similar across the three groups. Namely, 29% of the state pairs classified as repelling states are neighbor states. For magnet and hybrid states this share is found

[14]New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont. Middle Atlantic and coal countries: New Jersey, New York, Pennsylvania, West Virginia. Rust Belt: Illinois, Indiana, Michigan, Ohio. Sun Belt: Arizona, California, Florida, Nevada. Farm States: Idaho, Iowa, North Dakota, South Dakota. Oil States: Louisiana, Oklahoma, Texas, Wyoming.

to be 25% and 28% respectively.

2.2.5 Price Duration of States

As we have documented in Section 2.3 the three groups of state pairs differ in their dynamic responses of both net labor flows and employment to the state-specific productivity shock. From Galí (1999) we learn that nominal rigidities are crucial in explaining the responses of labor input after a positive technology shock. There is ample evidence that the frequency of price adjustments differs substantially across industries in the US economy[15]. Moreover, different states rely more or less on different industries[16]. As a consequence the aggregate degree of nominal rigidities possibly differs across US states. We empirically explore the two dimensions, the differences in average price duration per industry and the different sectoral composition across state economies, and show that state pairs being classified as repelling (magnet) are characterized by rather high (low) price duration in both states, and that hybrid state pairs contain states exhibiting asymmetric degrees of price stickiness, i.e. one state with high and one state with low price duration.

Ideally, we would use data on labor mobility across states at the industry level. Given the lack of such data we are missing information about the relative contribution of a given industry to total labor flows into and out of a given state. We therefore assume that labor flows across a given pair of states take place proportionally to the importance of a given industry in a given state, i.e. more important industries exhibit bigger labor flows. In order to define the relative importance of a given industry in a particular state we use four different measures, based on employment, wages, the number of establishments and the value added at the industry level, defined according to the American Industry Classification System (NAICS 2007). Table 2.8 provides a detailed description of all four measures. We use all industries included in the 75th

[15]See for example Blinder et al. (1998), Bils and Klenow (2004), Nakamura and Steinsson (2008)
[16]See for example Bernard and Jones (1996), U.S. Department of Labor (2011)

percentile[17] for each of the four measures as an approximation of the most important industries in a given state. For example, using observations for the number of employees per industry and state we define the industries lying in the 75th percentile of all industries in a given state, i.e. the most employee intensive industries in each state. Our assumption thus implies labor flows to take place predominantly across industries, which are relatively more employee intensive than others[18]. As a practical example, we look at the state pair capturing the biggest labor flows for our period of interest, namely Florida - New York. For all four measures under consideration the most important industries in Florida are *Real Estate and Rental Leasing*, *Arts, Entertainment, and Recreation*, and *Administrative-, Support-, Waste Management, Remediation Services.* For New York we identify *Educational Services*, *Information*, *Real Estate and Rental Leasing*, and *Finance and Insurance* as the most important industries across all four measures.

In order to compute the average price duration of a given industry we use data from Nakamura and Steinsson (2008), providing the median price duration for a wide range of product categories included in the CPI-basket over the time period 1998-2005. We match the roughly 270 product categories to one or several of total 19 industries, according to the North American Industry Classification System (NAICS 2007)[19]. We use the same weights per product category as the ones used in Nakamura and Steinsson (2008), i.e. the respective weight of a given category in the CPI basket, to compute the median price duration over a given industry, which ranges from 0.6 months for Mining up to 22.4 months for Retail Trade. Table 2.9 provides a summary for the computed

[17]Note, that our results are robust to considering the 50th percentile industries.

[18]One possible alternative way of defining the most important industries is considering volatilities rather than averages. For example, instead of using annual average employment per industry and state to total GDP in the same state (measure 1 in Table 2.8) we consider the standard deviation of the latter. Overall, the results are similar when using volatilites of our four measures for the most important industries.

[19]For example, according to the NAICS the product category "potatoes" appears in both industries *Agriculture, Forestry, Fishing, Hunting* and in *Manufacturing*, such that the median price duration of potatoes will be taken into account for both industries.

price durations over all industries[20].

For each state we match the most important industries, defined according to one out of the four available measures, with the respective price durations and then compute the aggregate price duration of a given state. We calculate the aggregate price duration as the weighted average of the price duration for the most important industries in each state, with the weight being defined according to one of the four measures. For Florida the average price duration of the above mentioned industries weighted by their relative importance ranges from 8.7 to 11.4 months. Equivalently, for New York we get weighted average price durations over the most important industries of 9.2 to 11.4 months.

Given the aggregate price duration in each state under consideration we define the average price duration of the most important industries over all states and use it as a threshold price duration in order to classify states as either sticky or flexible[21]. States for which the average price duration of the most important industries lies above (below) the threshold price duration are classified as sticky (flexible) states. Whenever the average price duration of a given state is more than one standard deviation above (below) the threshold level, we refer to the state as clearly sticky (flexible). For both Florida and New York, for all four measures we use to define the most important industries, the respective price duration is more than one standard deviation above the corresponding threshold values, such that both states are considered clearly sticky.

We distinguish between state pairs where both states are defined as (clearly) sticky, state pairs with both states being classified as (clearly) flexible, and between asym-

[20]Chang and Hong (2003) do a similar exercise with data for the manufacturing industry, only. They use data from Bils and Klenow (2004), whereas we base our calculations on data from Nakamura and Steinsson (2008). Nevertheless, Chang and Hong (2003) find an aggregate price duration for the aggregate manufacturing industry of 3.4 months, which is very close to the 3.57 months found in our computations.

[21]Note that results are robust to using alternative definitions of the threshold price duration. In particular, we consider median price duration or the weighted average price duration of the most important industries over all states, where the weight is defined by the GDP of a given state.

metric state pairs composed of one (clearly) flexible and one (clearly) sticky state. We identify a clear pattern across the three groups, as summarized in Table 2.10: For all four measures between 60-75% of repelling state pairs are classified as (clearly) sticky. The remaining 25-40% are either state pairs where both states are (clearly) flexible or state pairs with asymmetric price duration. For magnet states we find that, according to the measure used to define the most important industries, between 61-85% of state pairs are defined as (clearly) flexible. Hybrid states are composed of state pairs with asymmetric price durations, with the share varying between 69-83%.

The respective state pairs with the biggest fraction in aggregate labor flows, analyzed in Section 2.3, are classified accordingly, independently of the measure used to define the most important industries: The state pair Florida - New York is classified as clearly sticky, Ohio - Texas is a flexible state pair and our example state pair for hybrid states consists of California, which is classified as sticky and Texas, which is clearly flexible according to the data. Moreover, in Section 2.4 we have found that all farm states are classified as magnet states. This finding is consistent with our computations according to which the median price duration for the industry *Agriculture, Forestry, Fishing and Hunting* is 2.34 months, which lies at the lower bound of all 19 industries under consideration. We therefore conclude that the observed heterogeneity in the dynamics of employment and net labor flows after a technology shock go along with differences in the state level aggregate price duration.

2.2.6 Conclusions for the empirical exercise

The insights we gain from the empirical exercise lead to several conclusions: Technology shocks induce people to relocate geographically in a way that is different from unconditional moments of labor mobility. In particular, aggregate conditional moments induce that after a technology shock aggregate labor flows tend to be lower, whereas unconditionally labor flows are procyclical. Thus, comparing conditional and unconditional moments yields the exact opposite picture of labor flows, which provides an additional motive for studying unconditional moments. But even though aggregate conditional moments apparently provide a uniform picture, the results at the state pair level display essential heterogeneity in conditional moments across US states. The differences in the dynamic responses of employment and net labor flows in the state hit by the shock and the spill-over effect on employment in the other state of a given pair go along with differences in the degree of nominal price rigidities in the state pairs. In particular, the majority of repelling (magnet) state pairs for which we estimate a fall (rise) in both employment and net labor flows consist of states with high (low) price duration. Hybrid state pairs are mostly composed of two states with asymmetric state pairs. In the following Section we build a theoretical model consistent with the evidence presented in this Section.

2.3 A two country model with labor mobility

In this Section we build a theoretical model consistent with the empirical evidence provided in the previous Section. We consider a stochastic two region model with endogenous labor mobility. The model consists of two regions that belong to a monetary union. We refer to the regions as *Home* (i) and *Foreign* (j). The representative household in each of the two regions consists of a continuum $[0, 1]$ of family members. Each member can supply labor in either the domestic or the foreign labor market, with the respective fractions of family members to be decided at the household level. Working in the domestic and the foreign labor market are assumed to entail different utility costs, i.e households have a relative preference to work in the labor market of their region of nativity. Wages and returns from savings are pulled together and redistributed equally among members so that they all enjoy an identical level of consumption. Together with labor supply decisions, consumption and savings are defined at the household level[22], i.e. among family members of the same nativity but possibly active in different labor markets.

The economy features two production sectors producing intermediate and final goods respectively. Each of the two sectors is characterized by a continuum of firms selling a differentiated good under monopolistic competition. Firms are assumed to set prices in a staggered fashion, as in in Calvo (1983). We consider different scenarios of nominal price rigidities in the two production sectors. Final goods producers assemble domestically produced and imported intermediate goods into a non-traded final good. Intermediate goods producers employ native and migrant workers as sole production factor. Our general setup allows migrant and native born workers to be substitutable and possibly unequally productive in the production of intermediate goods. Given our focus on the US economy we calibrate the respective parameter values such that workers from different states are attached equal productivity and are considered perfect substitutes in production[23]. We consider two production sectors in order to be able to separate labor mobility and nominal rigidities. As we will show, our results do not rely on this separation and therefore also hold in a one sector setup.

2.3.1 Households' Problem

In each region there is a household consisting of a unit mass of infinitely lived family members, that obtain utility from consuming the final consumption good and disutility from supplying hours of labor in either of the two labor markets, i.e. some of the household's members are working in the domestic labor market as native workers and some are sent to work in the foreign labor market as migrant workers. Households

[22]See Andolfatto (1996) and Merz (1995) as general references, and Binyamini and Razin (2008) as an example for a an application of the big household assumption in a framework with labor mobility.

[23]This assumption implies that for production in a given state, say Texas, workers from Texas are equally productive as workers from New York or any other state. Moreover, workers from any other state are considered to be perfect substitutes for native workers from Texas.

choose aggregate consumption, savings and relative labor supply in both labor markets in order to maximize the expected lifetime utility:

$$U_o^i = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t^i)^{1-\sigma}}{1-\sigma} - \frac{(N_t^i)^{1+\varphi}}{1+\varphi} \right] \tag{2.3}$$

where C_t^i, N_t^i denote, respectively, consumption and hours worked, E_0 stands for the rational expectations operator using information up to time $t = 0$, $\beta \in [0, 1)$ is the discount factor, and $i \in [H, F]$ denotes the two regions, Home and Foreign, respectively. More precisely, C_t^i is an index of region i's final goods consumption, (i.e. goods supplied by final goods producers in region i itself), given by the CES function

$$C_t^i \equiv \left[\int_0^1 C_t^i(k)^{\frac{\varepsilon-1}{\varepsilon}} dk \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where $k \in [0, 1]$ denotes the type of good within the set produced in region i and $\varepsilon > 1$ defines the elasticity of substitution between varieties produced within any given region, independently of the producing region.

We allow for labor mobility in the following sense: Some household members offer their labor services to domestic firms while others are sent to work in the foreign labor market. Aggregate labor supply, as appearing in the household's utility function, is assumed to be a CES-aggregator of family members' labor supply in the domestic and in the foreign labor market, defined as N_t^{ii} and N_t^{ij} respectively:

$$N_t^i = \left[(1-\alpha_1)^{\frac{1}{\nu_1}} \left(N_t^{ii}\right)^{\frac{\nu_1-1}{\nu_1}} + (\alpha_1)^{\frac{1}{\nu_1}} \left(N_t^{ij}\right)^{\frac{\nu_1-1}{\nu_1}} \right]^{\frac{\nu_1}{\nu_1-1}} \tag{2.4}$$

where $\nu_1 < 0$ is a measure of the elasticity of substitution of working as a native in the domestic labor market and working as a migrant in the foreign labor market, and α_1 captures differences in the disutility attached to working in the home versus the foreign labor market.

Maximization of equation (2.3) is subject to a sequence of budget constraints:

$$\int_0^1 P_t^i(k) C_t^i(k) dk + E_t \left\{ Q_{t,t+1} D_{t+1}^i \right\} \leq D_t^i + W_t^{ii} N_t^{ii} + W_t^{ij} N_t^{ij} - T_t^i$$

for $t=0,1,2,...$, where $P_t^i(k)$ is the price of final good k produced in region i, expressed in units of the single currency. $W_t^{ii}N_t^{ii}$ is nominal labor income of family members working in the domestic labor market, $W_t^{ij}N_t^{ij}$ is nominal labor income of all members working in the foreign labor market and T_t^i contains profits.

We assume that households have access to a complete set of contingent claims, traded across the monetary union. $Q_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payoffs which is common across regions. $E_t\left\{Q_{t,t+1}\right\}R_t^{-1}=1$, where R_t is the gross nominal return on a riskless one-period bond paying off one unit of the common currency in $t+1$ or, for short, the gross nominal interest rate. Below, we assume that the union's central bank uses that interest rate as its main instrument for monetary policy.

We assume risk and consumption to be pooled among all members of a given household such that consumption is equal across all members of a given household[24]. The optimal allocation of any given expenditure on the final goods produced in a given region yields the demand function

$$C_t^i(k)=\left(\frac{P_t^i(k)}{P_t^i}\right)^{-\varepsilon}C_t^i$$

for $i\in[H,F]$ and $k\in[0,1]$. $P_t^i\equiv\left[\int_0^1 P_t^i(k)^{1-\varepsilon}dk\right]^{\frac{1}{1-\varepsilon}}$ represents region i's CPI-price index. Given the optimal allocation of expenditures the period budget constraint reads as

$$P_t^iC_t^i+E_t\left\{Q_{t,t+1}D_{t+1}^i\right\}\leq D_t^i+W_t^{ii}N_t^{ii}+W_t^{ij}N_t^{ij}-T_t^i$$

Households' optimality conditions are the domestic labor supply condition,

$$\frac{W_t^{ii}}{P_t^i}=\left(C_t^i\right)^{\sigma}\left(N_t^i\right)^{\varphi}\left(\frac{N_t^{ii}}{N_t^i}\right)^{-\frac{1}{\nu_1}}(1-\alpha_1)^{\frac{1}{\nu_1}} \tag{2.5}$$

[24]Note, that our setup implies native and migrant workers of the same household to consume the same bundle of goods. Assuming absence of home bias in the final goods sector implies consumption to be equal across households in both regions, and therefore also between native and migrant workers of a given region i

the condition for labor supply in the foreign labor market, which equivalently states

$$\frac{W_t^{ij}}{P_t^i} = \left(C_t^i\right)^{\sigma} \left(N_t^i\right)^{\varphi} \left(\frac{N_t^{ij}}{N_t^i}\right)^{-\frac{1}{\nu_1}} (\alpha_1)^{\frac{1}{\nu_1}} \tag{2.6}$$

Compared to a standard labor supply condition allowing for labor mobility implies that, for given aggregate labor supply, N_t^i, households optimally choose the composition of the latter, i.e. how many member to send to work in the domestic vs. the foreign labor market.

The remaining optimality condition for the household's problem is the standard intratemporal optimality condition, given by

$$\beta R_t E_t \left\{ \left(\frac{C_t^i}{C_{t+1}^i}\right)^{\sigma} \left(\frac{P_t^i}{P_{t+1}^i}\right) \right\} = 1 \tag{2.7}$$

It is useful to note that household's optimality conditions (2.5), (2.6) and (2.7) can be respectively written as log-linear deviations from the symmetric steady state:

$$w_t^{ii} - p_t^i = \sigma c_t^i + \varphi n_t^i - \frac{1}{\nu_1}\left(n_t^{ii} - n_t^i\right)$$

$$w_t^{ij} - p_t^i = \sigma c_t^i + \varphi n_t^i - \frac{1}{\nu_1}\left(n_t^{ij} - n_t^i\right)$$

$$c_t^i = E_t\{c_{t+1}^i\} - \frac{1}{\sigma}\left[r_t + E_t\{\pi_{t+1}^i\}\right]$$

where lower case letters denote log-deviations from the steady state value of the respective variable, i.e. $z_t = log(Z_t) - log(Z)$, and $\pi_t^i \equiv p_t^i - p_{t-1}^i$ is CPI inflation in region i. Note, that labor mobility in our setup will affect the intertemporal, but not the intratemporal choices of consumers. Labor supply in the domestic and in the foreign labor market crucially depend on the value of ν_1:

$$w_t^{ii} - w_t^{ij} = -\frac{1}{\nu_1}\left(n_t^{ii} - n_t^{ij}\right)$$

Higher values of the elasticity of substitution between working in the domestic vs. the foreign labor market, ν_1, imply labor supply for both types of workers to be more sensitive to changes in relative wages across the two regions.

2.3.2 International Risk Sharing

Under the assumption of complete markets for state-contingent assets across regions, the Euler condition holds in both regions, as stated in (2.7). Combining the two, together with the definition of the relative price of final goods in both regions, $Q_t^i \equiv \frac{P_t^j}{P_t^i}$, it follows (after iterating) that

$$C_t^i = \vartheta C_t^j \left(Q_t^i\right)^{\frac{1}{\sigma}}$$

for all t, where ϑ is a constant which will generally depend on initial conditions. Henceforth, and without loss of generality, we assume symmetric initial conditions (zero net foreign asset holdings, combined with an ex-ante identical environment) such that $\vartheta = 1$.

2.3.3 Intermediate goods producers

We assume that there is a continuum of monopolistically competitive firms producing each of them a different variety of the traded intermediate good, indexed by s on the unit interval $[0, 1]$. All firms have access to the same constant return to scale production technology linking aggregate labor input and the level of region-specific technology to output in the intermediate sector

$$X_t^i(s) = A_t^i L_t^i(s) \tag{2.8}$$

where region-specific productivity denoted by A_t^i is assumed to follow an AR(1) process

$$a_t^i = \rho_a a_{t-1}^i + \varepsilon_t^a$$

with $a_t^i = \log(A_t^i)$, $\rho_a \in [0, 1]$ and ε_t^a being white noise. Note that the production technology (2.8) by definition satisfies the identification restrictions used in the empirical part; only changes in A_t^i can have long run effects on labor productivity in region i[25].

[25]Note, that allowing for cross-state correlation of productivity shocks does not affect the results qualitatively.

We allow for labor mobility in the production sector as in Ottaviano and Peri (2012), i.e. we assume that firms hire both native and migrant workers for production, which are aggregated with a CES-function to total effective labor input for production of variety s

$$L_t^i(s) = \left[(1-\alpha_3)^{\frac{1}{\nu_3}} \left(N_t^{ii}(s)\right)^{\frac{\nu_3-1}{\nu_3}} + (\alpha_3)^{\frac{1}{\nu_3}} \left(N_t^{ji}(s)\right)^{\frac{\nu_3-1}{\nu_3}}\right]^{\frac{\nu_3}{\nu_3-1}} \tag{2.9}$$

where α_3 captures possible differences in the relative productivity of native and migrant workers and $\nu_3 > 0$ measures the aggregate elasticity of substitution between native and migrant workers in production[26].

The first order conditions for cost minimization determining intermediate firms' demand for both native and migrant workers are:

$$N_t^{ii}(s) = \frac{X_t^i(s)}{A_t^i} \left\{ (\alpha_3)^{\frac{1}{\nu_3}} \left(\frac{1-\alpha_3}{\alpha_3}\right)^{\frac{1-\nu_3}{\nu_3}} \left(\frac{W_t^{ji}}{W_t^{ii}}\right)^{1-\nu_3} + (1-\alpha_3)^{\frac{1}{\nu_3}} \right\}^{\frac{\nu_3}{1-\nu_3}} \tag{2.10}$$

$$N_t^{ji}(s) = \frac{X_t^i(s)}{A_t^i} \left\{ (1-\alpha_3)^{\frac{1}{\nu_3}} \left(\frac{\alpha_3}{1-\alpha_3}\right)^{\frac{1-\nu_3}{\nu_3}} \left(\frac{W_t^{ii}}{W^{ji}}\right)^{1-\nu_3} + (\alpha_3)^{\frac{1}{\nu_3}} \right\}^{\frac{\nu_3}{1-\nu_3}} \tag{2.11}$$

Combining the labor demand conditions defined as log-linear deviations from the symmetric steady state yields the following relationship between native and migrant workers:

$$w_t^{ii} - w_t^{ji} = -\frac{1}{\nu_3}\left[n_t^{ii}(s) - n_t^{ji}(s)\right]$$

Assuming the two types of workers to be perfectly substitutable implies labor demand for both types of workers to be rather sensitive to changes in relative wages.

[26]Assuming native and migrant workers to be perfect substitutes in production yields equality of their repective wages, i.e. $W_t^{ii} = W_t^{ji}$. But when assuming the two types of workers being perfectly substitutable ther are two corner solutions which need to be taken into account: $W_t^{ii} > W_t^{ji}$ with $N_t^{ii} = 0$ and $L_t^i = N_t^{ji}$, and $W_t^{ii} < W_t^{ji}$ with $N_t^{ji} = 0$ and $L_t^i = N_t^{ii}$, respectively. It is easy to show that when assuming imperfect substitutability of labor supply in the domestic vs. the foreign labor market in the Households' problem we can exlude these two corner solutions.

The real marginal cost of production expressed in terms of intermediate goods prices will be common across firms and is defined as

$$RMC_{x,t}^{i}(s) = (1-\tau_x^i)\left(\frac{P_t^i}{P_{x,t}^i(s)}\right)\left[\frac{W_t^{ii}}{P_t^i A_t^i}\left(\frac{N_t^{ii}(s)}{(1-\alpha_3)L_t^i(s)}\right)^{\frac{1}{\nu_3}} + \frac{W_t^{ji}}{P_t^i A_t^i}\left(\frac{N_t^{ji}(s)}{\alpha_3 L_t^i(s)}\right)^{\frac{1}{\nu_3}}\right] \tag{2.12}$$

where $\frac{P_{x,t}^i}{P_t^i}$ denotes the relative price of intermediate to final consumption goods in region i. Note, that intermediate firms can costlessly adjust either factor of production. Thus, the static first-order conditions for cost minimization imply that all firms have identical marginal cost per unit of output. Equation (2.12) can be rewritten in log-linear terms

$$\begin{aligned} rmc_{x,t}^{i}(s) =& \eta_1\left[w_t^{ii} - p_t^i - a_t^i + \frac{1}{\nu_3}\left(n_t^{ii}(s) - l_t^i(s)\right) - (p_{x,t}^i - p_t^i)\right] + \\ & \eta_2\left[w_t^{ji} - p_t^i - a_t^i + \frac{1}{\nu_3}\left(n_t^{ji}(s) - l_t^i(s)\right) - (p_{x,t}^i - p_t^i)\right] \end{aligned} \tag{2.13}$$

where η_1 and η_2 depend on steady state values and on τ_x^i, which is an employment subsidy neutralizing all distortions present in the intermediate sector, but the one related to nominal rigidities. In Appendix B.3 we compute the employment subsidy for the intermediate sector, τ_x^i, and show that it depends on the markup of intermediate goods producers, as in a standard setup without labor mobility.

When assuming nominal rigidities to be present in the intermediate production sector, we suppose that firms set prices in a staggered fashion, as in Calvo (1983). Hence, a measure $(1-\theta_x^i)$ of randomly selected firms in i sets new prices each period, with an individual firm's probability to re-optimize in any given period being independent of the time elapsed since it last reset its price. As in a standard model without labor mobility, inflation of intermediate goods prices can be expressed as a function of marginal costs:

$$\pi_{x,t}^i = \beta E_t\left\{\pi_{x,t+1}^i\right\} + \lambda_x^i rmc_{x,t}^i \tag{2.14}$$

where $\lambda_x^i \equiv \frac{(1-\beta\theta_x^i)(1-\theta_x^i)}{\theta_x^i}$ and $rmc_{x,t}^i$ is the log deviation of real marginal costs from its steady state value $mc_x = -\log\left(\frac{\varepsilon_x}{\varepsilon_x - 1}\right)$.

In presence of labor mobility the standard relation linking inflation to firms' real marginal cost of production still holds, with the latter to be defined differently. In particular, the real marginal cost of production depends on wages of both native and migrant workers in the labor market of region i, with each of them weighted by the relative share in overall labor input for production. The real marginal cost of production is therefore positively related to wages, negatively to productivity, and furthermore depends (inversely) on the relative price of intermediate to final goods. Hence, the channel through which labor mobility affects inflation of intermediate goods prices is by its effect on the marginal cost of production of intermediate goods producers.

Given that the fiscal authority in both regions fully neutralize the distortions associated with firms' market power by means of a constant employment subsidy, τ_x^i, we define the output gap in the intermediate sector $\tilde{x}_t^i$ as the deviation of (log) output x_t^i, from its natural level $\bar{x}_t^i$, where the latter is in turn defined as the equilibrium level of output in the absence of nominal rigidities. Combining (2.13) and (2.14) gives rise to the New Keynesian Phillips curve of the intermediate goods sector:

$$\begin{aligned}\pi_{x,t}^i = \beta E_t\left\{\pi_{x,t+1}^i\right\} + \lambda_x^i \Bigg\{ & \left(\frac{\nu_3 - 1}{\nu_3}\right)\tilde{x}_t^i + \\ & \eta\left[\left(\varphi + \frac{1}{\nu_1}\right)\left(\tilde{n}_t^i + \tilde{n}_t^j\right) + \gamma\left(\tilde{n}_t^{ii} + \tilde{n}_t^{ji}\right)\right]\Bigg\}\end{aligned} \tag{2.15}$$

where η depends on steady state values, $\gamma \equiv \left(\frac{\nu_3 - \nu_1}{\nu_1 \nu_3}\right)$, $\tilde{n}_t^i$ is the labor supply gap in region i and $\tilde{n}_t^{ii}$ the labor input gap of labor supplied by household members from region i employed in production in region i. The Phillips curve of intermediate goods producers in region i depends on gaps related to both labor inputs used in production of intermediate goods, i.e. on gaps linked to labor provided by both native and migrant workers ($\tilde{n}_t^{ii}$ and $\tilde{n}_t^{ji}$, respectively). Total labor used in production of the two types of workers, in turn, depends on the aggregate labor supply of households in both region

i and j ($\tilde{n}_t^i$ and $\tilde{n}_t^j$, respectively).

When comparing the Phillips curve of the intermediate sector in region i, (2.15), with the one corresponding to a setup without labor mobility

$$\pi_{x,t}^i = \beta E_t \left\{ \pi_{x,t+1}^i \right\} + \lambda_x^i (1+\varphi) \tilde{x}_t^i$$

it becomes evident that when allowing for labor mobility the isomorphism between a closed and an open economy is broken. In particular, the Phillips curve of a given region i does not only depend on its output gap but also on gaps related to both the domestic and the foreign labor inputs and thus (via the mobile labor force) to the foreign economy. The presence of labor mobility furthermore affects both the intercept and the slope: the slope will depend on the elasticity of substitution between the two types of workers, ν_3, but will always be strictly smaller than the slope of the Phillips curve corresponding to an intermediate goods sector with a fixed labor force. Allowing for labor mobility provides intermediate goods producers with an additional margin of adjustments, such that the effect of changes in the output gap on domestic inflation are reduced, i.e. the Phillips curve becomes flatter.

2.3.4 Final good producers

In each region there are infinitely many monopolistically competitive final goods producers that are indexed by k on the unit interval. All final goods producers have access to the same constant elasticity of substitution technology combining domestic and foreign intermediate goods to output in the final goods sector:

$$Y_t^i(k) = \left[(1-\alpha_2)^{\frac{1}{\nu_2}} \left(X_t^{ii}(k) \right)^{\frac{\nu_2 - 1}{\nu_2}} + (\alpha_2)^{\frac{1}{\nu_2}} \left(X_t^{ij}(k) \right)^{\frac{\nu_2 - 1}{\nu_2}} \right]^{\frac{\nu_2}{\nu_2 - 1}} \tag{2.16}$$

where $X_t^{ii}(k)$ stands for the demand of the final goods producer of variety k for the domestically produced intermediate good and $X_t^{ij}(k)$ with $j \in [H, F]$ and $j \neq i$, denotes the demand of the same producer for the imported intermediate good. $X_t^{ii}(k)$ is given by the constant elasticity of substitution function:

$$X_t^{ii}(k) = \left[\int_0^1 X_t^{ii}(k,s)^{\frac{\varepsilon_x - 1}{\varepsilon_x}} ds\right]^{\frac{\varepsilon_x}{\varepsilon_x - 1}}$$

where $s \in [0,1]$ denotes the variety of intermediate goods. Equivalently, $X_t^{ij}(k)$ is an index of imported intermediate goods:

$$X_t^{ij}(k) = \left[\int_0^1 X_t^{ij}(k,s)^{\frac{\varepsilon_x - 1}{\varepsilon_x}} ds\right]^{\frac{\varepsilon_x}{\varepsilon_x - 1}}$$

$\varepsilon_x > 1$ denotes the elasticity of substitution between varieties of intermediate goods produced within a given region, which is assumed to be equal for domestically produced and imported goods. The elasticity of substitution between domestically produced and imported intermediate goods is denoted by ν_2 and $(1 - \alpha_2)$ measures the home bias in absorption of intermediate goods such that $\alpha_2 \in [0,1]$ serves as a natural index of the degree of openness of a given region. Given our focus on different states or groups of states in the US we consider the particular case where $\alpha_2 = 0.5$, i.e. absence of home bias; that is, for any given relative price, final goods producers in both regions will demand the same quantities of the domestic good. But, as we will show below, our results do not rely on this particular case.

The optimal allocation of expenditure on each variety, k, yields final goods producers' demand function for a given variety s of domestically produced and imported intermediate goods, respectively

$$X_t^{ii}(k,s) = \left(\frac{P_{x,t}^i(s)}{P_{x,t}^i}\right)^{-\varepsilon_x} X_t^{ii}(k) \tag{2.17}$$

$$X_t^{ij}(k,s) = \left(\frac{P_{x,t}^j(s)}{P_{x,t}^j}\right)^{-\varepsilon_x} X_t^{ij}(k) \tag{2.18}$$

where $P_{x,t}^i \equiv \left[\int_0^1 P_{x,t}^i(s)^{1-\varepsilon_x} ds\right]^{\frac{1}{1-\varepsilon_x}}$ denotes the price index of domestically produced intermediate goods and $P_{x,t}^j \equiv \left[\int_0^1 P_{x,t}^j(s)^{1-\varepsilon_x} ds\right]^{\frac{1}{1-\varepsilon_x}}$ is a price index of imported intermediate goods.

Cost minimization yields the following demand functions for domestically produced and imported intermediate goods

$$X_t^{ii}(k) = (1-\alpha_2)\left(\frac{P_{x,t}^i}{P_t^i}\right)^{-\nu_2} Y_t^i(k) \tag{2.19}$$

$$X_t^{ij}(k) = \alpha_2\left(\frac{P_{x,t}^j}{P_t^i}\right)^{-\nu_2} Y_t^i(k) \tag{2.20}$$

where $P_t^i = \left[(1-\alpha_2)(P_{x,t}^i)^{1-\nu_2} + \alpha_2(P_{x,t}^j)^{1-\nu_2}\right]^{\frac{1}{1-\nu_2}}$ denotes the consumer price index, i.e. the aggregate price index of final, non-traded goods.

Real marginal costs of final goods producers in region i, expressed in terms of prices of the final consumption good, P_t^i, is defined as

$$RMC_t^i(k) = (1-\tau^i)\left[\frac{P_{x,t}^i}{P_t^i}\left(\frac{X_t^{ii}(k)}{(1-\alpha_2)Y_t^i(k)}\right)^{\frac{1}{\nu_2}} + \frac{P_{x,t}^j}{P_t^j}Q_t^i\left(\frac{X_t^{ij}(k)}{\alpha_2 Y_t^i(k)}\right)^{\frac{1}{\nu_2}}\right] \tag{2.21}$$

with τ^i being an employment subsidy exactly offsetting the effect of market power distortions in the final goods sector, and thus rendering the flexible price equilibrium allocation optimal. In appendix B.3 we compute the employment subsidy, τ^i, and show that it is not affected by labor mobility, i.e. simply depending on final goods producers' market power.

Equation (2.21) can be rewritten in log-linear terms

$$rmc_t^i = \eta_3\left[p_{x,t}^i - p_t^i + \frac{1}{\nu_2}(x_t^{ii} - y_t^i)\right] + \eta_4\left[p_{x,t}^j - p_t^j + q_t^i + \frac{1}{\nu_2}(x_t^{ij} - y_t^i)\right] \tag{2.22}$$

where η_3 and η_4 depend on steady state values. When assuming nominal rigidities to be present in the final goods sector, we suppose that firms set prices in a staggered fashion, as in Calvo (1983), with a measure of $(1-\theta^i)$ of randomly selected final goods producers setting new prices each period. Combining the optimal pricing condition with the aggregate price dynamics yields the standard relation between inflation and real marginal costs in the final goods sector of region i:

$$\pi_t^i = \beta E_t \left\{\pi_{t+1}^i\right\} + \lambda^i rmc_t^i \tag{2.23}$$

where $\lambda^i \equiv \frac{(1-\beta\theta^i)(1-\theta^i)}{\theta^i}$ and rmc_t^i is the log deviation of real marginal costs from its steady state value $mc = -\log\left(\frac{\varepsilon}{\varepsilon-1}\right)$.

The Phillips curve of the final goods sector can be derived combining real marginal costs, (2.22), with inflation dynamics, (2.23):

$$\begin{aligned}\pi_t^i = \beta E_t \left\{\pi_{t+1}^i\right\} + \lambda^i \Bigg\{ & \eta_3 \left[\tilde{p}_{x,t}^{ii} - \tilde{p}_t^i + \frac{1}{\nu_2}(\tilde{x}_t^{ii} - \tilde{y}_t^i)\right] \\ & + \eta_4 \left[\tilde{p}_{x,t}^{ij} - \tilde{p}_t^i + \frac{1}{\nu_2}(\tilde{x}_t^{ij} - \tilde{y}_t^i)\right]\Bigg\}\end{aligned}$$

Inflation of final goods in region i is linked to the foreign economy via trade in intermediate goods, and will thus not be affected directly by labor mobility.

2.3.5 Market clearing

The clearing of the market for variety s of intermediate goods produced in region i requires

$$X_t^i(s) = X_t^{ii}(s) + X_t^{ji}(s) \tag{2.24}$$

with $X_t^{ii}(s)$ denoting domestic absorption, i.e. the fraction of total intermediate production of region i which is consumed domestically, and $X_t^{ji}(s)$ determining exports from region i to region j. Combining (2.24) with the respective demand functions (2.17) - (2.20), together with the law of one price for traded intermediate goods yields total demand that a given intermediate producer s in region i faces:

$$X_t^i(s) = \left(\frac{P_{x,t}^i(s)}{P_{x,t}^i}\right)^{-\varepsilon_x} \left(\frac{P_{x,t}^i}{P_t^i}\right)^{-\nu_2} Y_t^i \left\{(1-\alpha_2) + \alpha_2 (Q_t^i)^{\nu_2 - 1}\right\}$$

for all $s \in [0,1]$ and all t. Using the previous condition in the definition of region i's aggregate output in the intermediate goods sector, $X_t^i \equiv \left[\int_0^1 X_t^i(s)^{\frac{\varepsilon_x - 1}{\varepsilon_x}} ds\right]^{\frac{\varepsilon_x}{\varepsilon_x - 1}}$, yields the aggregate intermediate goods market clearing condition for region i:

$$X_t^i = \left(\frac{P_{x,t}^i}{P_t^i}\right)^{-\nu_2} Y_t^i \left\{(1-\alpha_2) + \alpha_2 (Q_t^i)^{\nu_2 - 1}\right\} \tag{2.25}$$

The clearing of the market for variety k of final non-traded goods produced in region i requires

$$Y_t^i(k) = C_t^i(k)$$

which, given aggregate output in the final goods sector being defined as $Y_t^i \equiv \left[\int_0^1 Y_t^i(k)^{\frac{\varepsilon-1}{\varepsilon}} dk\right]^{\frac{\varepsilon}{\varepsilon-1}}$ states as

$$Y_t^i = C_t^i \tag{2.26}$$

Finally we can combine (2.26) with the household's log-linear Euler equation to derive the following relationship between output of final consumption goods and the real interest rate in region i:

$$y_t^i = E_t\{y_{t+1}^i\} - \left(r_t - E_t\{\pi_{t+1}^{ii}\}\right) \tag{2.27}$$

By solving (2.27) forward, it is easy to see that the level of output in region i is negatively related to current and anticipated domestic real interest rates, but independent of output in region j. Labor mobility in the given setup does therefore not affect the standard form of the IS-curve.

2.3.6 Monetary Policy

We consider the two regions i and j to form a monetary union. The central monetary authority sets the union-wide interest rate such as to stabilize a weighted average of domestic inflation in the two regions.

$$R_t = \beta^{-1}\left[\chi \pi_t^i + (1-\chi)\pi_t^j\right]^{\phi}$$

where $\chi \in [0,1]$ defines the weight the monetary authority of the union assigns to stabilization of domestic inflation in Home relative to Foreign, and ϕ measures the aggressiveness of the monetary authority in stabilizing the weighted average of inflation rates in both regions.

2.3.7 Dynamics after a region-specific labor productivity shock

In this Section we analyze the dynamics in the theoretical economies after a region-specific technology shock. We choose parameter values, as defined in Table 2.11, to mimic the structure of the economy of the United States. Some comments with respect to the calibration are in order: The utility cost of working in the foreign labor market, α_1, is chosen such as to match the average steady state share of state share of migrant workers to total labor input, $\frac{N^{ji}}{L^i}$, which according to our US state level data is 10.7 percent on average[27]. The value for the elasticity of substitution between domestic and foreign labor supply, ν_1, is chosen such as to match the average volatility of net flows over all states[28].

The value of the elasticity of substitution between domestically produced and imported intermediate goods in final goods production, ν_2, is worth some discussion. Elasticities of import- and export substitution have been extensively estimated for international trade, but limited information is available on elasticities of substitution for regional trade. A common assumption is that the elasticities for international trade are to be considered as lower bound for regional trade, mainly based on the argument of lower trade restrictions for regional- compared to international trade. Bilgic, King, Lusby and Schreiner (2002) provide an overview of the literature on regional trade elasticities and report values between 1.5 and 3.5 for the US. Morgan, Mutti and Partridge

[27]Over all 48 states under consideration we have this share to vary between 2-12%. As we will show our results are not sensitive to changes in α_1 within this range.

[28]The percentage standard deviation of net labor flows relative to GDP ranges from 1.62 to 7.70. On average over all 48 states under consideration it takes value 4.04.

(1989), using US data, estimate an inter-regional trade elasticity of 3. We set $\nu_2 = 3$ and provide extensive sensitivity analysis.

The degree of price stickiness in both the intermediate and the final goods sector is discussed in detail in what follows. All remaining parameter values are chosen consistently with the values used in the literature. We focus on a symmetric steady states where the share of native and migrant workers in total labor input is equal across regions. Considering an non-symmetric steady state does not alter the results[29].

High vs. Low degree of nominal rigidities in the intermediate goods sector

We first consider the case of nominal rigidities to be present only in the intermediate goods sector, i.e. $\theta^i = \theta^j = 0$[30]. Figure 2.10 describes the dynamics after a positive productivity shock in the intermediate goods sector in the Home economy, for a degree of price stickiness implying an average price duration of four quarters ($\theta_x^i = \theta_x^j = 0.75$). In the region hit by the shock production of intermediate goods increases as a direct consequence of the raise in productivity. The presence of nominal rigidities prevents intermediate producers to perfectly adjust prices such that they make use of the only alternative margin of adjustment, namely labor demand. Consequentially labor input in intermediate goods production in the region hit by the shock falls.

Given the common monetary policy union-wide interest rates are downward ad-

[29] In particular, we considerd differences in labor income taxes across the two regions, which gives rise to a non-symmetric steady state with different shares of native to migrant workers across regions. Assuming labor income taxes to be relatively higher in region i leads to a smaller amount of labor used in production of intermediate goods in region i, and thus a strictly smaller steady state output of final goods. Nevertheless, an asymmetric labor income tax does not have an important impact on the dynamics in response to a technology shock and does therefore not account for the observed heterogeneity in the dynamics docmented in Section 2.

[30] Assuming the presence of the employment subsidy eliminating distortions related to market power, τ^i, the final goods sector operates in a perfectly competitive environment, where final goods producer assemble domestically produced and imported goods to the final, non-traded consumption good. Alternatively, we can think of households' utility to depend on consumption of both imported and domestically produced goods, such that consumption of final goods in the utility function (2.3) is defined according to equation (2.16). In the latter case, we can think of the economy as being characterized by one production sector only

justed, in response to the productivity shock in region i. As it becomes evident from the IS-curve, (2.27), consumption and production of final goods increase in the economy of region j which has not been directly hit by the shock. Demand for intermediate goods produced in j thus increases, which translates directly into a raise in labor demand in the same region. Households in both economies, observing the fall in labor demand in region i and the increase in labor demand in j, thus optimally send more members to work in the labor market in region j. As a consequence net flows in region i fall in response to the productivity shock, i.e. workers flow out of the economy directly hit by the shock, given that the latter offers less employment.

The impact responses of employment and of net labor flows in region i crucially depend on two opposing effects: First, prices for intermediate goods produced in the region hit by the shock are relatively lower and thus induce a demand substitution of intermediate goods across the two regions, i.e. final goods producers in both regions demand relatively more of the relatively cheaper intermediate goods. This effect is referred to as *expenditure switching effect*. As a direct consequence of the increasing demand for intermediate goods produced in region i firms in this sector have an incentive to hire more workers. The expenditure switching effect therefore induces an upward pressure on employment in region i. The second effect is linked to the presence of *nominal rigidities*. As we have discussed above, the impossibility of adjusting prices immediately after the shock induces intermediate producers in region i to reduce employment. Consequentially, the presence of nominal rigidities acts as a downward pressure on employment in region i. For a moderate to high degree of nominal rigidities we have the downward pressure on employment resulting from price stickiness to be more pronounced than the upward pressure due to the expenditure switching effect. Labor input in region i thus falls in response to the productivity shock. Given the increase in intermediate goods production and labor input in region j we observe labor to flow from region i to region j, i.e. a decrease in net labor flows in the region hit by the shock. Figure 2.11 displays both the theoretical and empirical impulse response functions for the state pair New York - Florida. We calibrate the utility cost of working in the foreign labor market, the elasticity of substitution between working in the domestic labor market as native vs. working in the foreign labor market as migrant and the respective degree of price stickiness using data for the two states, only. In particular, the respective degree of price stickiness according to the computations in Section 2.4 are $\theta_x^{NY} = 0.67$ and $\theta_x^{FL} = 0.48$ for New York and Florida, respectively. The average share of migrants to total labor input across the two states defines $\alpha_1 = 0.04$, and the value for $\nu_1 = -2$ is chosen such as to match the average volatility of net flows between New York and Florida. Figure 2.11 shows that our mechanism is able to reproduce the conditional evidence on the response of both employment and net labor flows. The theoretical model correctly replicates the positive impact of the shock on production, that is however somewhat underestimated.

We then consider the case of a low degree of nominal rigidities in the intermediate goods sector in both regions. Figure 2.12 displays the dynamics in response to a positive productivity shock in region i for $\theta_x^i = \theta_x^j = 0.3$, corresponding to an average price duration of roughly four months. Clearly, in this case we have the expenditure switching effect to be stronger, i.e. employment in region i increases in response to the shock. The relative fall in prices for intermediate goods produced in i is more pronounced compared to the previous case such that the increase in demand for and production of intermediate goods is bigger. The subsequent increase in employment more than offsets the reduction of the work force due to an incomplete adjustment in prices. For region j the decrease in demand for its intermediate goods induces a fall in production and employment. Households in both economies will therefore observe an increase in labor demand in region i, a fall in labor demand in j and therefore send more household members to work in the labor market in i. Net labor flows in region i will therefore increase after the positive technology shock, i.e. workers flow into the economy directly hit by the shock, given that the latter offers relatively more employment after the productivity shock. Figure 2.13 displays theoretical and empirical impulse response functions for the state pair Ohio - Texas. According to our computations in Section 2.4 we set $\theta_x^{OH} = 0.18$ and $\theta_x^{TX} = 0.22$ for Ohio and Texas, respectively. The utility cost of working as a native in the foreign labor market is calibrated consistently with the average share of migrants to total labor input between Ohio and Texas, $\alpha_1 = 0.1$. The elasticity of substitution between working in the domestic vs. the foreign labor market, $\nu_1 = -11$, matches the average volatility of net flows between Ohio and Texas. As for the repelling state pair the theoretical model replicates the conditional dynamics of both employment and net labor flows, but somewhat underestimates the positive response of state-level production.

The dynamics in net labor flows and employment in the economy hit by the technology shock are very robust to the value of key parameters: Figures 2.16 and 2.18 display the impact impulse response functions for net labor flows and employment over a range of reasonable values of all three elasticities of substitution, ν_1, ν_2, and ν_3, for high and low degrees of nominal rigidities, respectively. Furthermore, as it becomes clear from Figures 2.17 and 2.19, the impact dynamics are robust to all three share-parameters, α_1, α_2, and α_3. Consequentially, some strong assumptions that we have made for our model economy can be relaxed without affecting the dynamics quantitatively: First of all, our assumption of the two types of workers being perfectly substitutable in production induces labor demand to adjust quickly in response to changes in relative wages. As it comes out in Figures 2.16 and 2.18 relaxing this assumption and allowing the two types of workers to be imperfect substitutes still generates a fall in both net flows and employment for high degrees of nominal rigidities, and an increase for low average price durations. The magnitude of the impact response is negatively related to the degree of substitutability of the two types of workers. Hence, other than on the degree of price rigidities, the qualitative impact response of net flows does not hinge on the assumption of perfect substitutability between the two types of workers.

Secondly, assuming native and migrant workers to be attached a different productivity, i.e. $\alpha_3 \neq 0.5$, does yield the same qualitative dynamics after a positive technology shock. Figures 2.17 and 2.19 illustrate this point in showing the impact response of net labor flows for different values of α_3[31].

Thirdly, both the value for the elasticity of substitution between domestic and imported intermediate goods, ν_2, and the degree of openness of the intermediate goods sector, α_2, clearly affect the size of the expenditure switching effect. The higher the value of ν_2 the bigger this effect, whereas the presence of some home bias will make the effect smaller. But as it becomes clear from Figures 2.16 to 2.19 the dynamics are robust to changes within the range of admissible values for both parameters.

Combining the empirical evidence with the theoretical predictions of the model presented in this Section thus suggests that the dynamic behavior of labor flows in response to a region-specific productivity shock depends primarily on the adjustment of employment in the two regions and thus on the degree of nominal rigidities in the sector where labor mobility is observed. In particular, according to our economic model labor flows for repelling state pairs are primarily between production sectors displaying high degrees of nominal rigidities, whereas labor flows between magnet states take place primarily between industries characterized by low price durations. Moreover, in our model economy the two groups differ in terms of their implied spill-over effect on the labor market of region j, which has not been directly hit by the productivity shock. Whenever prices adjust slowly the expenditure switching effect is rather small such that production of intermediate goods and so employment in region j will be increasing. The increase in employment in j after the region-specific productivity shock in i is referred to as a *positive spill-over*. On the contrary, when prices adjust rapidly the

[31]Note, that assuming both types of workers to be perfectly substitutable makes the impact response of labor input independent of α_3. Relaxing both of our working assumptions, i.e. the two types of workers being imperfectly substitutable and unequally productive does not alter our results qualitatively.

spill-over effect on region j's economy will be negative due to an important demand substitution of intermediate goods produced in j with goods produced in i. Both production of intermediate goods and employment in region j are therefore falling. These theoretical predictions are consistent with the empirical evidence presented in Section 2.

Asymmetric degrees of nominal rigidities in the intermediate goods sector

One of the underlying assumptions of the economy presented in the previous Section is that labor flows between production sectors characterized by symmetric degrees of nominal rigidities. There is ample evidence that the frequency of price adjustments differs substantially across sectors in the US economy[32]. Given that the economies of different US states are more or less dependent on particular sectors[33], labor flows affect sectors with different degrees of nominal rigidities. As we have shown in Section 2.4, differences in price adjustment across sectors in the US economy and differences in the sectoral composition across state economies map into differences in the aggregate price duration across states. In the previous Section we have taken one possible extreme view, namely that the degree of price rigidity is the same for both regions. In the alternative setup presented in this Section we analyze the implications of labor flowing between sectors with asymmetric price durations. Figure 2.14 describes the dynamic effects of a positive technology shock to the intermediate goods sector in region i, assuming $\theta_x^i = 0.6$ and $\theta_x^j = 0.3$. All remaining parameters are set as in Table 2.11. Intermediate goods produced in region i become relatively cheaper after the shock such that respective demand from final goods producers of both regions increases. Production of intermediate goods in region i thus raises. But given that intermediate producers in i can not immediately adjust prices they optimally reduce employment. The size of the expenditure switching effect affecting employment in i is

[32] See for example Blinder et al. (1998), Bils and Klenow (2004), Nakamura and Steinsson (2008)
[33] See for example Bernard and Jones (1996), U.S. Department of Labor (2011)

therefore smaller than the size of the effect linked to the presence of nominal rigidities. For the labor market in j the opposite is true: Given the relatively short average price duration of approximately 3 months the size of the negative effect on employment due to sticky prices is rather small. At the same time, intermediate goods producers increase their prices relatively quickly, such that the size of the expenditure switching effect is relatively big. Consequentially, employment in region j falls.

In general, when the two regions are characterized by different degrees of nominal rigidities, the inverse symmetry in the net effect on employment is broken. The net effect of both the expenditure switching effect and the effect linked to the presence of nominal rigidities is therefore of different size for both economies. As we have seen, for the case of nominal rigidities to be present in the region hit by the shock, this implies employment to be falling in both regions. Whenever the degree of price rigidity is higher in the economy hit by the shock, i.e. $\theta_x^i > \theta_x^j$, the fall in employment in j is strictly bigger than the reduction in employment in i. Observing the relative worsening of labor market conditions in region j induces households in both regions to reduce labor supply in j, such that net flows in region i increase in response to the shock. Figure 2.15 displays theoretical and empirical impulse response functions for the state pair California - Texas, where $\theta_x^{CA} = 0.48$, $\theta_x^{TX} = 0.22$, $\alpha_1 = 0.01$ and $\nu_1 = -12$. As for the previous cases, we conclude that the theoretical model replicates correctly the conditional dynamics in employment and net labor flows, while underestimating the increase in state-level production.

Figure 2.20 provides an overview of the impact responses of net labor flows and employment in both states, respectively, when varying the degree of price rigidity in the intermediate goods sector in both regions[34]. As we have concluded before, for high

[34]We group the observed patterns in the impact responses of both net labor flows and employment in the region hit by the shock accordingly to the classification used in the empirical Section: Repelling states represent negative impact responses in both employment and net labor flows, magnet states encompass positive impact responses in both variables, and hybrid states refer to a positive impact response in net labor flows and a negative impact response in employment

values of both θ_x^i and θ_x^j the expenditure switching effect is always stronger than the effect linked to price stickiness. Consequentially, employment falls in region i, increases in j such that labor flows out of i and into j. These dynamics correspond to what we have previously referred to as repelling states. On the contrary, for low values of both θ_x^i and θ_x^j the opposite is true: Employment increases in region i, falls in region j and labor flows into the region hit by the shock i (magnet states). In between these two clear cut cases we have an intermediate case, replicating the empirical evidence of state pairs we have previously classified as hybrid. For our calibration, when $\theta_x^i \in [0.55, 0.68]$ and $\theta_x^j < \theta_x^i$ the theoretical model generates a fall in employment in both region i and region j, with the latter being bigger than the former. Labor therefore flows out of region j into i. Note, that the range of values for θ_x^i reproducing the estimated dynamics of hybrid states depends on the calibration. In particular, lower values for ν_2 imply a slightly bigger and strictly lower range of values for θ_x^i, i.e. setting $\nu_2 = 1.5$ implies an admissible range of θ_x^i between $[0, 0.34]$. For given price duration, lower values of ν_2 imply a smaller expenditure switching effect. In region i this implies a more pronounced fall in employment, whereas in region j employment falls by less or even increases. In order for employment to fall by more in region j we need prices to adjust slightly faster in i such as to enlarge the impact of the expenditure switching effect on employment in j. In other words, we need the negative effect on employment in region i linked to nominal rigidities to be smaller.

Other than affecting the range of admissible values for the degree of price rigidities in region i, as for the setup with symmetric degrees of nominal rigidities, the qualitative dynamics of the model economy replicating the empirical evidence of hybrid states does not rely on our calibration.

To sum up, as in the setup with symmetric nominal rigidities in the intermediate goods sector we have labor to flow to the economy with relatively better labor market conditions after the shock. Combining the theoretical predictions of the model presented in this Section with the empirical evidence thus leads to the conclusion that labor flows between hybrid states primarily take place between states with moderate, but unequal degrees of price rigidities. The direction of the flows is determined by the relative price duration across the two states. These theoretical predictions are consistent with the empirical evidence presented in Section 2.

Nominal rigidities in the final goods sector

So far we have assumed perfectly flexible prices in the final goods sector. Relaxing this assumption does not affect the previously discussed results in any important way, given that the underlying mechanism of adjustment remains the same. The presence of price stickiness in the final goods sector most of all reduces the size of the expenditure switching effect: Given the presence of nominal rigidities final goods producers are no longer able to perfectly adjust their prices in response to a shock and therefore make adjustments in their demand for intermediate goods. Figure 2.21 represents impact responses of net labor flows and employment in both regions, respectively, when varying the degree of price rigidity in the intermediate goods sector, assuming the degree of price stickiness in the final sector to be relatively high, i.e. $\theta^i = \theta^j = 0.75$. For our given calibration, assuming prices in the final goods sector to be sticky does therefore still allow to replicate the respective dynamic behavior of repelling, magnet and hybrid states that we have observed in the data.

2.3.8 The Role of a mobile labor force on the spill-over of a region-specific shock

Previously we have concluded that allowing for labor mobility gives rise to an additional transmission channel between the two regions in our model economy. Specifically, we have seen that the Phillips curve depends on gaps related to labor market variables in the other region. Our theoretical model replicates the estimated spill-over effects in the data: After a positive productivity shock in state i employment in state j increases when both states' intermediate sector displays some degree of nominal rigidities (repelling states). For both magnet and hybrid states the data indicates a positive spill-over effect on the other state's employment. In our model economy employment in state j falls when both states display a low or asymmetric degree of nominal rigidities.

One important issue we have not addressed so far is the impact of a mobile labor force on the propagation of the region-specific shock. In order to isolate the effects of labor mobility on the transmission of a productivity shock in region i we consider the following counterfactual exercise: We shut down trade in intermediate goods between the two regions and compare the effects of the productivity shock in region i with and without labor mobility. Figure 2.22 displays the corresponding impulse response functions, for perfectly flexible prices in both sectors and regions. On the one hand, in a closed economy without migration the only effect the productivity shock in region i has on the economy in j is an increase in prices of both goods. The spill-over effect on the economy not directly hit by the shock therefore does not imply any real effects. In a closed economy with labor mobility, on the other hand, we observe a clear spill-over effect on both sectors of the economy in j, where the sign of the spill-over crucially depends on the degree of nominal rigidities in the intermediate goods sector. As we know from Backus, Kehoe and Kydland (1992) in a baseline two-country model with a fixed labor force technology spill-overs crucially depend on the correlation of the shocks across countries. Hence, in their model there is no endogenous channel inducing positive spill-over effects which allow to match the observed co-movement of output and consumption in the data. From this exercise we can thus conclude that labor mobility provides an endogenous transmission channel of productivity shocks in an otherwise standard two-country model.

2.4 Conclusions

The first part of the present Chapter provides empirical evidence on the dynamic behavior of labor flows across US states in response to state-specific labor productivity shocks. References to the cyclicality of internal migration have appeared before in the literature, but have not analyzed conditional moments of migration rates which are important for a thorough understanding of labor mobility as an alternative adjustment mechanism. We use data on state-to-state migration in the US for the period 1976 to 2008 to identify labor productivity shocks for 226 state pairs representing 80 percent of aggregate labor flows in the same period. We find no uniform pattern describing the dynamic behavior of economic variables in response to the technology shock. The crucial difference in the conditional behavior across state pairs lies in the dynamic responses of both employment and net labor flows. This Chapter therefore contributes to the literature investigating whether the finding of technology shocks reducing employment in the short run is robust at a more disaggregate level [35].

In the second part of this Chapter we provide a new open economy model with endogenous labor mobility consistent with the established empirical evidence. We use this model to show that an explanation consistent with the observed heterogeneity in the dynamic behavior of labor flows is a varying degree of nominal rigidities in the sector affected by labor mobility. We discuss the differences in the dynamics of the model economy with high (low) degrees of nominal rigidities, compared to a two-region economy with asymmetric price durations across regions. In particular, we show that whenever the degree of nominal rigidities is high (low) and firms adjust prices rather slowly (quickly), states experiencing a labor augmenting productivity shock become less (more) attractive to workers. Namely, labor market condition will be relatively worse (better) in the region hit by the shock, such that labor will flow out of (in to) the

[35] Franco and Philippon (2007), Marchetti and Nucci (2005), Chang and Hong (2003), Carlsson (2003) is a representative, though not exhaustive sample.

region hit by the shock. For states with clearly asymmetric degrees of nominal rigidities labor will be flowing into the state with relatively better labor market conditions.

Finally, we show with a simple empirical exercise that the provided theoretical explanation for the observed heterogeneity in the dynamics of labor flows across US states is confirmed in the data.

The present Chapter offers (at least) two interesting extensions: First of all, our theoretical model provides a starting point in order to analyze the optimal monetary policy in an environment with labor mobility. In particular, it would be interesting to study to what extent labor mobility affects the attractiveness of coordination of monetary policies across countries. Secondly, skills endowments have an important influence in the direction of internal migration flows, as it has been pointed out by Borjas, Bronars and Trejo (1992). One promising extension would thus be to analyze to what extend the differences in workers' skills account for the observed heterogeneity in labor flows across states.

Table 2.1: **Aggregate unconditional correlations**

	Employment	Productivity	Net Flows
GSP	0.6256	0.8100	0.2713
Employment		0.0821	0.4385
Productivity			0.0258

Table 2.2: **Aggregate correlations conditional on labor productivity shocks**

	Employment	Productivity	Net Flows
GSP	-0.8766	0.7330	-0.2345
Employment		-0.4132	0.3392
Productivity			-0.4115

Table 2.3: **Percentage Standard Deviations across groups**

	Repelling States	**Hybrid States**	**Magnet States**	**All States**
σ_Y	1.84	1.70	2.19	1.99
$\sigma_{\frac{N}{Y}}$	0.63	0.62	0.56	0.60
$\sigma_{\frac{A}{Y}}$	0.79	0.81	0.77	0.79
$\sigma_{\frac{NET}{Y}}$	4.57	4.31	3.92	4.04

Average standard deviations are computed as a simple average over standard deviations for all states within a given group.

Table 2.4: **Repelling States (133 state pairs, 34% of aggregate labor flows)**

Impact Response Net Flows	Impact Response Employment	State Pairs
- and significant	- and significant	73
- and significant	- but non significant	38
- but non significant	- and significant	17
- but non significant	- but non significant	5

Table 2.5: **Magnet States (155 state pairs, 15% of aggregate labor flows)**

Impact Response Net Flows	Impact Response Employment	State Pairs
+ and significant	+ and significant	63
+ and significant	+ but non significant	54
+ but non significant	+ and significant	29
+ but non significant	+ but non significant	9

Table 2.6: **Hybrid States (123 state pairs, 26% of aggregate labor flows)**

Impact Response Net Flows	Impact Response Employment	State Pairs
+ and significant	- and significant	48
+ and significant	- but non significant	41
+ but non significant	- and significant	25
+ but non significant	- but non significant	9

Table 2.7: **Unconditional correlations across groups**

Repelling States	Employment	Productivity	Net Flows
GSP	0.6126	0.7733	0.2119
Employment		0.0019	0.3885
Productivity			0.0422

Magnet States	Employment	Productivity	Net Flows
GSP	0.6497	0.8266	0.2737
Employment		0.1389	0.4297
Productivity			0.0483

Hybrid States	Employment	Productivity	Net Flows
GSP	0.5843	0.7817	0.2491
Employment		-0.0235	0.3761
Productivity			0.0230

Average correlations are computed as a simple average over correlations for all states belonging to a given group. All correlations are significant at the 5% level.

Table 2.8: **Four measures for the most important industries per state**

Measure	Definition
1	Annual average employment per industry and state to total GDP in the same state, relative to aggregate annual average employment per industry (over all states) to US GDP
2	Annual average number of establishments per industry and state to total GDP in the same state, relative to aggregate annual average number of establishments per industry (over all states) to US GDP
3	Gross Operating Surpluses per industry and state relative to aggregate US Gross Operating Surpluses in the same industry
4	Compensation of Employees per industry and state relative to aggregate US compensation of employees per industry

Table 2.9: **Median Price Duration (in months) per industry (according to 2007 NAICS classification)**

Industry (according to 2007 NAICS classification)	Median Price duration
Mining, Quarrying, Oil- and Gas Extraction	0.60
Utilities	1.83
Real Estate and Rental Leasing	1.97
Administrative-, Support-, Waste Management, Remediation Services	2.11
Management of Companies and Enterprises	2.01
Agriculture, Forestry, Fishing, Hunting	2.34
Wholesale Trade	2.68
Manufacturing	3.57
Information	4.06
Transportation and Warehousing	8.19
Other Services	12.31
Finance and Insurance	13.25
Health Care and Social Assistance	15.25
Accommodation and Food Services	15.48
Educational Services	16.15
Arts, Entertainment, and Recreation	16.20
Construction	16.43
Professional-, Scientific-, and Technical Services	20.49
Retail Trade	22.38

Table 2.10: **Price duration across state-pairs according to the four measures for the relative importance of a given industry in a given state**

	Repelling States		Magnet States		Hybrid States	
Measure	Both (clearly) sticky	Other	Both (clearly) flexible	Other	Asymmetric	Other
1	60.47	39.53	71.43	28.57	63.38	36.62
2	75.56	24.44	85.71	14.29	73.24	26.76
3	63.04	36.96	75.68	24.32	69.01	30.99
4	71.43	28.57	61.54	38.46	84.51	15.49

Table 2.11: **Parameter Values**

Parameter	**Mnemonic**	**Value**
Utility Cost of working abroad	α_1	0.107
Elasticity of Substitution Labor Supply (N_t^{ii} vs. N_t^{ij})	ν_1	-15
Home-Bias	α_2	0.5
Elasticity of Substitution Domestic vs. Foreign Goods	ν_2	3
Relative Productivity Native vs. Foreign Workers	α_3	0.5
Elasticity of Substitution Labor Demand (N_t^{ii} vs. N_t^{ji})	ν_3	10'000
Discount Factor	β	0.99
Labor Supply Elasticity	$\frac{1}{\varphi}$	$\frac{1}{3}$
Elasticity of Substitution among varieties	ε=ε_x	6
Relative weight Monetary Authority	χ	0.5
Inflation Reaction Coefficient	ϕ	1.5
Persistence Technology Shock	ρ_a	0.85
Degree of Nominal Rigidities (Final Goods Sector)	$\theta^H = \theta^F$	0 (0.75)

Figure 2.1: Estimated impulse response functions for labor productivity, employment, GSP and net labor flows, for the repelling state-pair New York - Florida

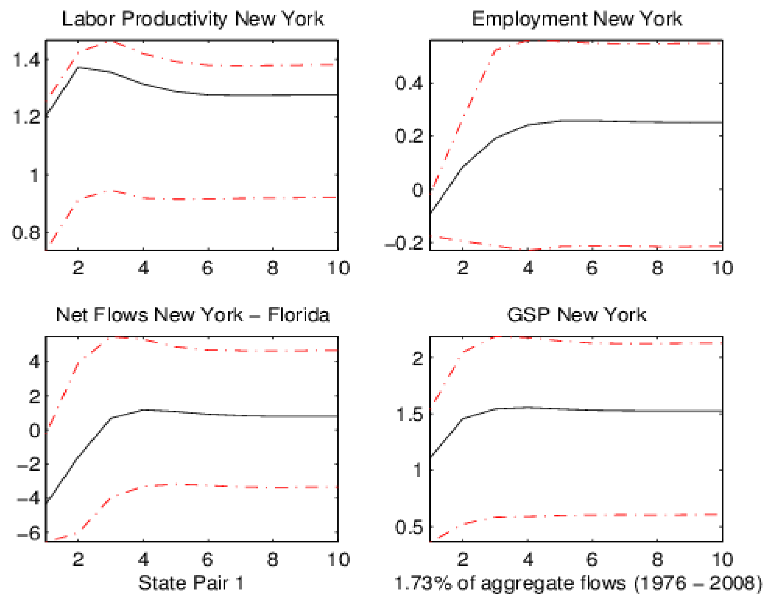


Figure 2.2: Estimated impulse response functions of the augmented SVAR for the repelling state-pair New York - Florida

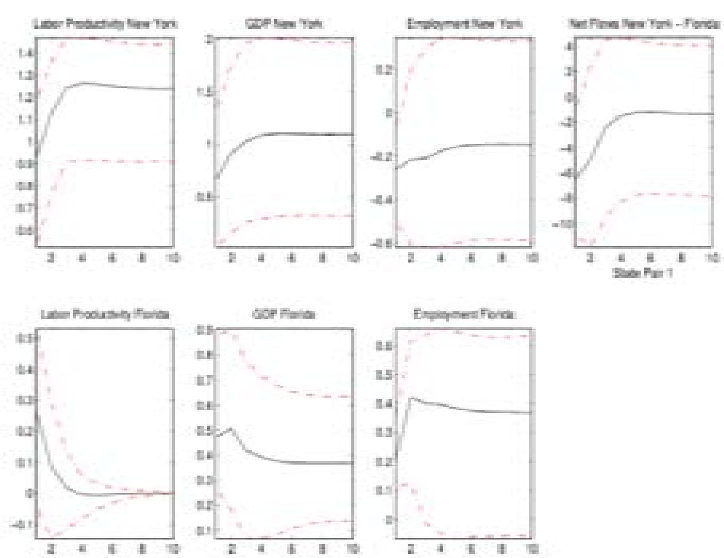


Figure 2.3: Estimated impulse response functions for labor productivity, employment, GSP and net labor flows, for the magnet state-pair Ohio - Texas

Figure 2.4: Estimated impulse response functions of the augmented SVAR for the magnet state-pair Ohio - Texas

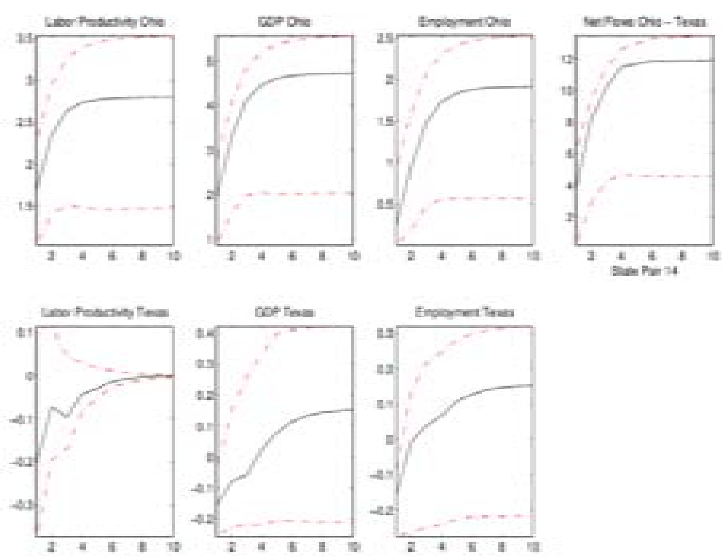


Figure 2.5: Estimated impulse response functions for labor productivity, employment, GSP and net labor flows, for the hybrid state-pair California - Texas

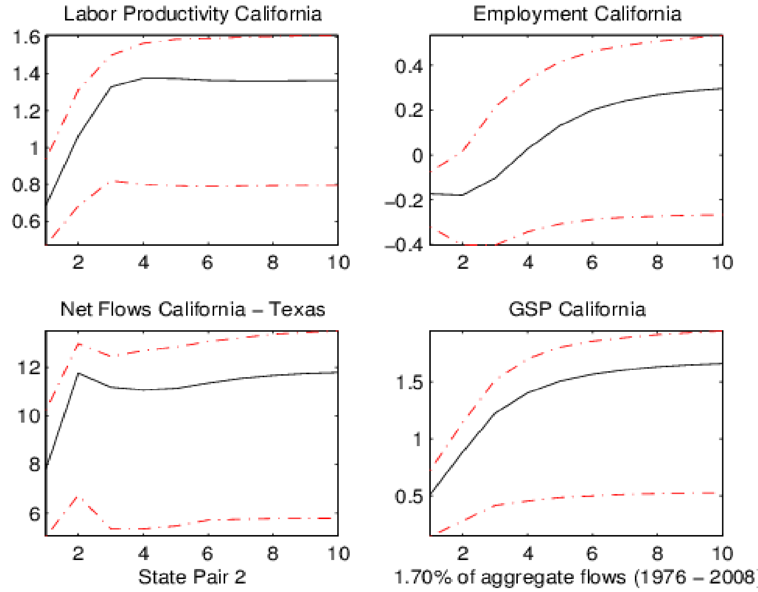


Figure 2.6: Estimated impulse response functions of the augmented SVAR for the hybrid state-pair California - Texas

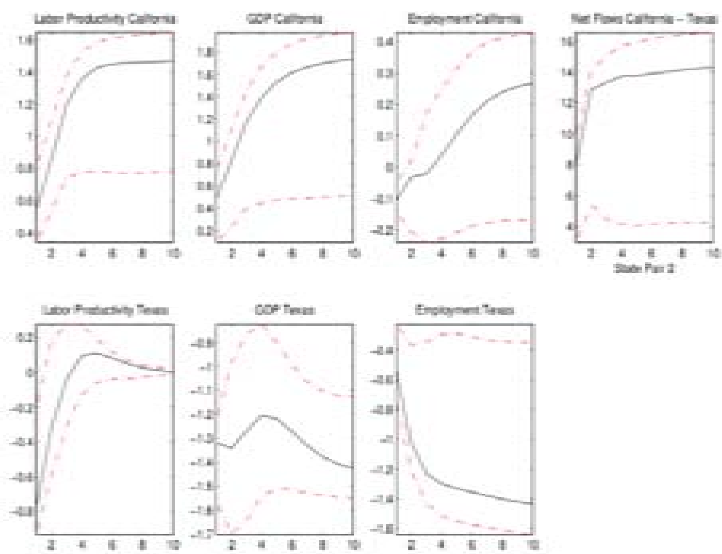
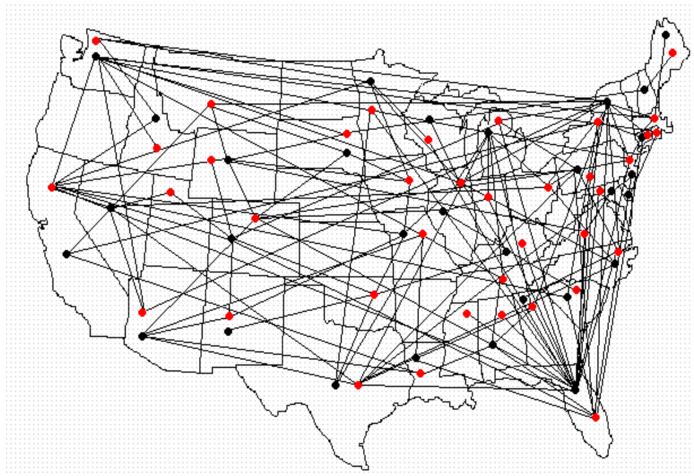
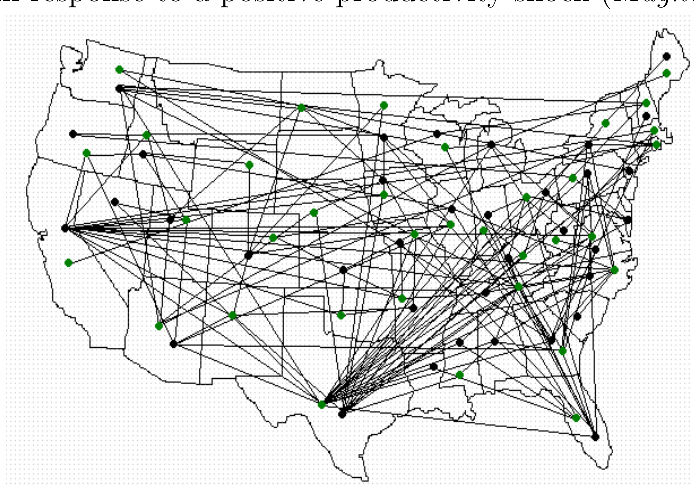


Figure 2.7: 133 state pairs displaying an estimated fall in employment and net labor flows in response to a positive productivity shock (*Repelling States*)



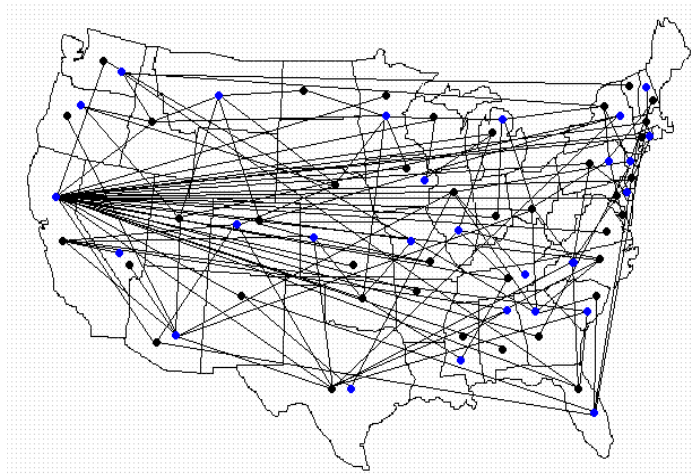
Red dots denote the state where the productivity shock is identified, and black dots denote the respective partner state for a given pair.

Figure 2.8: 155 state pairs displaying an estimated increase in both employment and net labor flows in response to a positive productivity shock (*Magnet States*)



Green dots denote the state where the productivity shock is identified, and black dots denote the respective partner state for a given pair.

Figure 2.9: 123 state pairs displaying an estimated fall in employment and an increase in net labor flows in response to a positive productivity shock (*Hybrid States*)



Blue dots denote the state where the productivity shock is identified, and black dots denote the respective partner state for a given pair.

Figure 2.10: Theoretical impulse response functions to a productivity shock in the intermediate goods sector in the Home economy, assuming high price duration in the intermediate goods sector ($\theta_x^i = \theta_x^j = 0.75$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)

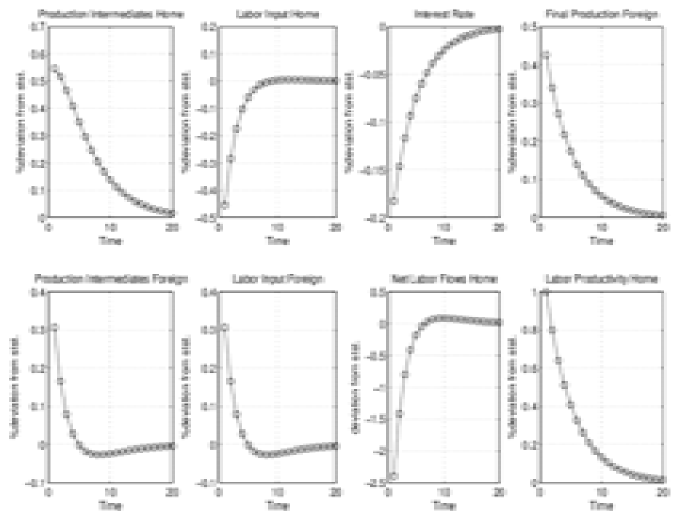


Figure 2.11: Theoretical impulse response functions to a productivity shock in New York, of size 1.2 standard error, with $\nu_1 = -2$, $\alpha_1 = 0.04$, $\theta_x^{NY} = 0.67$, $\theta_x^{FL} = 0.48$, ($\theta^{NY} = \theta^{FL} = 0$)

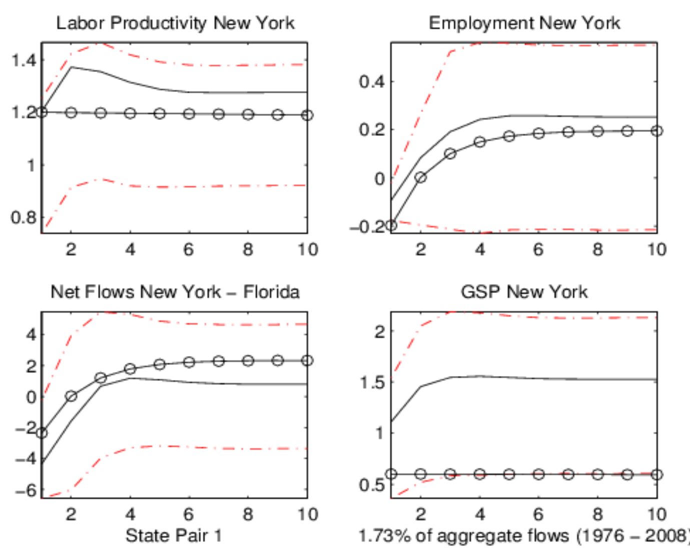


Figure 2.12: Theoretical impulse response functions to a productivity shock in the intermediate goods sector in the Home economy, assuming low price duration in the intermediate goods sector ($\theta_x^i = \theta_x^j = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)

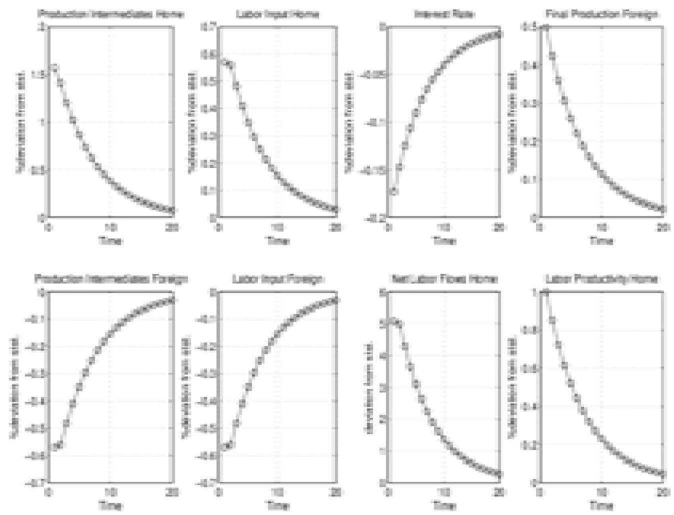


Figure 2.13: Theoretical impulse response functions to a productivity shock in Ohio, of size 1.85 standard error, with $\nu_1 = -11$, $\alpha_1 = 0.1$, $\theta_x^{OH} = 0.18$, $\theta_x^{TX} = 0.22$, ($\theta^{OH} = \theta^{TX} = 0$)

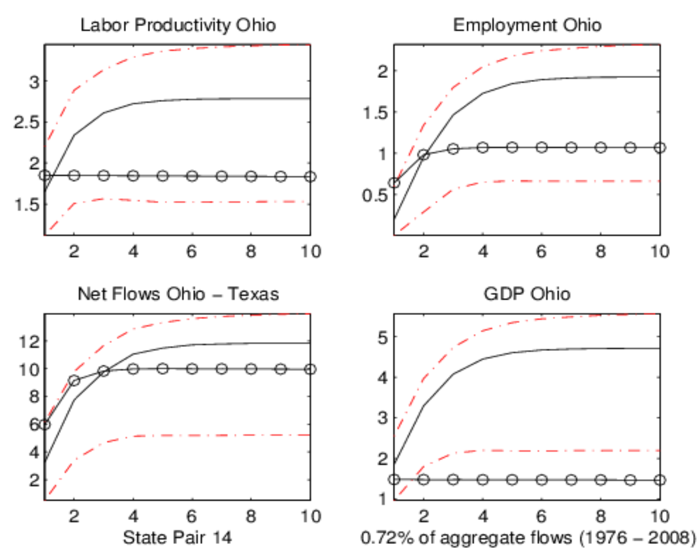


Figure 2.14: Theoretical impulse response functions to a productivity shock in the intermediate goods sector in the Home economy, assuming asymmetric price duration in the intermediate goods sector of the two regions ($\theta_x^i = 0.6$ and $\theta_x^j = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)

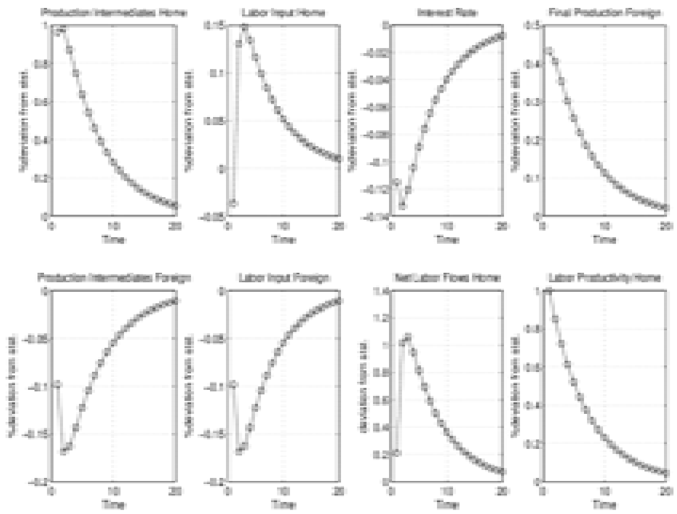


Figure 2.15: Theoretical impulse response functions to a productivity shock in California, of size 1.0 standard error, with $\nu_1 = -12$, $\alpha_1 = 0.01$, $\theta_x^{CA} = 0.48$, $\theta_x^{TX} = 0.22$, ($\theta^{CA} = \theta^{TX} = 0$)

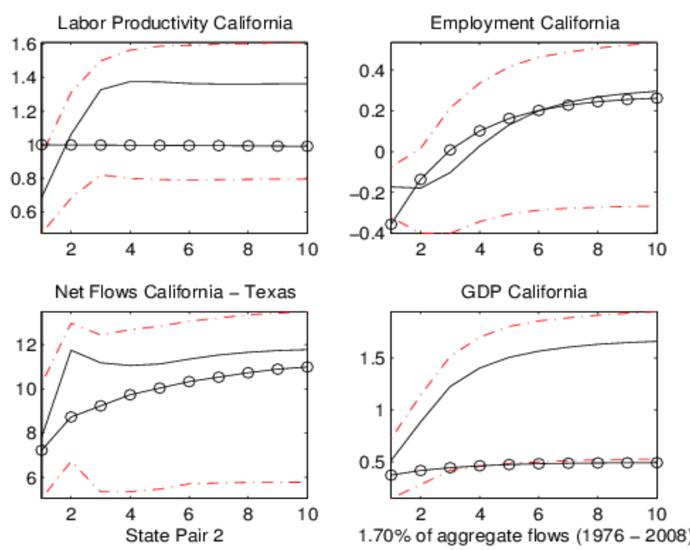


Figure 2.16: Sensitivity of the impact response of net labor flows and employment to the elasticity of substitution between domestic and foreign labor supply, ν_1, between domestic and foreign intermediate goods, ν_2, and between native and migrant workers in intermediate production, ν_3, assuming high price duration in the intermediate goods sector ($\theta_x^i = \theta_x^j = 0.75$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)

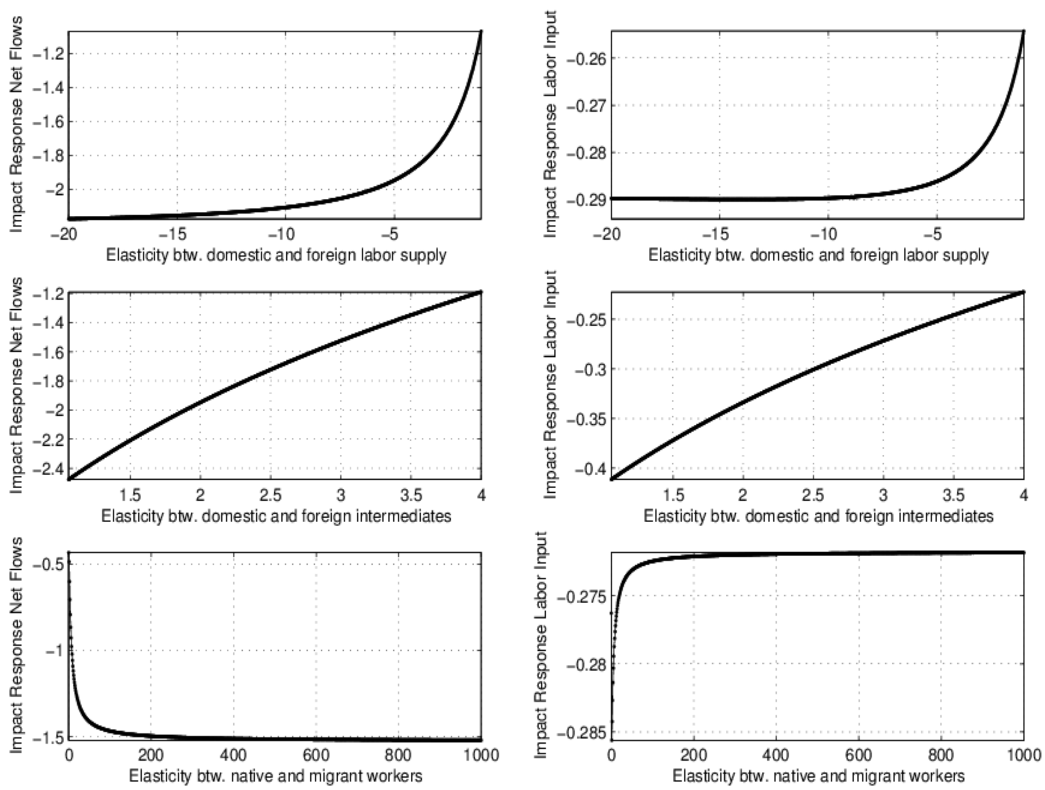


Figure 2.17: Sensitivity of the impact response of net labor flows and employment to the utility cost of moving, α_1, the degree of openness in the intermediate goods sector, α_2, and the relative productivity of native versus migrant workers, α_3, assuming high price duration in the intermediate goods sector ($\theta_x^i = \theta_x^j = 0.75$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)

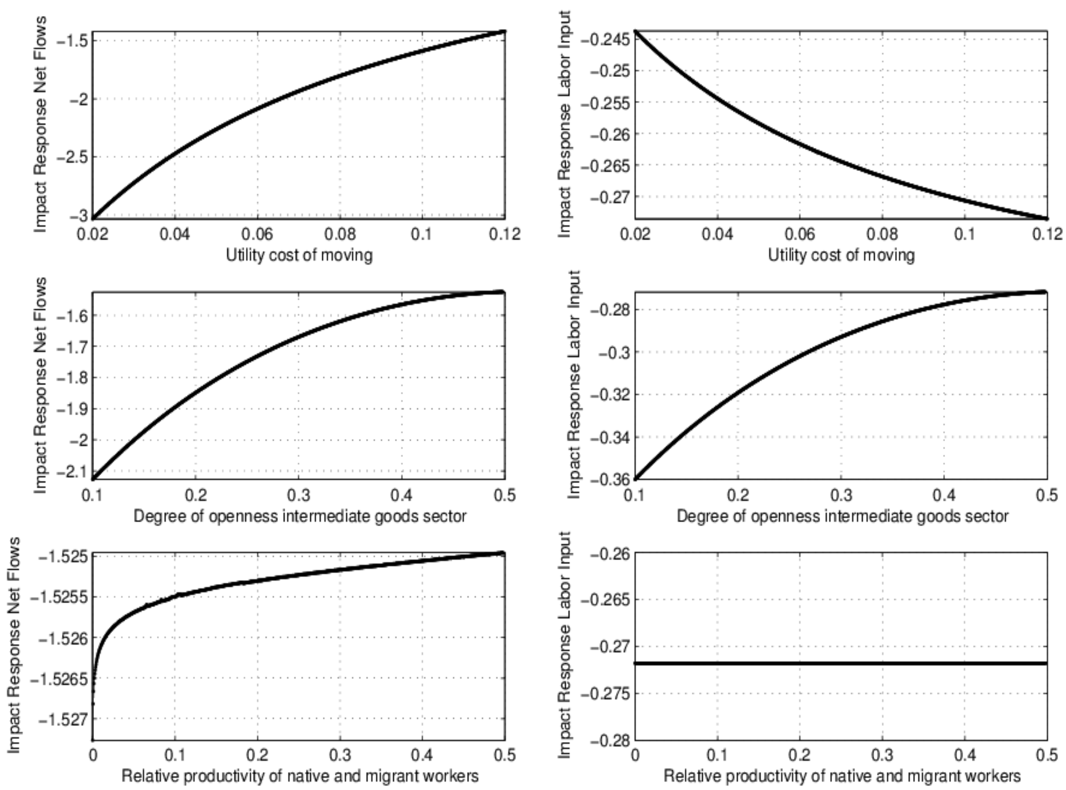


Figure 2.18: Sensitivity of the impact response of net labor flows and employment to the elasticity of substitution between domestic and foreign labor supply, ν_1, between domestic and foreign intermediate goods, ν_2, and between native and migrant workers in intermediate production, ν_3, assuming low price duration in the intermediate goods sector ($\theta_x^i = \theta_x^j = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)

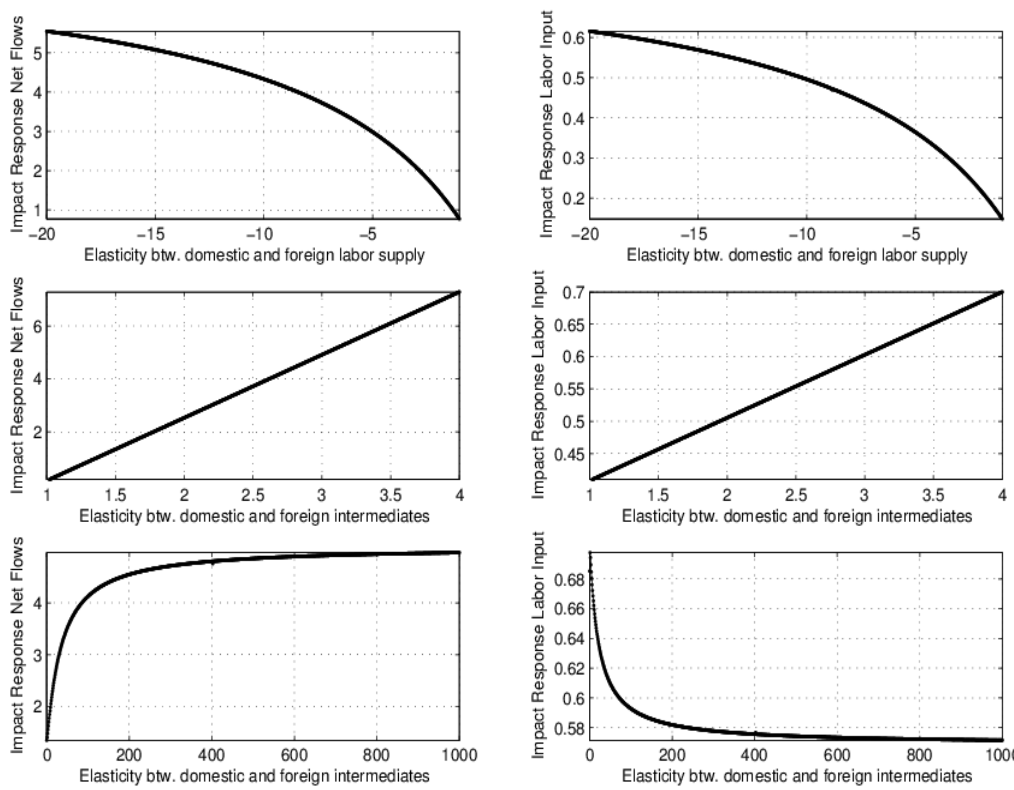


Figure 2.19: Sensitivity of the impact response of net labor flows and employment to the utility cost of moving, α_1, the degree of openness in the intermediate goods sector, α_2, and the relative productivity of native versus migrant workers, α_3, assuming low price duration in the intermediate goods sector ($\theta_x^i = \theta_x^j = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)

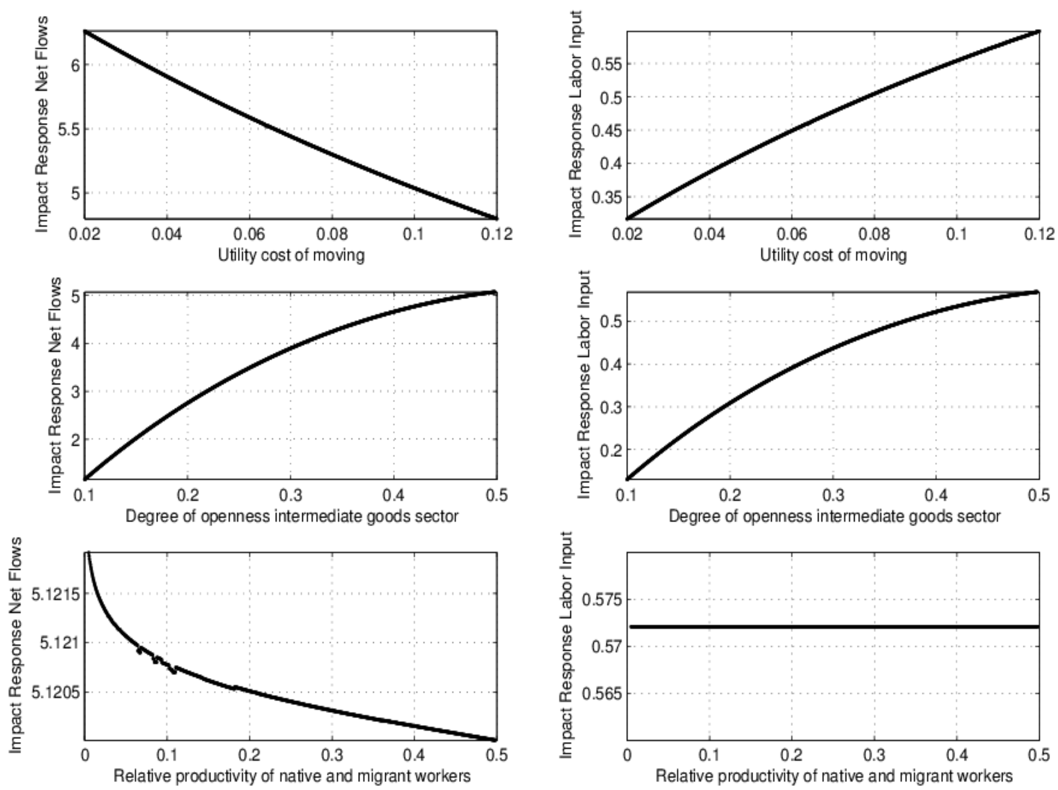


Figure 2.20: Theoretical patterns in the impact impulse responses of net labor flows and employment to a technology shock in the intermediate goods sector in the Home economy, for different degrees of price rigidities in the intermediate goods sector of the two regions, and assuming flexible prices in the final goods sector

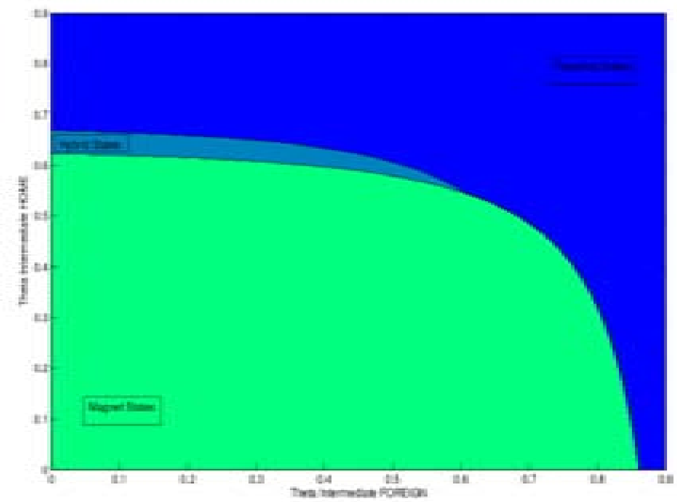


Figure 2.21: Theoretical patterns in the impact impulse responses of net labor flows and employment to a technology shock in the intermediate goods sector in the Home economy, for different degrees of price rigidities in the intermediate goods sector of the two regions, and assuming sticky prices in the final goods sector

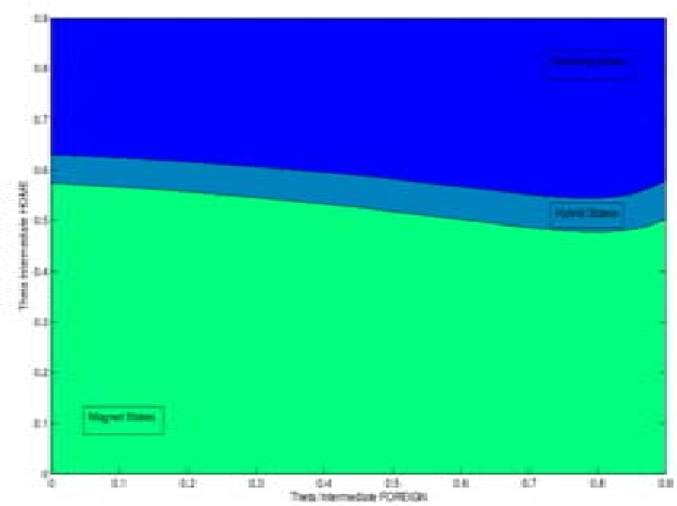
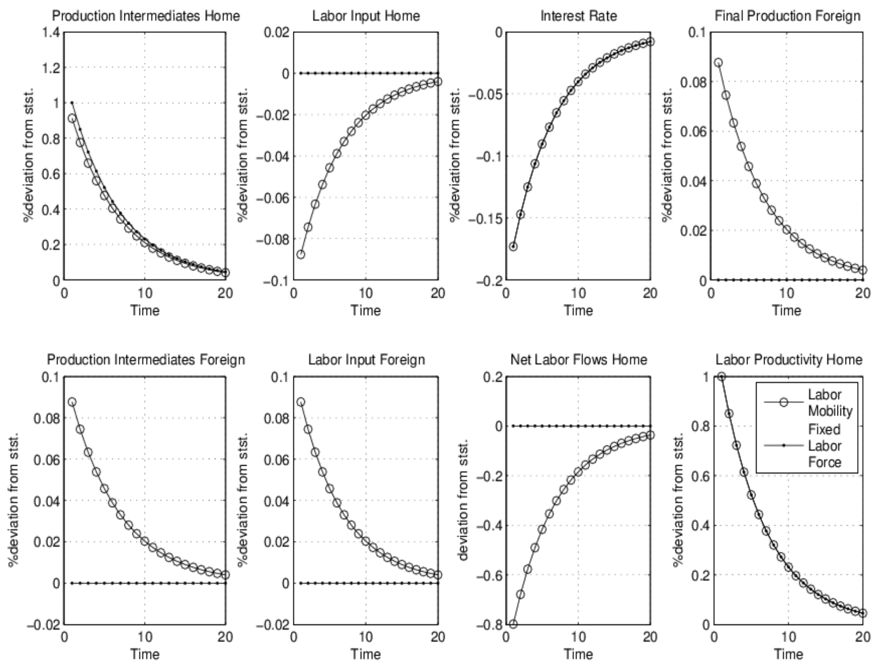


Figure 2.22: Counterfactual Exercise: Closed Economy with and without labor mobility assuming prices to be perfectly flexible in both sectors and regions



Chapter 3

Housework and fiscal expansions

joint with Stefano Gnocchi and Evi Pappa

3.1 Introduction

The recent financial crisis demanded daring initiatives in order to boost aggregate economic activity. Since conventional monetary policy has been limited by the zero bound, increasing political interest has turned to fiscal policy as a possible remedy. While fiscal policy for some years has been downplayed, it faced a renaissance with high expectations as to what it can accomplish. In many countries there has been a vivid debate on the need for a fiscal stimulus, its magnitude, and its composition, and several countries have undertaken fiscal stimulus packages. Calls for expansionary fiscal policy have been issued by many, including the G20 summit and the EU Commission.

The renewed interest for fiscal policy begged the questions of what role government expenditure can play in boosting aggregate demand. In the traditional literature on the effects of fiscal policy, the conclusions on its efficacy typically depend on the identification restrictions used to extract fiscal shocks from the data[1]. However, Perotti (2008)

[1]Blanchard and Perotti (2002), Ramey (2011), Ramey and Shapiro (1998), Burnside, Eichenbaum and Fisher (2004), Erceg and Linde (2012), Mountford and Uhlig (2002), Canova and Pappa (2006), Pappa (2009) and Uhlig (2010) are a representative, though not exhaustive, sample.

and Caldara and Kamps (2008) reconcile the evidence and conclude that shocks to government spending generate demand effects that typically increase consumption and output. The estimated size of output multipliers varies in the $(0.4, 1.5)$ interval, but many recent contributions[2] argue that multipliers can be even larger during recessions, reconfirming the seminal intuition by Keynes.

On the theoretical side, standard theories of business cycles have a hard time to generate output multipliers that quantitatively match the estimates, because the negative wealth effect following a fiscal stimulus detains the expansion of aggregate economic activity. As emphasized by Hall (2009), two key features are needed for a model to deliver sizeable multipliers: a decline in price mark-ups occurring when production rises and a sufficiently elastic response of employment. The former mechanism couples the output expansion with a redistribution of profits from producers to households in the form of higher real wages that makes it particularly attractive to work and to consume when the government is spending. If labor supply is sufficiently elastic, the surge in employment is strong enough to generate a large output multiplier as well as an increase in consumption.

In this third Chapter, following the argument by Hall (2009), we propose a model of housework and nominal rigidities where the substitutability between home-produced and market goods is an important driver of labor supply elasticity. Our model can account for the observed output multiplier, if the elasticity of substitution between home and market goods is calibrated in line with the available microeconomic evidence. Our emphasis on home production is motivated by recent theoretical and empirical contributions pointing to the great deal of substitutability between housework and market work. The American Time Use Survey confirms indeed that households spend be-

[2] In particular, recent empirical work incorporates the notion that fiscal policy might have non-linear effects depending on whether: the economy is in a recession or in an expansion (Auerbach and Gorodnichenko (2012)); unemployment rates are high or low (Barro and Redlick (2011)); the nominal interest rate has reached or not the zero lower bound (Christiano, Eichenbaum and Rebelo (2011), Erceg and Linde (2010) and Canova and Pappa (2011)).

tween 11 and 18 percent of their time endowment in home related activities, producing services that are not exchanged on the market. Also, purchases of consumer durable goods and residential investment exceed purchases of producer durable goods and non-residential investment in the United Sates. Aguiar and Hurst (2005, 2007) document that over the life-cycle people substitute market work with housework. In fact, retirees rely on home production to compensate for the fall in the value of market purchases typically following the exit from the labor force. In the same vein, Aguiar, Hurst and Karabarbounis (2012) document substitutability between housework and market work over the business cycle, by estimating that home production absorbs about 30 percent of foregone market work. Benhabib, Rogerson and Wright (1991) and Greenwood and Hercowitz (1991) were the first to claim that home production is an empirically significant entity and its inclusion in an otherwise standard business cycle model is helpful to account for macroeconomic data. McGrattan, Rogerson and Wright (1997) first introduced housework in a real business cycle model with fiscal policy. Karabarbounis (2012) shows that a model with home production can account for cyclical fluctuations of the labor wedge. The novelty of this Chapter is to show that substitutability between market and non-market activity, coupled with a fall of price mark-ups, provides the key features advocated by Hall (2009) to reconcile the theory with the conditional evidence on fiscal expansions.

Our findings contribute to the literature in several respects. First, we present a channel for generating increases in private consumption and significant output effects after a government spending shock. In particular, we focus on how housework affects the dynamics in an otherwise standard New-Keynesian model and we determine the structural parameters that are crucial in matching the model with the empirical predictions. In line with previous theoretical contributions[3], price stickiness, and some, though small, capital adjustment costs are crucial for our channel to be operative. Un-

[3] On the role of nominal rigidities and non-separability between consumption and leisure see Woodford (2011), Hall (2009) and Basu and Kimball (2002).

der flexible prices, a positive government expenditure shock only generates, through a negative wealth effect, an increase of the labor supply and a consequent fall in the real wage. In other words, households do not work more because they find it more attractive, but simply because they want to partially smooth the reduction in consumption that is necessary to finance the increased tax burden. As a consequence, irrespective of the elasticity of substitution between home and market goods, labor supply is never elastic enough to boost market consumption and to match the observed size of the output multiplier. Similarly, without adjustment costs to capital, households smooth the shock by reducing investment, a fact that not only detains the increase of aggregate demand, but that also depresses future labor market productivity and the real wage. Only when both of these features are present, one can make the labor supply elastic enough to generate an increase of market consumption by including in the model a home production sector. Also, the way monetary and fiscal policy interact is key. In line with the case made by Canova and Pappa (2011), Christiano et al. (2011) and Erceg and Linde (2010), if the monetary authority reacts too strongly to inflation, after a government expenditure shock the real interest rate increases so as to make consumption fall. Hence, in order to match the VAR evidence we include an interest rate smoother in the monetary policy rule that allows us both to reproduce the estimated muted response of the nominal interest rate and to generate a sizeable output multiplier.

Second, and more broadly, we see our result as pointing to the importance of modelling housework as an alternative option to market work, if one wants to rely on business cycle models to predict the effects of policy. In fact, the substitutability between home and market goods interacts with nominal and real frictions in driving households' incentive to participate in the labor market. Since fiscal and monetary policies affect the relevance of frictions at business cycle frequencies, models neglecting the home sector may lead to incorrect conclusions about the evaluation of those policies. In our particular case, model abstracting from housework understate the elasticity of labor supply and this fact is partially responsible for the failure of baseline business cycle models to account for the VAR evidence on fiscal shocks[4].

Finally, our results are relevant for the literature suggesting consumption and hours' complementarities in the utility function as a way of generating increases in consumption after a fiscal expansion. For instance, see Monacelli and Perotti (2008), Hall (2009), Christiano et al. (2011) and Nakamura and Steinsson (2011). The intuition behind their mechanism is simple: if consumption and hours worked are complements, the negative wealth effect originating from the increase in government's absorption should result in a positive consumption response and, as a result, in a higher output multiplier. Our home production model with high substitutability between market and home consumption nests a reduced-form model without home production, but in which market consumption and market work are strong complements in the utility function. Yet, explicitly modelling housework offers the noticeable advantage of tying the importance of the transmission channel to the data by relying on the abundant microeconomic evidence.

Our goal is not to give a general theory of the effects of fiscal policy on macroeconomic variables, neither to offer an exhaustive explanation of the VAR evidence. Rather, we view our mechanism as complementary to the many alternative explanations suggested by the literature: Woodford (2011) considers that making consumption respond to current income, according to the old Keynesian tradition, generates sizeable demand effects and output multipliers; along this line, Galí, Lopez-Salido and Valles (2007) were the first to model rule-of-thumb consumers in order to break the link between the real interest rate and private consumption, allowing thus the latter to react to current income. Corsetti, Meier and Muller (2009) explain a positive private consumption response with spending reversals: current higher government expendi-

[4]See Brückner and Pappa (2010) and Campolmi and Gnocchi (2011) for a similar argument applied to the effects of monetary and fiscal policy on unemployment.

ture implies permanently lower future expenditure, so as to keep constant long-run government debt. In their setup, an increase in government spending implies higher consumption both in the future and, through consumption smoothing, at the time of the shock. Finally, Morten, Schmitt-Grohé and Uribe (2012) focus on deep habits. In this case, an increase in domestic aggregate demand provides an incentive for firms to lower markups shifting the labor demand curve outwards and increasing real wages. The rise in wages induces households to substitute consumption for leisure and this substitution effect can be strong enough to offset the negative wealth effect and result in an equilibrium increase in private consumption.

The rest of the Chapter is organized as follows: Section 2 presents the model and Section 3 its baseline parametrization. Section 4 describes the dynamics of the model after a fiscal expansion, examines the sensitivity of the results to changes in key parameters and compares the model with the VAR evidence. Section 5 concludes.

3.2 The Model

We consider an otherwise standard New-Keynesian model, where households have access to a technology that combines time and capital to produce non-tradable home goods. As in Benhabib et al. (1991) and McGrattan et al. (1997)[5], households enjoy leisure and consumption of a composite index that aggregates market and home goods according to a constant elasticity of substitution. The central bank is in charge of setting the nominal interest rate. The fiscal authority buys market goods and finances expenditures by levying a mix of lump-sum and distortive taxes. In what follows we define the economic environment and agents' optimality conditions. We summarize the full system of equations defining the competitive equilibrium in Appendix C.

[5]Differently from Greenwood and Hercowitz (1991) we allow households to substitute leisure with time spent working either at home or on the market.

3.2.1 Policy makers

In the economy there are infinitely many varieties of final market consumption goods indexed by $i \in [0,1]$. The fiscal authority buys each market variety $G_t(i)$ at its market price $P_t(i)$. We define aggregate government expenditure, G_t, as a composite index

$$G_t = \left[\int_0^1 (G_t(i))^{\frac{\varepsilon-1}{\varepsilon}} \, di \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where $\varepsilon > 1$ is the constant elasticity of substitution across varieties and $log(G_t)$ exogenously evolves according to an AR(1) process, with mean equal to some parameter $log(G)$. We assume that the government chooses the quantities $G_t(i)$ in order to minimize the total expenditure $\int_0^1 P_t(i)G_t(i) \, di$, given G_t. Hence, the condition

$$G_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} G_t$$

pins down public consumption of each variety i where

$$P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon} \, di \right]^{\frac{1}{1-\varepsilon}} \tag{3.1}$$

Government expenditure is financed by a mixture of distortive taxes on households' capital and labor income as well as by lump-sum taxes. Tax rates on capital and labor income are exogenously given and constant, while lump-sum taxes can be used in a state-contingent way to balance the government budget constraint in every period. The central bank chooses the nominal interest rate by following a simple Taylor rule that targets inflation

$$(1 + R_t) = \beta^{-1} \Pi_t^{\Phi_\pi} \tag{3.2}$$

with $\Phi_\pi > 1$ and $\Pi_t \equiv (P_t / P_{t-1})$.

3.2.2 Households

Preferences over consumption C_t and leisure l_t are defined by

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[(C_t)^b (l_t)^{1-b}\right]^{1-\sigma} - 1}{1-\sigma}$$

where $b \in (0,1)$, $\sigma \geq 1$ and C_t is an index that combines market and home goods denoted by $C_{m,t}$ and $C_{n,t}$, respectively, according to

$$C_t = \left[\alpha_1 (C_{m,t})^{b_1} + (1-\alpha_1)(C_{n,t})^{b_1}\right]^{\frac{1}{b_1}}$$

$\alpha_1 \in [0,1]$ and $b_1 < 1$. Therefore, households can substitute market and home goods at a constant elasticity[6] $(1-b_1)^{-1}$. The market good is the standard Dixit-Stiglitz aggregator of the infinitely many varieties of market consumption goods

$$C_{m,t} = \left[\int_0^1 (C_{m,t}(i))^{\frac{\varepsilon-1}{\varepsilon}} \, di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.3}$$

and can be bought for either consumption or investment purposes. Aggregate investment also combines varieties as in (3.3), at the same elasticity of substitution ε. Let investment be denoted by I_t. Hence, capital evolves over time according to

$$K_{t+1} = (1-\delta)K_t + exp\{\mu_t\}I_t - \frac{\xi}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2 \tag{3.4}$$

and it depreciates at a rate δ. We allow for positive capital adjustment costs by setting $\xi > 0$ and we consider an investment specific shock μ_t. In each period, the existing capital stock can be rented to firms or used by the household for home production. Let $K_{m,t}$ be the capital stock available to firms and $K_{n,t}$ the capital stock available for non-market activity. Hence,

[6] Recall the following limiting cases: when b_1 approaches one, $C_{m,t}$ and $C_{n,t}$ are perfect substitutes. They are instead perfect complements if b_1 tends to minus infinity. $b_1 = 0$ nests the Cobb-Douglas specification.

$$K_t = K_{m,t} + K_{n,t}$$

Home goods are not traded. Rather, the household produces them by allocating capital and labor to the following technology

$$C_{n,t} = \left[\alpha_2 (K_{n,t})^{b_2} + (1-\alpha_2)\left(exp\{s_{n,t}\}h_{n,t}\right)^{b_2}\right]^{\frac{1}{b_2}} \tag{3.5}$$

where $h_{n,t}$ stands for hours worked at home, $s_{n,t}$ captures exogenous technological progress in the home production sector, $\alpha_2 \in [0,1]$ and $b_2 < 1$. As an alternative to housework, time can be rented to firms so that the following constraint must hold

$$l_t = 1 - h_{m,t} - h_{n,t}$$

where $h_{m,t}$ represents hours worked in the market and the time endowment is normalized to one. We assume that households are price-takers in all markets and that financial markets are complete. Therefore, optimal allocation of expenditure across varieties implies a flow budget constraint

$$\begin{aligned} & E_t\{Q_{t,t+1}B_{t+1}\} + P_t(C_{m,t} + I_t) \\ & \qquad \leq B_t + (1-\tau_h)W_t P_t h_{m,t} + (1-\tau_k) r_t P_t K_{m,t} + \delta\tau_k P_t K_{m,t} + T_t \end{aligned}$$

P_t is the minimum cost of a unit of the composite bundle $C_{m,t}$, as in (3.1), B_{t+1} is a portfolio of state contingent assets and $Q_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payoffs[7]. r_t is the real rental price of market capital, W_t is the real wage and the term $\delta\tau_k P_t K_{m,t}$ arises because we assume that depreciated market capital is tax deductible. Finally, T_t includes all lump-sum transfers and taxes, in addition to the profits stemming from market power.

[7]The stochastic discount factor in period t is the price of a bond that delivers one unit of currency if a given state of the world realizes in period $t+1$, divided by the conditional probability that the state of the world occurs given the information available in t. The nominal interest rate R_t relates to the discount factor according to $(1+R_t) = \{E_t Q_{t,t+1}\}^{-1}$ by a standard no-arbitrage argument.

Given initial values of the capital stock K_0 and assets B_0, and given all prices and policies, households choose state-contingent sequences of: aggregate, market and home consumption, C_t, $C_{m,t}$ and $C_{n,t}$, respectively; leisure, l_t, and hours worked both on the market, $h_{m,t}$, and at home, $h_{n,t}$; the stock of capital rented to firms, $K_{m,t}$, and the stock used in the non-market production, $K_{n,t}$; investment, I_t, as well as the total capital stock, K_{t+1}, and the amount of bonds B_{t+1} to carry over to the next period. The solution to the households' problem needs to satisfy three intra-temporal conditions

$$\frac{\alpha_1}{1-\alpha_1}\left[\frac{C_{m,t}}{C_{n,t}}\right]^{b_1-1} = \frac{1-\alpha_2}{W_t(1-\tau_h)}\left[\frac{C_{n,t}}{h_{n,t}}\right]^{1-b_2}[exp\{s_{n,t}\}]^{b_2} \tag{3.6}$$

$$\frac{\alpha_1}{1-\alpha_1}\left[\frac{C_{m,t}}{C_{n,t}}\right]^{b_1-1} = \frac{\alpha_2}{(1-\tau_k)r_t+\delta\tau_k}\left[\frac{C_{n,t}}{K_{n,t}}\right]^{1-b_2} \tag{3.7}$$

$$W_t(1-\tau_h)(1-h_{n,t}-h_{m,t}) = \frac{1-b}{b\alpha_1}C_{m,t}^{1-b_1}C_t^{b_1} \tag{3.8}$$

Equation (3.6) drives the optimal allocation of time between the home and the market sector. It establishes that the marginal rate of substitution between home and market consumption has to equalize the corresponding relative price which is the ratio between the return to housework, i.e. the marginal productivity of labor in the non-market sector, and the return to market work, i.e. the after-tax real wage. Similarly, equation (3.7) requires that the marginal rate of substitution between the two consumption goods is equal to the ratio of returns to capital in the two sector, marginal productivity of capital at home and the after-tax market rental rate of capital, taking into account that depreciation is tax deductible. Obviously, taken together, the two conditions imply that returns to labor, relative to capital, are equalized across sectors which is a direct consequence of the fact that the household can freely re-allocate both time and capital between market and non-market activity. Equation (3.8) is the standard intra-temporal optimality condition solving for the leisure-consumption trade-off.

In addition, two conventional Euler equations are required for the allocation to be optimal inter-temporally, one for the capital stock and one for financial assets

$$\beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{exp\{\mu_t\}}{exp\{\mu_{t+1}\}} \left[1 + \frac{\xi}{K_t} \left(\frac{K_{t+1}}{K_t} - 1 \right) \right]^{-1} \right.$$
$$\left. \left[1 - \delta + \xi \left(\frac{K_{t+2}}{K_{t+1}} - 1 \right) \left(\frac{K_{t+2}}{K_{t+1}^2} \right) + exp\{\mu_{t+1}\}(1 - \tau_k) r_{t+1} + \delta \tau_k \right] \right\} = 1 \qquad (3.9)$$

$$\beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} (1 + R_t) \Pi_{t+1}^{-1} \right\} = 1$$

where λ denotes the marginal utility of consumption and reads as

$$\lambda_t = b\alpha_1 (1 - h_{n,t} - h_{m,t})^{(1-b)(1-\sigma)} C_{m,t}^{b_1 - 1} (C_t)^{b(1-\sigma) - b_1}$$

3.2.3 Firms

Each market good variety i is produced by a monopolistically competitive firm that combines market capital and time according to the production function

$$Y_t(i) = \left[\alpha_3 (K_{m,t}(i))^{b_3} + (1 - \alpha_3) \left(exp\{s_{m,t}\} h_{m,t}(i) \right)^{b_3} \right]^{\frac{1}{b_3}} \qquad (3.10)$$

where $\alpha_3 \in [0, 1]$, $b_3 < 1$ and $s_{m,t}$ represents labor augmenting technological progress. Cost minimization with respect to capital and labor subject to the technological constraint (3.10) yields

$$\alpha_3 RMC_t \left(\frac{K_{m,t}(i)}{Y_t(i)} \right)^{b_3 - 1} = r_t \qquad (3.11)$$

$$(1 - \alpha_3) RMC_t \left(\frac{h_{m,t}(i)}{Y_t(i)} \right)^{b_3 - 1} [exp\{s_{m,t}\}]^{b_3} = W_t \qquad (3.12)$$

where RMC_t is the real marginal cost which is constant across all firms i as an implication of constant returns to scale and perfect competition on the markets of all factors of production. We follow Calvo (1983) and we assume that in any given period each firm resets its price $P_t(i)$ with a constant probability $(1-\theta)$. The demand of any good i is

$$Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} Y_t^d \tag{3.13}$$

where $Y_t^d \equiv [C_{m,t} + I_t + G_t]$. Maximization of profits

$$E_t \left\{ \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} \left[P_t(i) Y_{t+j}(i) - P_{t+j} RMC_{t+j} Y_{t+j}(i) \right] \right\}$$

subject to constraint (3.13) yields the following first order condition for any firm i that is allowed to re-optimize in period t

$$E_t \left\{ \sum_{j=0}^{\infty} \theta^j Q_{t,t+j} Y_{t+j}(i) \left[\frac{P_t^*}{P_t} - \frac{\varepsilon}{\varepsilon - 1} RMC_{t+j} \Pi_{t,t+j} \right] \right\} = 0 \tag{3.14}$$

P_t^* is the optimal price, $Q_{t,t+j}$ denotes the stochastic discount factor in period t for nominal profits j periods ahead and it is such that

$$Q_{t,t+j} = \beta^j E_t \left\{ \frac{\lambda_{t+j}}{\lambda_t} \Pi_{t,t+j}^{-1} \right\}$$

and $\Pi_{t,t+j} \equiv (P_{t+j}/P_t)$. Calvo-pricing conventionally implies the following relation between inflation and the relative price charged by re-optimizing firms

$$\frac{P_t^*}{P_t} = \left(\frac{1 - \theta \Pi_t^{\varepsilon - 1}}{1 - \theta} \right)^{\frac{1}{1-\varepsilon}} \tag{3.15}$$

The necessary condition for profit maximization (3.14) can easily be rewritten as

$$\frac{P_t^*}{P_t} = \frac{x_{1,t}}{x_{2,t}} \tag{3.16}$$

where the auxiliary variables $x_{1,t}$ and $x_{2,t}$ are recursively defined by

$$x_{1,t} = Y_t^d \frac{\varepsilon}{\varepsilon - 1} RMC_t + \beta\theta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \Pi_{t+1}^{\varepsilon} x_{1,t+1} \right\} \tag{3.17}$$

$$x_{2,t} = Y_t^d + \beta\theta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \Pi_{t+1}^{\varepsilon-1} x_{2,t+1} \right\} \tag{3.18}$$

3.2.4 Aggregation and market clearing

After defining aggregate production Y_t

$$Y_t = \left[\int_0^1 (Y_t(i))^{\frac{\varepsilon-1}{\varepsilon}} \, di \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

the clearing of all final goods markets implies

$$Y_t = C_{m,t} + I_t + G_t \tag{3.19}$$

Define the market capital-labor ratio, $k_t \equiv (K_{m,t}(i)) / (h_{m,t}(i))$. By equations (3.11) and (3.12) the ratio is constant across firms and satisfies

$$k_t = \left[\frac{r_t(1-\alpha_3)exp\{s_{m,t}\}}{W_t \alpha_3} \right]^{\frac{1}{b_3-1}}$$

Let aggregate labor demand $h_{m,t}^d$ be

$$h_{m,t}^d = \int_0^1 h_{m,t}(i) \, di$$

that coincides with $h_{m,t}$ by the clearing of the labor market. Therefore, integrating equation (3.10) over all firms i yields

$$Y_t = \Delta_t^{-1} \left[\alpha_3 k_t^{b3} + (1-\alpha_3) \right]^{\frac{1}{b_3}} h_{m,t} \tag{3.20}$$

where Δ_t denotes relative price dispersion which reads as

$$\Delta_t = \int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} di$$

and it is a state-variable that evolves according to

$$\Delta_t = (1-\theta) \left(\frac{P_t^*}{P_t} \right)^{-\varepsilon} + \theta \Pi_t^{\varepsilon} \Delta_{t-1}$$

It is well-known that $log\left(\Delta_t\right)$ is a second order term and can thus be neglected when the model is approximated to the first order around the non-stochastic steady state. Aggregate demand of market capital is

$$K_{m,t}^d = \int_0^1 K_{m,t}(i)\ di$$

It follows that the clearing of the capital rental market implies the relation

$$K_{m,t} = k_t h_{m,t} \tag{3.21}$$

Finally, by using (3.21) into (3.20), one can obtain the aggregate production function

$$Y_t = \Delta_t^{-1} \left[\alpha_3 K_{m,t}^{b3} + (1-\alpha_3) h_{m,t}^{b3} \right]^{\frac{1}{b_3}} \tag{3.22}$$

as well as the aggregate counterparts of equations (3.11) and (3.12)

$$\alpha_3 RMC_t \left(\frac{K_{m,t}}{\Delta_t Y_t} \right)^{b_3-1} = r_t \tag{3.23}$$

$$(1-\alpha_3) RMC_t \left(\frac{h_{m,t}}{\Delta_t Y_t} \right)^{b_3-1} \left[exp\{s_{m,t}\} \right]^{b_3} = W_t \tag{3.24}$$

3.3 Parametrization of the model

To begin with, we restrict the elasticity of substitution in production to 1 by choosing b_2 and b_3 equal to 0. We do so in order to be comparable with most of the related literature that focuses on the case of Cobb-Douglas production functions[8].

We resort to data in order to calibrate as many structural parameters as we can, so as to match the value of endogenous variables at the non-stochastic steady state with their observable counterparts. By doing so, we determine the following parameters: α_1, α_2, α_3, G, δ and b. Ten structural parameters are left to be determined: the discount factor β; tax rates τ_k and τ_h; the elasticity of substitution between market and home goods $(1-b_1)^{-1}$; price stickiness θ; the elasticity of substitution across market good varieties, ε; the inverse of the inter-temporal elasticity of substitution, σ; capital adjustment costs ξ; the Taylor rule coefficient Φ_π. These parameters can hardly be identified by matching the steady state with the data and they are potentially crucial for the dynamic response of endogenous variables to shocks. Hence, we discipline the model by using information coming from previous studies. In the next section, we perform extensive sensitivity analysis with respect to all of them in order to make clear how the parametrization affects our results. We set the discount factor β to 0.99 which implies an annual interest rate of roughly 4 percent per year. In the baseline parametrization, we restrict to the case of lump-sum taxation, as in most of the literature that investigates the ability of standard business cycle models in replicating empirical impulse responses of market consumption to government expenditure shocks. We choose $\theta = 0.75$, $\varepsilon = 11$, $\sigma = 2$, and $\Phi_\pi = 1.5$, a calibration that is fairly standard in business cycle models. As far as capital adjustment costs are concerned, estimates display great variability[9], ranging from $\xi = 3$ to $\xi = 110$. We restrict to a value in the middle range, $\xi = 50$. $(1-b_1)^{-1}$ is the parameter we are mostly interested

[8]Table 3.1 summarizes the values for the other parameters.
[9]For a survey see Neiss and Pappa (2002)

in since affects significantly the elasticity of labor supply to G shocks. To have a broad idea of an empirically relevant range for $(1-b_1)^{-1}$, one can refer to a variety of both micro- and macroeconomic studies that find estimates between 1.8 and 5[10]. We fix the elasticity to 4, implying $b_1 = 0.75$. However, in most of our exercises we leave the parameter free to vary, so as to assess its importance for the sensitivity of our results.

3.3.1 Data

We collect time series of capital, investment, market consumption, government expenditure and the consumer price index (price index for personal consumption expenditure) from the U.S. Bureau of Economic Analysis. All the series refer to the time period 1950:Q1-2007:Q2, excluding the financial crisis, they are available at a quarterly frequency, with the exception of capital that is annual, and they are all seasonally adjusted. The data have been downloaded in current dollars and divided by the consumer price index. We obtain a measure of GDP by summing up market consumption, investment and government expenditure. We only consider purchases of goods in government expenditure and we exclude purchases of non-military durable goods and structures. The series of market consumption includes non-durable goods and services, after subtracting the value of services from housing and utilities that in turn we consider as a part of the non-market sector[11]. We obtain total investment by adding purchases of durable goods to the fixed investment component, both residential and non-residential, but we leave out inventories, as in Smets and Wouters (2007). Consistently, we assign

[10]The preferred calibration chosen by Benhabib et al. (1991) in their seminal contribution about home production is 5. McGrattan et al. (1997) estimate a version of the model by Benhabib et al. (1991) via maximum likelihood and find a value slightly below 2. Chang and Schorfheide (2003) estimate a home production model with Bayesian techniques and find that $(1-b_1)^{-1}$ is roughly 2.3. Aguiar et al. (2012) use data from the American Time Use Survey (ATUS) to establish that home production absorbs about 30 percent of foregone market work hours at business cycle frequencies. Then, they show that the Benhabib et al. (1991) model is consistent with the ATUS evidence under a 2.5 elasticity. Karabarbounis (2012) shows that a value of 4 accounts for cyclical fluctuations of the labor wedge.

[11]This is conventional in the home production literature. See for instanceMcGrattan et al. (1997).

fixed non-residential assets to market capital, while we consider residential assets and the stock of durable goods as part of the home capital. Government expenditure as a share of GDP amounts to 0.18, which we use to calibrate the mean of the stochastic process for public spending G. The market and home capital to output ratio, 1.29 and 1.69, are informative for choosing technology parameters α_3 and α_2, respectively. Data on capital and investment pin down the depreciation rate δ. We normalize the time endowment to 1 and we match steady state hours worked in the market and in the home sector with averages observed in the data by choosing utility parameters b and α_1, respectively. To this purpose, we use the information contained in the American Time Use Survey (ATUS) as summarized by Aguiar et al. (2012). The ATUS provides nationally representative estimates of how Americans spend their time supplying data on a wide range of non-market activities, from child-care to volunteering, for a cross-section of roughly 100000 individuals over the period 2003-2010. Respondents are randomly selected from a subset of households that have completed their eight and final month of interviews for the Current Population Survey (CPS). As a fraction of the weekly endowment, time allocated to market work is 0.33, time for housework amounts to 0.19 and the rest is devoted to leisure which excludes sleeping, eating and personal care time[12].

3.3.2 Non-stochastic steady state and calibration

We find the non-stochastic steady state of the model by setting all shocks to their unconditional mean which we normalize[13] to 0 for s_m, s_n and μ. Then, the equilibrium

[12]As reported by Aguiar et al. (2012) in Table B1 of their online Appendix, the average respondent devotes 31.62 hours to market work and 18.12 hours to home production per week. Our figures obtain after subtracting from the weekly time endowment sleeping, personal care and eating, for a total of 72.92 hours. Instead, if those activities are included, market work and home production time result in 0.18 and 0.11, respectively. Both ways of accounting time are used in the home production literature. We choose the former in our baseline calibration, but we check that our results are robust to the latter definition.

[13]Instead, $log(G)$ is chosen consistently with the data as we show below.

conditions evaluated at the non-stochastic steady state are used to recover the values of α_1, α_2, α_3, G, δ and b, given the calibration targets. The steady state version of the capital accumulation equation, (3.4), determines the depreciation rate, δ, by using data on capital and investment. The Euler equation on capital, (3.9), thus implies that the steady state rental rate is

$$r = \frac{1 - \beta\delta\tau_k - \beta(1-\delta)}{\beta(1-\tau_k)} \tag{3.25}$$

which is pinned down by knowing β, δ and the capital income tax rate. Equations (3.15)-(3.18), together with the monetary rule (3.2), imply that the steady state value of the real marginal cost is

$$RMC = \frac{\varepsilon - 1}{\varepsilon}$$

while $\Pi = P^*/P = \Delta = 1$ and $(1+R) = \beta^{-1}$. By equation (3.23),

$$\frac{K_m}{Y} = \left(\frac{r\varepsilon}{\alpha_3(\varepsilon-1)}\right)^{\frac{1}{b_3-1}} \tag{3.26}$$

which allows to retrieve α_3 given the market capital-to-output ratio, b_3 and ε, after substituting equation (3.25). Furthermore, we use the production function (3.22) to find

$$\frac{h_m}{Y} = \left[\frac{1}{1-\alpha_3} - \frac{\alpha_3}{1-\alpha_3}\left(\frac{K_m}{Y}\right)^{b_3}\right]^{\frac{1}{b_3}} \tag{3.27}$$

which is solely a function of known parameters. Therefore, given the target on h_m, one can easily solve for Y and K_m via (3.26) and (3.27), while equation (3.24) determines the real wage W

$$W = \frac{(1-\alpha_3)(\varepsilon-1)}{\varepsilon}\left(\frac{h_m}{Y}\right)^{b_3-1}$$

If Y is known, it follows from definitions (3.17) and (3.18) that

$$x_1 = x_2 = (1 - \beta\theta)Y$$

Conditions (3.6) and (3.7) imply

$$\frac{h_n}{Y} = \left[\frac{\alpha_2 W(1-\tau_h)}{(1-\alpha_2)[(1-\tau_k)r + \delta\tau_k]}\right]^{\frac{1}{b_2-1}} \frac{K_n}{Y}$$

and α_2 must be chosen to make consistent the target on hours worked at home with the observed home capital-to-output ratio. Once α_2 has been set, also K_n is pinned down, hence C_n can be found by using (3.5). Define g as the share of government expenditure in GDP. The resource constraint (3.19) together with (3.6) yields

$$\frac{\alpha_1}{1-\alpha_1}\left[\frac{(1-g)Y - I}{C_{n,t}}\right]^{b_1-1} = \frac{1-\alpha_2}{W_t(1-\tau_h)}\left[\frac{C_{n,t}}{h_{n,t}}\right]^{1-b_2} \tag{3.28}$$

where all endogenous variables have been determined. As a consequence, given b_1 and b_2, α_1 must be chosen such that (3.28) holds. Finally, $G = gY$ while the labor supply equation (3.8) recovers the value of b consistent with all our targets.

3.4 Housework, market consumption and fiscal multipliers

The purpose of this section is twofold. First, we document that in the model substitutability between market and home consumption is an important driver of the labor supply response to government expenditure shocks and, as a consequence, it affects the predicted magnitude of the fiscal multiplier as well as the effect on market consumption of fiscal expansions. Finally, we compare the predictions of our model with the VAR evidence on the macroeconomic consequences of exogenous changes in public spending.

3.4.1 Inspecting the mechanism

Under our calibration, market consumption increases after a positive government expenditure shock. This result stands in contrast with the predictions of a baseline business cycle model with nominal rigidities. Figure 3.1 makes clear the contribution of home production by comparing impulse response functions across two alternative parameterizations. We label as "GHP" the responses obtained under the calibration reported in Table 3.1, while "Baseline" refers to a counterfactual world where hours worked and capital in the home sector are set to zero. In both cases, we consider an exogenous increase in government expenditure that is normalized to one percentage point of steady state GDP and we analyze its impact on market consumption, hours worked on the market, real wages, GDP and investment. We assume[14] that the shock follows an $AR(1)$ process with persistence $\rho_g = 0.8$. The responses of consumption and investment have been expressed as shares of GDP, while for GDP and real wages we present percentage deviations from the steady state[15]. As a consequence, the impact of the shock on GDP can be conventionally interpreted as the fiscal multiplier and directly compared to the corresponding VAR evidence. We maintain this normalization in the rest of the present Chapter. It is evident that the "GHP" model implies bigger fiscal multipliers, as compared to the baseline, and it predicts a positive rather than negative consumption response. This is because the substitutability between the two goods induces a higher elasticity of labor supply to exogenous changes in public spending. The intuition of the result is straightforward. The household needs to pay for the shock out of her wealth in the form of higher current or future taxes, so that a temporary fiscal expansion has a negative wealth effect. Therefore, it is optimal to reduce investment on the one hand and to work more on the other hand, so as to

[14]Monacelli and Perotti (2008, 2010) show that $\rho_g = 0.8$, implying that roughly fifty percent of the shock dies out in about four quarters, is in line with the VAR evidence. We further discuss such value below when we compare our model with an identified government expenditure shock.

[15]To this purpose, we multiply the log response of consumption and investment by their steady state shares in GDP. Everything is multiplied by 100 so that the scale is already in percentage points.

spread the tax burden between lower savings and larger labor income. Also, in a model with nominal rigidities a positive government expenditure shock induces substitution of leisure and housework with market work for an additional reason. The fiscal expansion stimulates aggregate demand, reduces price mark-ups and consequently raises the real wage, making it relatively more attractive to work in the market sector. The wealth and the aggregate demand effects reinforce each other in boosting employment, but they push the real wage in opposite directions and the final outcome is ultimately a quantitative question. In a model without home production market hours worked increase and generate a positive fiscal multiplier on output which is not large enough to allow for an increase of market consumption: the additional labor income is indeed only used to finance the tax burden. However, when the household has the possibility of reallocating time from housework to market activity, the incentive to do so clearly depends on the elasticity of substitution between home and market goods and one would expect a stronger response of hours when b_1 grows larger[16]. Figure 3.2 confirms that this is indeed the case. In fact, if we reduce the elasticity of substitution from 4 to 1 and keep all the remaining parameters at the values displayed in Table 3.1, the response of hours is dampened enough to make market consumption fall, as in the baseline business cycle model. Not surprisingly, also the fiscal multiplier is smaller. Hence, we conclude that neglecting the substitutability between housework and market work downplays the actual elasticity of labor supply to fiscal shocks and, as a consequence, their impact on production and market consumption.

Nominal rigidities are key in shaping the relationship between the elasticity of substitution b_1 and the elasticity of labor supply to G shocks, as it becomes clear from Figure 3.3, where the elasticity of substitution is kept constant and equal to its baseline value, while price stickiness varies from 0 to 0.75. If nominal rigidities are low enough, our transmission channel does not seem to be operative. This fact can be

[16]Recall that higher values of b_1 imply a higher elasticity of substitution and when $b_1 = 0$ preferences are Cobb-Douglas.

easily explained by the behavior of the real wage. When prices become more flexible, a fiscal expansion affects price mark-ups to a lesser extent. As a result, the outward shift of the labor supply curve due to the negative wealth effect becomes more and more important, relatively to the fall in mark-ups, and the real wage does not increase much or it even falls. It follows that a high elasticity of substitution between home and market goods cannot reinforce the increase in market hours worked: the household does not find it more attractive to work on the market, rather it works the amount needed to pay the tax burden and optimally smooth the shock over time. To conclude, the elasticity of substitution between home and market goods is relevant if households work more on the market after the shock not simply because they have to, but because they find it more attractive than home producing.

3.4.2 Robustness

We now discuss the robustness of our results. In fact, the model parametrization may hide some forces that can under- or overstate the quantitative importance of substitutability between market and home goods. We postpone to the next section an extended discussion emphasizing that a proper modelling of the interaction between monetary and fiscal policy is crucial to obtain sensible predictions[17]. Two structural parameters are naturally expected to be relevant: the cost of adjustment of the capital stock, ξ, and the inverse of the inter-temporal elasticity of substitution, σ. Intuitively, the former discourages households from smoothing the fiscal shock by reducing savings and investment. The latter, as emphasized by Basu and Kimball (2002), also acts through the inter-temporal margin and it affects the complementarity between hours worked and consumption. In particular, a smaller inter-temporal elasticity of substitution, i.e. a higher σ, magnifies the relevance of our channel. We finally show that our results are robust to the inclusion of distortive tax rates on capital and labor in-

[17]For an illustration of the empirical importance of monetary accommodation after fiscal shocks see for instance Canova and Pappa (2011).

come. In all of the following exercises we maintain parameters to the calibrated values displayed in Table 3.1, unless otherwise specified.

In Figure 3.4, we plot the impulse response function of market consumption for different values of ξ that we decrease from 50 to the lower bound of the empirically relevant range, 3. This exercise shows that capital adjustment costs are important for the elasticity of labor supply to government expenditure shocks. However, under our baseline parametrization, market consumption increases for all the values of the adjustment cost that are above the lower bound typically used in the literature.

As far as σ is concerned, its quantitative relevance is assessed in Figure 3.5. The left hand panel displays the impulse response of market consumption for different values of σ, while the right hand panel shows the corresponding plots for the model without a home production sector. It is evident that the inter-temporal elasticity of substitution is a key parameter, even though an elasticity in line with the microeconomic evidence cannot generate a rise in market consumption if a home production sector is not included in the model.

Figure 3.6 makes sure that the inclusion of distortive tax rates on capital and labor income does not undermine our results. In particular, the figure plots the impulse response of market consumption and GDP when capital and labor are taxed at rates equal to 0.57 and 0.23, respectively. The values have been chosen in line with the estimates by McGrattan et al. (1997).

We conclude this section by showing that under a plausible parametrization the model is not able to generate a positive response of market consumption either when the home production sector is not included or when one abstracts from nominal price rigidities. To this purpose, we consider 50000 draws of parameters from uniform distributions defined over an empirically relevant range. In particular, we consider the following parameters with their respective bounds: $\theta \in [0, 0.8]$, $\xi \in [0, 25]$, $\rho_g \in [0, 0.99]$, $\Phi_\pi \in [1.1, 1.5]$, $\varepsilon \in [6, 11]$, $G \in [0.05, 0.25]$, and $b_1 \in [0.3, 0.8]$. The 50000 draws generate a distribution of impulse response functions of market consumption to government expenditure shocks. Figure 3.7 plots the median, the 75-th and the 25-th quantiles of such distribution. The left hand panel reports the case without home production but with nominal rigidities, while the right hand panel shows the case of home production under flexible prices.

3.4.3 Comparison with the VAR evidence

The VAR evidence seems to agree that fiscal expansions stimulate demand and increase aggregate consumption. See for instance Caldara and Kamps (2008) and Perotti (2008). Various theories accounting for the VAR estimates have been proposed in the literature. Our main argument is not meant to be an exhaustive alternative explanation, rather it is intended to point out that the substitutability between market and home consumption has important effects on the labor supply elasticity that are relevant for fiscal expansions. Still, we believe it is interesting to see to what extent our channel alone is consistent with the conditional evidence. To this purpose, we identify fiscal shocks by resorting to the restriction proposed by Blanchard and Perotti (2002) and we quantify their impact on market consumption, GDP and the nominal interest rate in the data. Then, we compare the empirical responses with the predictions of our model. We are interested in the behavior of the nominal interest rate, because, as we anticipated above, modelling the interaction between monetary and fiscal policy is crucial.

In addition to the data described above, we collect the quarterly and seasonally adjusted time series of tax revenues net of transfers from the U.S. Bureau of Economic Analysis and the three month treasury bill rate from the Federal Reserve Bank of St. Louis database. The reduced form model contains a constant and a trend and the following variables in this particular order: The log of real per capita tax revenues, the log of real per capita government consumption expenditures, the log of real GDP per capita, the log of real private consumption expenditures and the rate on T-bills. The lag length of our VAR model is based on information criteria and set equal to two. The ordering of the variables in the VAR implies that government spending does not react contemporaneously to changes in output and private consumption, nor to changes in the monetary policy instrument[18]. Figure 3.8 presents the responses of endogenous variables to a shock in government spending normalized to one percent of GDP. After the shock, both output and consumption increase significantly and tax revenues react positively with a lag. The nominal interest rate does not react significantly on impact, it increases two periods after the shock and falls thereafter and significantly so approximately six quarters after the initial impact.

In order to compare the model to the data, we perform the following exercise. First, we choose a monetary policy rule that qualitatively matches the response of the nominal interest rate to an expansionary fiscal shock. Then, we look for the elasticity of substitution between home and market goods such that the model delivers an impact response of market consumption that is consistent with the data. Finally, we make sure that the needed value of b_1 agrees with previous estimates and, in particular, with microeconomic data.

A simple Taylor rule as the one assumed in (3.2) implies that the central bank tightens the monetary stance by raising the nominal interest rate, after an expansionary fiscal shock. However, even though the monetary policy maker wants to aggressively react to inflation unconditionally, she may prefer to accommodate an exogenous government expenditure shock and avoid increasing the interest rate right when the fiscal policy maker is expanding. This intuition seems to be consistent with our estimated response of the nominal interest. A simple monetary rule augmented with an interest rate smoother that keeps a long-run inflation response of 1.5 as in (3.2) qualitatively

[18]We have used alternative sign restrictions to identify the government spending shock as a shock that moves positively output, deficits and government spending. Results are very similar and we do not present them here for economy of space.

replicates the conditional evidence. Hence, we consider the following rule

$$(1 + R_t) = (1 + R_{t-1})^{\rho_m} \left\{\beta^{-1}\Pi_t^{\Phi_\pi}\right\}^{1-\rho_m}$$

We maintain Φ_π as in Table 3.1 and we choose[19] $\rho_m = 0.82$. Also, we set $\rho_g = 0.85$ to match the persistence of the identified government expenditure shock. Finally, we choose $b_1 = 0.8$. Figure 3.8 shows that our mechanism is able to reproduce the conditional evidence on the response of market of consumption and it generates a fiscal multiplier higher than 1, that is however somewhat over-predicted. Since $b_1 = 0.8$ is admittedly on the upper bound of available estimates, we repeat the comparison in Figure 3.9 by imposing a more conservative parametrization and setting $b_1 = 0.6$. In this case, we can explain about half of the response of consumption and we match exactly the impact response of GDP. The model fails to replicate the persistence of both consumption and output.

3.5 Conclusions

We build an otherwise standard New-Keynesian model that encompasses a home production sector and we show that, for plausible calibrations of the elasticity of substitution between home and market goods, after a fiscal expansion market consumption increases. In addition, we can match the predicted size of the output multipliers with the empirical estimates. The presence of nominal rigidities and the possibility of substituting housework with market work makes it more attractive to work on the market and to consume market goods when the government is spending. The higher elasticity of labor supply to government expenditure shocks explains the improved ability of the model to match the conditional evidence, as compared to the baseline business cycle model.

[19] See Smets and Wouters (2007), Justiniano, Primiceri and Tambalotti (2010) and Justiniano, Primiceri and Tambalotti (2011).

Table 3.1: Baseline calibration

Parameter	**Mnemonic**	**Value**
Discount Factor	β	0.99
Risk Aversion	σ	2
Preference parameter	α_1	0.5438
Preference parameter	b	0.5089
Technology parameter	α_2	0.1034
Technology parameter	α_3	0.0485
Inverse elasticity of substitution home-market goods	$1 - b_1$	0.25
Inverse elasticity of substitution capital-labor at home	$1 - b_2$	1
Inverse elasticity of substitution capital-labor on the market	$1 - b_3$	1
Elasticity of substitution among final goods varieties	ε	11
Capital adjustment costs	ξ	50
Price stickiness	θ	0.75
Inflation reaction coefficient	ϕ	1.5
Depreciation rate of capital	δ	0.0241
Labor income tax rate	τ_h	0
Capital Income tax rate	τ_k	0
Steady state government expenditure	G	0.0602

Figure 3.1: Impulse responses for the model calibrated as in Table 3.1, labelled as GHP, and impulse responses of the model without home sector, labelled as Baseline.

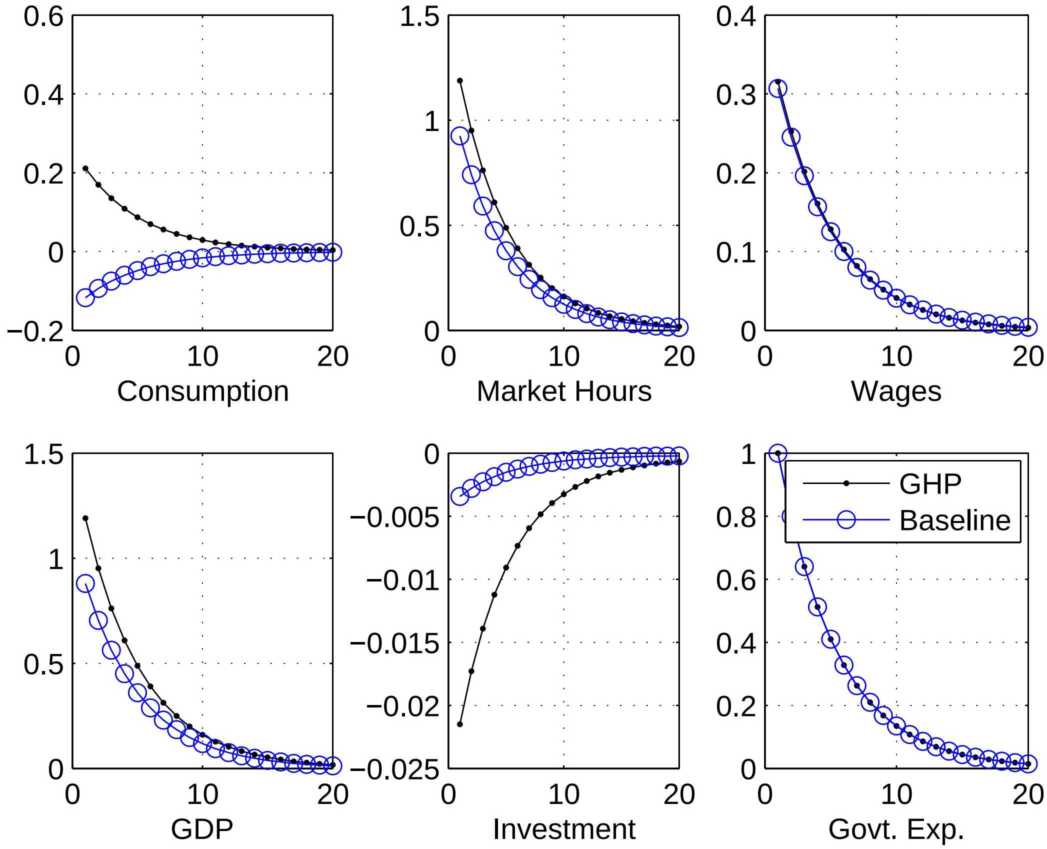


Figure 3.2: Impulse responses of market consumption to a G shock for different values of the elasticity of substitution between home and market goods. All the other parameters are calibrated as in Table 3.1.

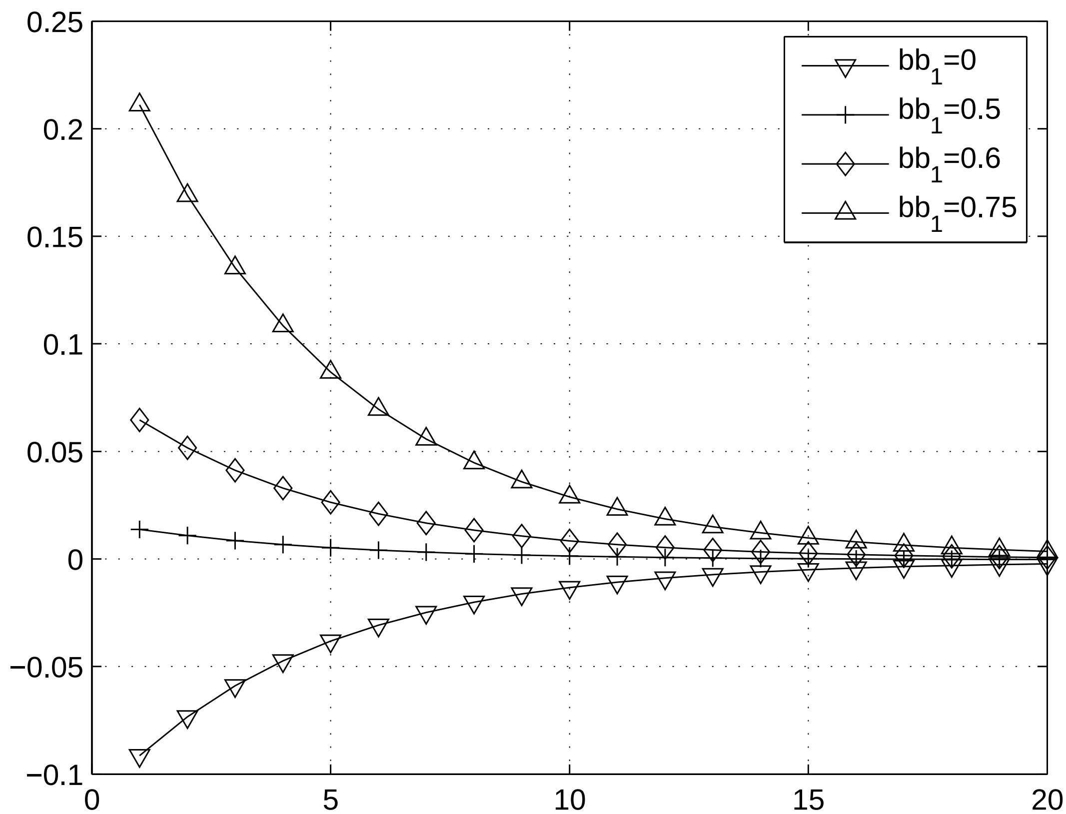


Figure 3.3: Impulse responses of market consumption to a G shock for different values of price stickiness. All the other parameters are calibrated as in Table 3.1.

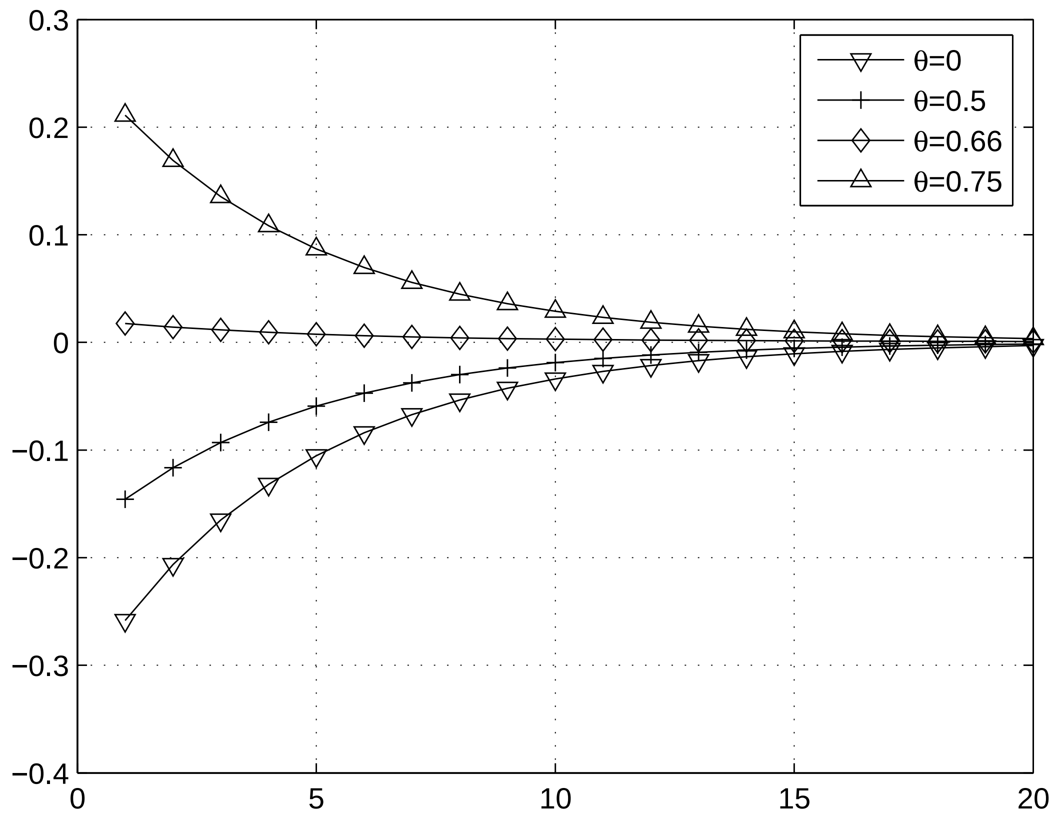


Figure 3.4: Impulse responses of market consumption to a G shock for different values of capital adjustment costs. All the other parameters are calibrated as in Table 3.1.

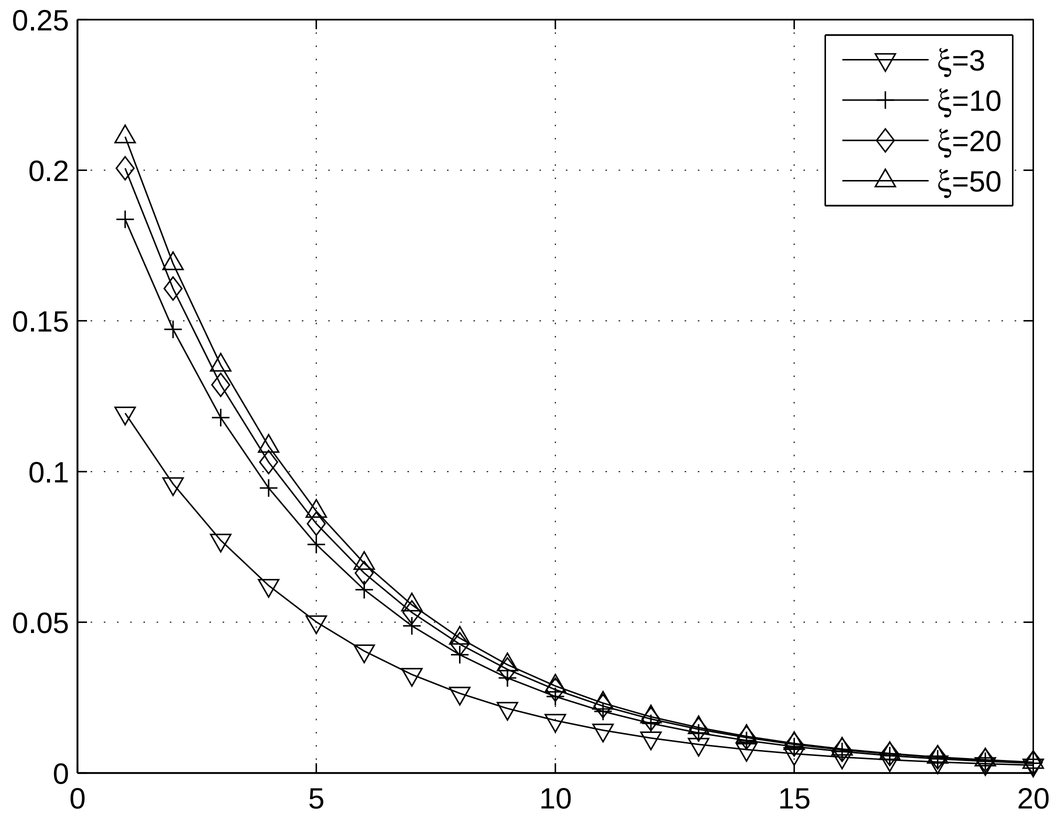


Figure 3.5: Impulse responses of market consumption to a G shock for different values of the elasticity of inter-temporal substitution. All the other parameters are calibrated as in Table 3.1. The left and the right panel show the model with and without home sector, respectively.

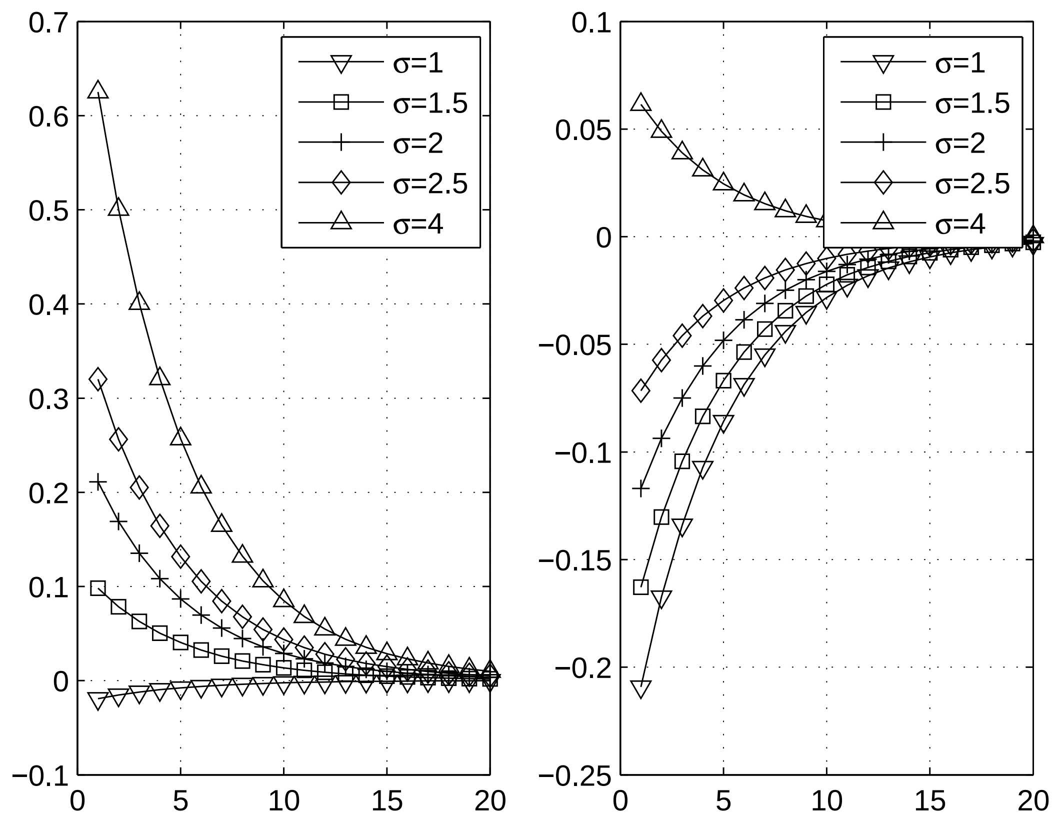


Figure 3.6: Impulse responses for the case of distortive taxation. All the other parameters are calibrated as in Table 3.1. The impulse responses of the model without home sector are labelled as Baseline.

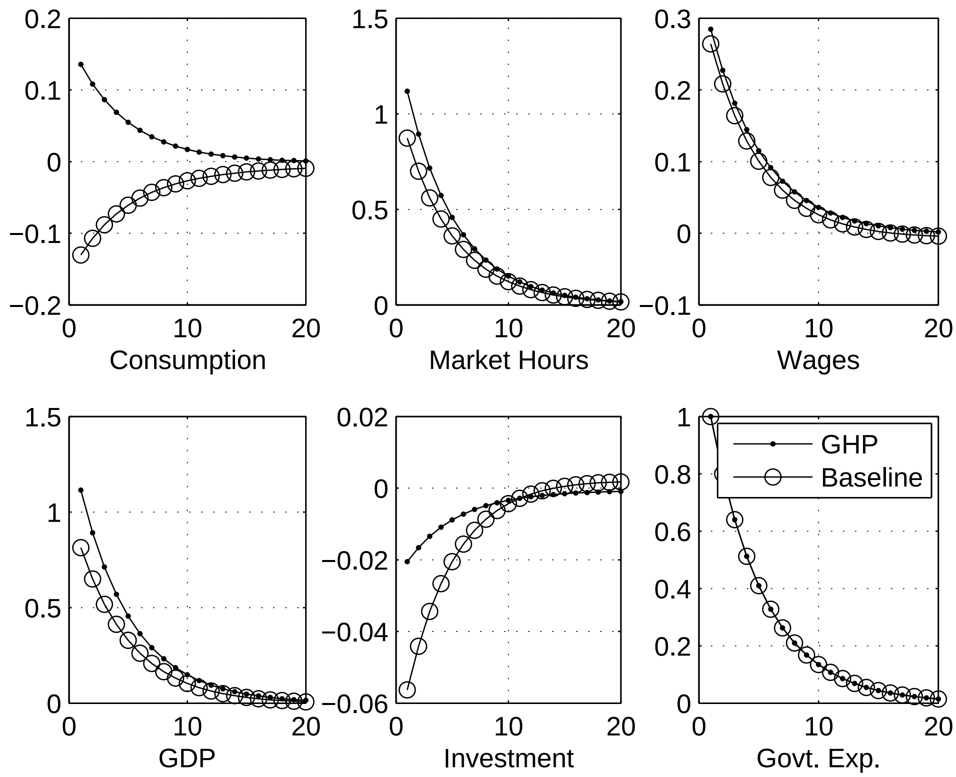


Figure 3.7: 75th, 50-th and 25-th quantiles of the distribution of impulse responses of market consumption to a G shock for 50000 draws uniform distributions of the following parameters, with their respective bounds: $\theta \in [0, 0.8]$, $\xi \in [0, 25]$, $\rho_g \in [0, 0.99]$, $\Phi_\pi \in [1.1, 1.5]$, $\varepsilon \in [6, 11]$, $G \in [0.05, 0.25]$, and $b_1 \in [0.3, 0.8]$. All the other parameters are chosen as in Table 3.1. The left hand panel reports the case without home production but with nominal rigidities, while the right hand panel shows the case of home production under flexible prices.

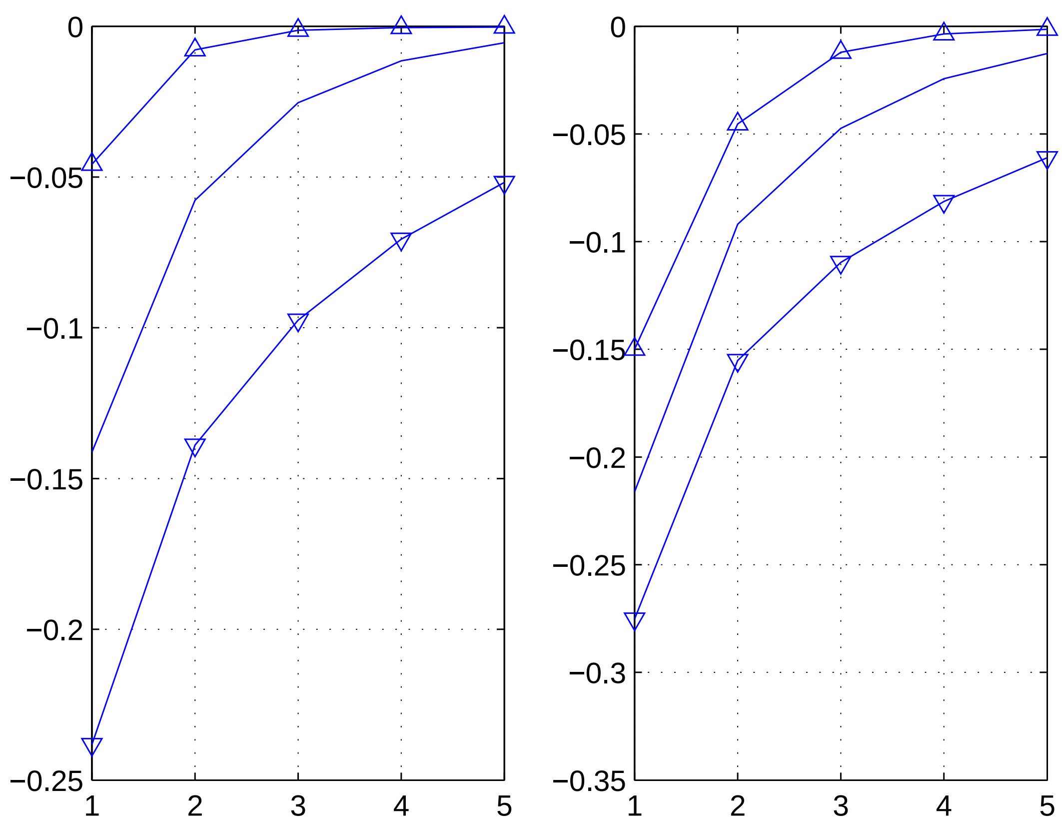


Figure 3.8: Empirical and theoretical impulse responses after an identified government expenditure shock, $b_1 = 0.8$.

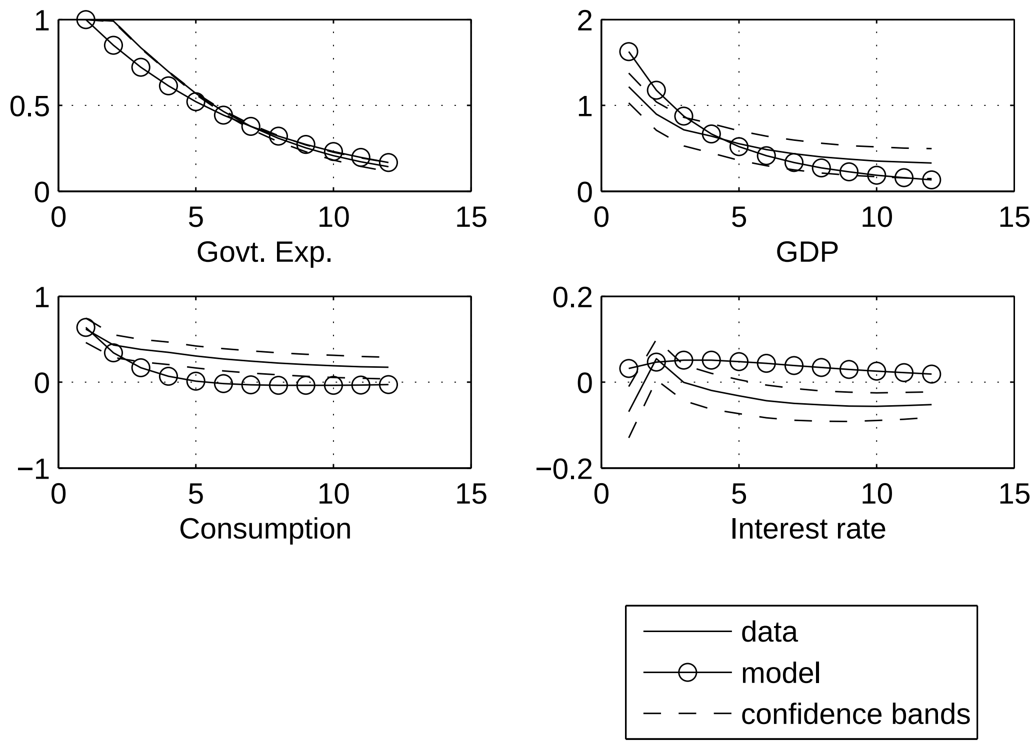
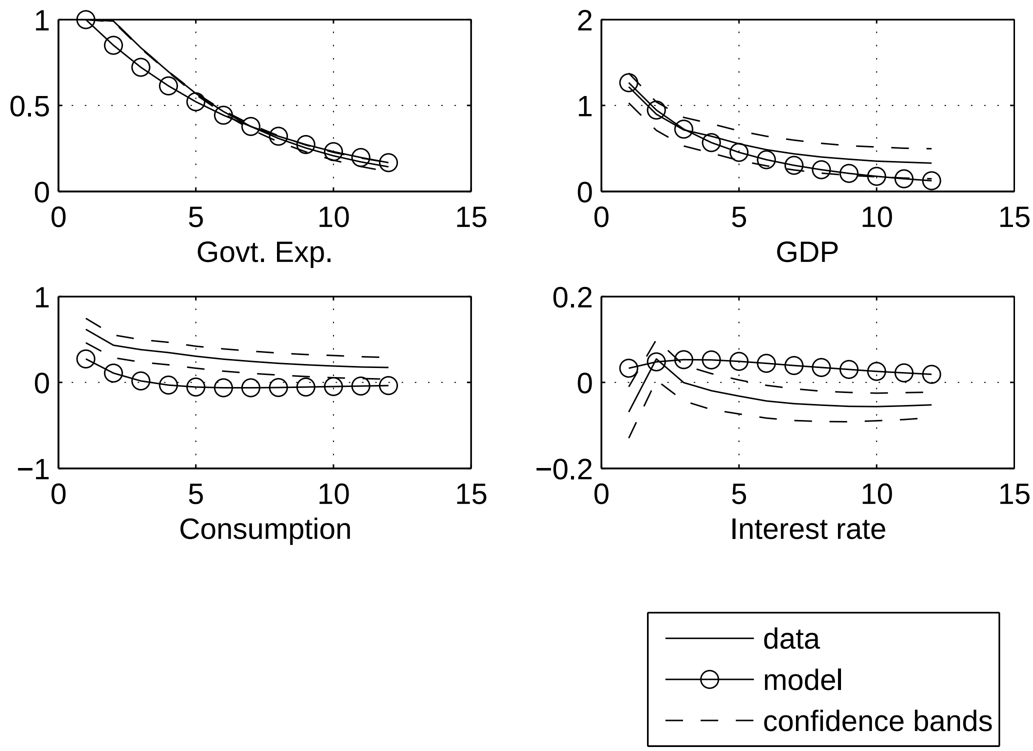


Figure 3.9: Empirical and theoretical impulse responses after an identified government expenditure shock, $b_1 = 0.6$.



Appendix A

Addendum to Chapter 1

A.1 Alternative Model

An alternative way of modelling the friction in firms' pricing behavior is the one proposed in the partial equilibrium model in Uribe (1997): The cost of selling goods in the domestic currency is introduced indirectly by the assumed timing of markets. Firms are allowed to convert Dollar-earnings of a given period t only in the financial market in period $t+1$, such that (expected) devaluation of the nominal exchange rate affects the optimal Dollar-price. Hence, when setting Dollar-prices firms take into account the fact that their production costs are paid for in the domestic currency, whereas their income is denominated in Dollars. Assuming that firms have to bear the production cost today, but will only receive the income of their production tomorrow, makes them to take into account the depreciation of the domestic currency. In particular, a depreciation of the Peso induces production costs to be relatively lower and therefore provides an incentive for firms to set relatively lower Dollar-prices. This alternative modelling strategy does neither affect the households problem, nor the optimal Peso-price, defined by equation (1.15). The maximization problem that firms solve in order to set Dollar-prices now states as follows:

$$\max_{P_{H,t}^{D}(i)} P_{H,t}^{D}(i) Y_t(i) - \frac{W_t}{E_t\left\{\varepsilon_{t+1}\right\} A_t} Y_t(i)$$

subject to the common technology (1.12) and to their demand schedule (1.14). The optimal Dollar-price, which under the modelling assumptions in the main part of Chapter 1 is given by (1.16), is now defined as follows:

$$S^D_{H,t} \equiv \frac{P^D_{H,t}}{P_{H,t}} = \left(\frac{\varepsilon}{\varepsilon - 1}\right) \frac{W_t}{\varepsilon_t A_t P_t} S^\alpha_t E_t \left\{\frac{\varepsilon_t}{\varepsilon_{t+1}}\right\}$$
$$= \left(\frac{\varepsilon}{\varepsilon - 1}\right) MC^D_t E_t \left\{\frac{\varepsilon_t}{\varepsilon_{t+1}}\right\}$$

where $MC^D_t = \frac{W_t}{\varepsilon_t A_t P_t} S^\alpha_t E_t \left\{\frac{\varepsilon_t}{\varepsilon_{t+1}}\right\}$ denotes real marginal cost of production of firms selling the period's production in Dollars. For prices being perfectly flexible, the relationship between the optimal Peso- and Dollar-price, previously defined by equation (1.17), now states as follows:

$$\frac{P^P_{H,t}}{P^D_{H,t}} = E_t \{\varepsilon_{t+1}\}$$

which implies

$$\frac{S^P_t}{S^D_t} = E_t \left\{\frac{\varepsilon_{t+1}}{\varepsilon_1}\right\}$$

The wedge between optimal prices in both sectors is now a function of changes in the nominal exchange rates, whereas in the previous model setup it was depending on the level of the period's nominal exchange rate and the pass-through elasticity.

Assuming the presence of price adjustment costs in the line of Rotemberg (1982), yields the following maximization problem in the Dollar-sector:

$$E_t \sum_{s=0}^{\infty} Q_{t,t+s} \{P^D_{H,t+s}(i) Y_{t+s}(i) - \frac{W_{t+s}}{E_t \{\varepsilon_{t+1+s}\} A_{t+s}} Y_{t+s}(i) -$$
$$\frac{\lambda}{2} \Phi(i, K_{t+s})^{-\varepsilon} \left(\frac{P^D_{H,t+s}(i)}{\Pi^D_{SS} P^D_{H,t+s-1}(i)} - 1\right)^2 Y_{t+s}\}$$

subject to the common technology (1.12) and to their demand schedule (1.14). Assuming $\Pi^D_{SS} = 1$ yields the following first order condition:

$$\left(\Pi^D_{H,t} - 1\right)\Pi^D_{H,t} = Q_{t,t+1}\left(\frac{K_{t+1}}{K_t}\right)^{\alpha_2\varepsilon}\left(\Pi^D_{H,t+1} - 1\right)\left(\Pi^D_{H,t+1}\frac{Y_{t+1}}{Y_t}\right) + \left(\frac{1-\varepsilon}{\lambda}\right)\left(S^D_t\right)^{1-\varepsilon} + \left(\frac{\varepsilon}{\lambda}\right)\left(S^D_t\right)^{-\varepsilon} MC^D_t$$

which coincides with the first order condition of the previous model, except for the marginal cost of production of Dollar-firms, MC^D_t. Consequentially, the log-linearized Dollar-Phillips curve coincides with (1.18) and states as follows:

$$\pi^D_{H,t} = \beta E_t\left\{\pi^D_{H,t+1}\right\} + \eta_8 mc^D_t + \eta_9 s^D_{H,t} + \eta_{10}$$

where $\eta_8 \equiv \left(\frac{\varepsilon}{\lambda}\right)(S^D)^{-\varepsilon}MC^D$, $\eta_9 \equiv \left(\frac{1-2\varepsilon}{\lambda}\right)(S^D)^{1-\varepsilon}$, and η_{10} is a convolution of parameters. $\pi^D_{H,t} = p^D_{H,t} - p^D_{H,t-1}$ defines the evolution of optimal Dollar-prices set by firms. The log-linear version of the marginal cost of production of firms selling in Dollars in the alternative model setup is given by

$$\begin{aligned} mc^D_t &= \sigma y^*_t + \varphi y_t + \left(\frac{1}{1-\alpha}\right)q_t - (1+\varphi)a_t - \left(\frac{\alpha}{1-\alpha}\right)\lambda_t + E_t\left\{e_{t+1}\right\} - e_t \\ &= mc^P_t + e_t - E_t\left\{e_{t+1}\right\} \end{aligned}$$

Hence, changes in the depreciation rate of the domestic currency drive a wedge between the marginal cost of production across the two sectors. The degree of dollarization in the benchmark case with perfectly flexible price, previously defined by equation (1.19) is now given by

$$\Phi(\theta^j_t, K_t) = E_t\left\{\frac{\varepsilon_t}{\varepsilon_{t+1}}\right\}$$

for $j \in [H, F]$. Note, that in this alternative model there is one unique steady state with zero dollarization. Hence, dollarization, unlike in the setup in the main part of Chapter 1, occurs only temporarily, which implies that at the steady state both the Peso- and the Dollar-price are stabilized at the efficient level.

Appendix B

Addendum to Chapter 2

B.1 Data sources and definitions

B.1.1 Data used for the VAR-exercise in Section 2

The data set used for the structural VAR estimation consists of US data series for gross state product, employment and net flows for 48 states in the United States at a yearly frequency from 1976-2008. We exclude Alaska, District of Columbia and Hawaii.

Gross State Product (GSP): Obtained from Bureau of Economic Analysis (BEA). GDP by state is the value added in production by the labor and capital located in a state, originating in all industries in a state (including all private industries and government). GDP by state is the state counterpart of the nation's gross domestic product (GDP).

Employment: Obtained from Bureau of Economic Analysis (BEA). The BEA employment series for states and local areas comprises estimates of the number of jobs, full-time plus part-time, by place of work. Full-time and part-time jobs are counted at equal weight. Employees, sole proprietors, and active partners are included, but unpaid family workers and volunteers are not included.

Labor Productivity: Consistent with Galí (1999) we construct the baseline series for labor productivity for each state by subtracting the log of employment from the log of GDP.

Net Flows: Obtained from Internal Revenue Service (IRS), US Population Migration Data. Internal migration data for the United States are based on year-to-year address changes reported on individual income tax returns filed with the IRS. IRS data include records from the domestic tax forms 1040, 1040A and 1040EZ as well as the foreign tax forms 1040NR, 1040PR, 1040VI and 1040SS and contains about 95 to 98 percent of all returns filed during any given tax year, within the mentioned categories. We focus on the data capturing migration patterns by state for the entire United States. Net flows for a given state are defined as the difference between inflows and outflows, where inflows measures the number of individuals who moved to a state and where they migrated from, and outflows the number of individuals leaving a state and where they went.

B.1.2 Industry-level data used for the empirical exercise in Section 2

Annual average employment per industry and state: Obtained from Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages. Data is available at a yearly frequency from 2001-2007. The series include reported monthly employment data representing the number of covered workers who worked during, or received pay for, the pay period which included the 12th day of the month. The annual average employment is an average of the monthly employment levels.

Annual average number of establishments per industry and state: Obtained from Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages. Data is available at a yearly frequency from 2001-2007. The series include reported number of establishments representing the number of establishments whose activities were reported to the unemployment insurance system for the quarter. An establishment is an economic unit, such as a farm, mine, factory, or store, which produces goods or provides services. It is typically at a single physical location and engaged in one, or predominantly one, type of economic activity for which a single industrial classification may be applied. The annual average number of establishments is an average of the corresponding quarterly number of establishment levels.

Gross Operating Surpluses per industry and state: Obtained from Bureau of Economic Analysis (BEA), Regional Economic Accounts. Data is available at a yearly frequency from 1997-2008. The value is derived as a residual after subtracting total intermediate inputs, compensation of employees, and taxes on production and imports less subsidies from total industry output. Gross operating surplus includes consumption of fixed capital, proprietors' income, corporate profits, and business net current transfer payements. Prior to 2003 this series was referred to as value added or property-type income.

Compensation of Employees per industry and state: Obtained from Bureau of Economic Analysis (BEA), Regional Economic Accounts. Data is available at a yearly frequency from 1997-2008. The series includes the sum of employee wages and salaries and supplements to wages and salaries. Wages and salaries are measured on an accrual, or "when earned" basis.

B.2 Augmented structural VAR

In this Section of the appendix we describe in further detail the augmented, five-variable structural VAR. Compared to the structural VAR discussed in Section 2 of Chapter 2, we additionally include employment in state i. Therefore, the vector of observables for a given pair of states i and j is defined as

$$Y_t = [\Delta x_{i,t}, \Delta x_{j,t}, \Delta n_{i,t}, \Delta n_{j,t}, \Delta net_{ji,t}]'$$

where all variables are defined as in Section 2 of Chapter 2. The corresponding bilateral structural VAR, written as an $MA(\infty)$ states as

$$\begin{bmatrix} \Delta x_{i,t} \\ \Delta x_{j,t} \\ \Delta n_{i,t} \\ \Delta n_{j,t} \\ \Delta net_{ji,t} \end{bmatrix} = \begin{bmatrix} C^{11}(L) & C^{12}(L) & C^{13}(L) & C^{14}(L) & C^{15}(L) \\ C^{21}(L) & C^{22}(L) & C^{23}(L) & C^{24}(L) & C^{25}(L) \\ C^{31}(L) & C^{32}(L) & C^{33}(L) & C^{34}(L) & C^{35}(L) \\ C^{41}(L) & C^{42}(L) & C^{43}(L) & C^{44}(L) & C^{45}(L) \\ C^{51}(L) & C^{52}(L) & C^{53}(L) & C^{54}(L) & C^{55}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_t^1 \\ \varepsilon_t^2 \\ \varepsilon_t^3 \\ \varepsilon_t^4 \\ \varepsilon_t^5 \end{bmatrix} = C(L)\varepsilon_t$$

Our identification restriction is that the structural shocks ε_t^3, ε_t^4, ε_t^5 do not have permanent effects on labor productivity, employment and net flows. This implies that the matrix of long run multipliers, $C(1)$, is lower triangular. As in Section 2 of Chapter 2, we use these long-run restrictions to identify a technology shock in state j, ε_t^2, for each state pair under consideration. Note, that the results of the augmented SVAR are robust to changing the order of employment in either state, and net labor flows.

B.3 Optimality of flexible price equilibrium

In the present appendix we study the implications of labor mobility on the efficient allocation and in particular on the employment subsidy implementing the latter. In the economy of both regions i and j we have various distortions to be present which yield suboptimality of the equilibrium allocation. The present distortions are three: Market power of firms, terms of trade externality, and nominal rigidities. For the particular case of log-utility and unitary elasticity of substitution between domestically produced and imported goods, $\nu_2 = 1$, we can derive analytically the employment subsidy that exactly offsets the combined effects of market power and the terms of trade distortions, and thus rendering the flexible price equilibrium allocation optimal. As we are showing in this appendix, the employment subsidy is not affected by the presence of labor mobility such that it takes the same form as in a standard two country model with a fixed labor force.

B.3.1 Efficient allocation

The social planner in the two sector economy maximizes a weighted average of the utility function in both countries subject to the technological constraints in both sectors, (2.8) and (2.16), and the market clearing conditions for both intermediate and final goods, (2.24) and (2.26). The first order conditions under the assumption of equal weight given to welfare in both countries are defined by

$$N_t^{ii} = \gamma_1 \frac{(L_t^i)^{\gamma_2}}{(N_t^i)^{\gamma_3}} \tag{B.1}$$

where $\gamma_1 \equiv \left(\frac{(1-\alpha_3)^{\frac{1}{\nu_3}}}{(1-\alpha_1)^{\frac{1}{\nu_1}}} \right)^{\frac{\nu_1 \nu_3}{\nu_1 - \nu_3}}$, $\gamma_2 \equiv \frac{\nu_1(1-\nu_3)}{\nu_1 - \nu_3}$, and $\gamma_3 \equiv (\varphi + \frac{1}{\nu_1})(\frac{\nu_1 \nu_3}{\nu_1 - \nu_3})$. Equation B.1 defines the optimal amount of domestic labor in region i as a function of aggregate domestic labor input, L_t^i, and aggregate domestic labor supply, N_t^i.

$$N_t^{ji} = \gamma_4 \frac{(L_t^i)^{\gamma_2}}{(N_t^j)^{\gamma_3}} \tag{B.2}$$

with $\gamma_4 \equiv \left(\frac{(\alpha_3)^{\frac{1}{\nu_3}}}{(\alpha_1)^{\frac{1}{\nu_1}}} \right)^{\frac{\nu_1 \nu_3}{\nu_1 - \nu_3}}$ defines the optimal amount of migrant labor used in production in region i, as a function of aggregate domestic labor input, L_t^i, and aggregate labor supply in the foreign region j.

$$\frac{X_t^{ii}}{X_t^{ji}} = \frac{1-\alpha_2}{\alpha_2}$$

defines the optimal amount of domestically produced vs. imported intermediate goods in production of final goods in region i.

B.3.2 Decentralization of the efficient allocation in the intermediate sector

We know that the flexible price equilibrium satisfies

$$\frac{\varepsilon_x - 1}{\varepsilon_x} = RMC^i_{x,t} \tag{B.3}$$

Using (2.12) together with (2.5), (2.6), (2.8) and (2.25) we can rewrite (B.3) as follows:

$$\frac{\varepsilon_x - 1}{\varepsilon_x} = \left(1 - \tau^i_x\right)\left(L^i_t\right)^{\frac{\nu_3 - 1}{\nu_3}}\left[\gamma_5\left(N^i_t\right)^{\varphi + \frac{1}{\nu_1}}\left(N^{ii}_t\right)^{\frac{1}{\nu_3} - \frac{1}{\nu_1}} + \gamma_6\left(N^j_t\right)^{\varphi + \frac{1}{\nu_1}}\left(N^{ji}_t\right)^{\frac{1}{\nu_3} - \frac{1}{\nu_1}}\right] \tag{B.4}$$

where $\gamma_5 \equiv \left(\frac{(1-\alpha_1)^{\frac{1}{\nu_1}}}{(1-\alpha_3)^{\frac{1}{\nu_3 - 1}}}\right)$ and $\gamma_6 \equiv \left(\frac{(\alpha_1)^{\frac{1}{\nu_1}}}{(\alpha_3)^{\frac{1}{\nu_3 - 1}}}\right)$.
Combining the first order conditions of the social planners problem, (B.1) and (B.2) for both regions i and j, with the two labor aggregation functions (2.4) and (2.9), and equation (B.4) yields:

$$\frac{\varepsilon_x - 1}{\varepsilon_x} = \left(1 - \tau^i_x\right)$$

such that the employment subsidy in the intermediate goods sector, τ^i_x, implementing the optimal allocation under flexible prices is equal to $\frac{1}{\varepsilon_x}$. Allowing for labor mobility in the present setup makes the employment subsidy to be defined as a function of the markup of monopolistic producers as in the standard model with a fixed labor force.

B.3.3 Decentralization of the efficient allocation in the final goods sector

We know that the flexible price equilibrium satisfies

$$\frac{\varepsilon - 1}{\varepsilon} = RMC^i_t \tag{B.5}$$

Combining (B.5) with (2.5), (2.6), (2.8), (2.16), (2.10), (2.11), (2.24), and (2.26) yields

$$\frac{\varepsilon - 1}{\varepsilon} = \left(1 - \tau^i\right)\left(L^i_t\right)^{\frac{\nu_3 - 1}{\nu_3}}\left(N^i_t\right)^{\varphi + \frac{1}{\nu_1}}\left(N^{ii}_t\right)^{\frac{1}{\nu_3} - \frac{1}{\nu_1}}\gamma_7 \tag{B.6}$$

where $\gamma_7 \equiv \left(\frac{(1-\alpha_1)^{\frac{1}{\nu_1}}}{(1-\alpha_3)^{\frac{1}{\nu_3}}} \right)$.

Combining (B.6) with the first order conditions of the social planner yields:

$$\frac{\varepsilon - 1}{\varepsilon} = (1 - \tau^i)$$

such that the employment subsidy implementing the efficient allocation is the same as in a standard two-country model with a fixed labor force.

Appendix C

Addendum to Chapter 3

C.1 Equilibrium Definition

The equilibrium of the model is a set of state contingent plans for variables C_t, $C_{m,t}$, $C_{n,t}$, $K_{m,t}$, $K_{n,t}$, K_t, $h_{m,t}$, $h_{n,t}$, I_t, λ_t, Y_t, Π_t, Δ_t, $\frac{P_t^*}{P_t}$, $x_{1,t}$, $x_{2,t}$, RMC_t, R_t, W_t and r_t that satisfy the following system of equation

$$C_t = \left[\alpha_1 (C_{m,t})^{b_1} + (1-\alpha_1)(C_{n,t})^{b_1}\right]^{\frac{1}{b_1}} \tag{C.1}$$

$$C_{n,t} = \left[\alpha_2 (K_{n,t})^{b_2} + (1-\alpha_2)\left(exp\{s_{n,t}\}h_{n,t}\right)^{b_2}\right]^{\frac{1}{b_2}} \tag{C.2}$$

$$K_t = K_{m,t} + K_{n,t} \tag{C.3}$$

$$exp\{\mu_t\}I_t = K_{t+1} - (1-\delta)K_t + \frac{\xi}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2 \tag{C.4}$$

$$\frac{\alpha_1}{1-\alpha_1}\left[\frac{C_{m,t}}{C_{n,t}}\right]^{b_1-1} = \frac{1-\alpha_2}{W_t(1-\tau_h)}\left[\frac{C_{n,t}}{h_{n,t}}\right]^{1-b_2}\left[exp\{s_{n,t}\}\right]^{b_2} \tag{C.5}$$

$$\frac{\alpha_1}{1-\alpha_1}\left[\frac{C_{m,t}}{C_{n,t}}\right]^{b_1-1} = \frac{\alpha_2}{(1-\tau_k)r_t + \delta\tau_k}\left[\frac{C_{n,t}}{K_{n,t}}\right]^{1-b_2} \tag{C.6}$$

$$W_t(1-\tau_h)(1-h_{n,t}-h_{m,t}) = \frac{1-b}{b\alpha_1} C_{m,t}^{1-b_1} C_t^{b_1} \tag{C.7}$$

$$\beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{exp\{\mu_t\}}{exp\{\mu_{t+1}\}} \left[1 + \frac{\xi}{K_t} \left(\frac{K_{t+1}}{K_t} - 1 \right) \right]^{-1} \right.$$
$$\left. \left[1 - \delta + \xi \left(\frac{K_{t+2}}{K_{t+1}} - 1 \right) \left(\frac{K_{t+2}}{K_{t+1}^2} \right) + exp\{\mu_{t+1}\}(1-\tau_k) r_{t+1} + \delta \tau_k \right] \right\} = 1 \tag{C.8}$$

$$\beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} (1+R_t) \Pi_{t+1}^{-1} \right\} = 1 \tag{C.9}$$

$$\lambda_t = b\alpha_1 (1-h_{n,t}-h_{m,t})^{(1-b)(1-\sigma)} C_{m,t}^{b_1-1} (C_t)^{b(1-\sigma)-b_1} \tag{C.10}$$

$$\frac{P_t^*}{P_t} = \left(\frac{1-\theta \Pi_t^{\varepsilon-1}}{1-\theta} \right)^{\frac{1}{1-\varepsilon}} \tag{C.11}$$

$$\frac{P_t^*}{P_t} = \frac{x_{1,t}}{x_{2,t}} \tag{C.12}$$

$$x_{1,t} = Y_t \frac{\varepsilon}{\varepsilon - 1} RMC_t + \beta\theta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \Pi_{t+1}^{\varepsilon} x_{1,t+1} \right\} \tag{C.13}$$

$$x_{2,t} = Y_t + \beta\theta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \Pi_{t+1}^{\varepsilon-1} x_{2,t+1} \right\} \tag{C.14}$$

$$Y_t = C_{m,t} + I_t + G_t \tag{C.15}$$

$$Y_t = \Delta_t^{-1} \left[\alpha_3 K_{m,t}^{b3} + (1-\alpha_3) h_{m,t}^{b3} \right]^{\frac{1}{b_3}} \tag{C.16}$$

$$\alpha_3 RMC_t \left(\frac{K_{m,t}}{\Delta_t Y_t} \right)^{b_3-1} = r_t \tag{C.17}$$

$$(1-\alpha_3)RMC_t\left(\frac{h_{m,t}}{\Delta_t Y_t}\right)^{b_3-1}[exp\{s_{m,t}\}]^{b_3}=W_t \tag{C.18}$$

$$\Delta_t=(1-\theta)\left(\frac{P_t^*}{P_t}\right)^{-\varepsilon}+\theta\Pi_t^{\varepsilon}\Delta_{t-1} \tag{C.19}$$

$$(1+R_t)=\beta^{-1}\Pi_t^{\Phi_\pi} \tag{C.20}$$

for all t, for given tax rates and government expenditure. To close the equilibrium definition we furthermore need the respective law of motion for market- and home productivity and government expenditures.

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