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THE ROLE OF EXCHANGE RATE PASS-THROUGH AND ASSET MARKET STRUCTURES IN INTERNATIONAL RISK SHARING

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But I will sacrifice unto thee with the voice of thanksgiving; I will pay that that I have vowed. Salvation is of the Lord.

Jonah 2:9

Aknowledgement

I am exceedingly grateful to my God for allowing me to have the opportunity to finish my master's degree. It has been a true blessing.

I am indebted to both of my parents. Their support during this time was essential. Thank you for believing in me. And I especially thank my mom for her unconditional encouragement and prayers during my twenty-five years of life. Once again I am happy to say, 'We did it'.

To my classmates and friends, I express my appreciation. Together we all achieved this. May this be the beginning of a new chapter full of success.

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Abstract

This thesis addresses the Backus-Smith puzzle, which refers to the positive comovement between relative consumption and real exchange rate that arises in open-economy models, whereas this correlation is negative in the data. The proposed model is a two-country, two-good sticky-price DSGE model that allows for pricing-to-market behavior through the inclusion of local retailers. This feature breaks the law of one price and results in incomplete exchange rate pass-through. It also considers two asset market structures: complete and incomplete asset markets. International real business cycles are generated through productivity shocks. The three key findings of the thesis are: 1) Incomplete exchange rate pass-through provides a solution to the Backus-Smith puzzle under both complete and incomplete asset markets; 2) Lower pass-through levels generate more volatile fluctuations in the real exchange rate regardless of the asset market structure; and 3) Introducing incomplete pass-through gives opportunity for a wider interval of the elasticity of substitution between home and foreign goods to resolve the Backus-Smith puzzle.

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Chapter 1

Introduction

A well known puzzle in international macroeconomics is the Backus-Smith puzzle. It refers to the property of open-economy macroeconomic models to generate a positive relationship between relative consumption and the real exchange, in contrast to the negative correlation observed in the data for most country pairs[1]. This means that models predict a high level of international risk sharing, which is opposed to what the data yields. In order to provide evidence for this fact, Table 1.1 reports the correlations between real exchange rate and relative consumption for selected countries relative to the U.S. and to a weighted aggregate of other OECD countries, using annual data.

Different attempts have been made in order to address this puzzle. For example, Obstfeld & Rogoff (2000) suggest that transportation costs and capital market imperfections have an important role in understanding the puzzle. Some other papers have tried to explain the Backus-Smith puzzle by introducing incomplete asset markets (Chari et al., 2002; Adams & Barrett, 2017), limited asset market participation[2] (Kollmann, 2012; Gao et al., 2014), additional shocks[3] (Raffo, 2010; Mandelman et al., 2011; McKnight & Povoledo, 2019; Heathcote & Perri, 2007), non-traded goods (Benigno & Thoenissen, 2008; Tuesta, 2013; Moon, 2016), and distribution services (Corsetti et al., 2008; Selaive & Tuesta, 2003; Selaive & Tuesta, 2006).

In this thesis, I decide to follow the approach of tradable goods distribution costs (transportation, wholesaling, and retailing). Evidence points to the fact that such

[1] Backus & Smith (1993) were the first to illustrate this anomaly.

[2] Kollmann (2012) introduces limited asset market participation by allowing a fraction of households to trade in a complete international financial market. Gao et al. (2014) compares a standard IRBC model with a model that introduces limited asset market participation for different asset market structures.

[3] Raffo (2010) and Mandelman et al. (2011) incorporate investment specific technology shocks, McKnight & Povoledo (2010) use sunspot shocks, and Heathcote & Perri (2007) consider taste shocks.

Table 1.1. Correlations Between Real Exchange Rate and Relative Consumption

	Correlation[1]	
	HP-filtered	
Country	U.S.	Rest of the world
Austria	-0.11	0.05
Canada	-0.52	-0.31
Finland	-0.30	-0.49
France	-0.20	0.43
Germany	-0.51	-0.27
Ireland	-0.39	0.72
Italy	-0.28	-0.52
Japan	0.05	0.25
Netherlands	-0.45	-0.20
Spain	-0.63	-0.64
Sweden	-0.56	-0.40
United Kingdom	-0.51	-0.21
U.S.	N/A	-0.71
Median	-0.42	-0.27

[1] The correlations were taken from Corsetti et al. (2008) for selected countries

distribution costs are high. For example, Burstein et al. (2003) estimate that more than 40% of the retail price in the U.S. is accounted for distribution costs. Moreover, such costs have an important role in determining the dynamics of the real exchange rate. Hence, if the data shows that these costs exist, it is impossible to assume that the purchasing power parity holds, which in turn leads to have deviations in the law of one price. In particular, I look at local retailers who import goods for which the law of one price only holds at the dock, because of the presence of incomplete exchange rate pass-through, following Monacelli (2005). This approach is appropriate, as it is in line with empirical patterns of exchange rate pass-through. Indeed, Campa & Goldberg (2002) estimate pass-through into import prices for 25 OECD countries, where the exchange rate pass-through is understood as the percentage change in local currency import prices resulting from a one percent change in the exchange rate between the exporting and importing country. Table 1.2 summarizes their empirical estimates. The authors have two main findings concerning the behavior of pass-through: 1) In the short-run, pass-through is partial and 2) In the long-run, pass-through tends to be closer to one[4]. These two results would suggest that in open-economy models it is not only appropriate, but necessary to account for incomplete exchange rate pass-through, since the law of one price is not something that constantly holds; this law only holds at the dock. Six out of the twenty-five studied countries showed a moderate low pass-through level (i.e. between 25% and 50%). The exchange rate pass-through for the U.S. in the short-run is of 0.26, while in the long-run it is of 0.41. In line with this later result, Gopinath & Rigobon (2006) estimate that for the U.S. exchange rate pass-through is also low (22%).

Table 1.2. Exchange Rate Pass-Through into Import Prices

	Exchange Rate Pass-Through[1]	
Country	Short-Run	Long-Run
Australia	0.55	0.69
Canada	0.65	0.68
France	0.53	1.21
Germany	0.59	0.79
Ireland	0.79	1.37
Italy	0.67	0.62
Japan	0.88	1.26
Netherlands	0.75	0.77
Spain	0.66	0.56
United Kingdom	0.39	0.47
U.S.	0.26	0.41

[1] The estimated exchange rate pass-through was taken from Campa & Goldberg (2002) for selected countries

Given these facts, the model that is presented in this thesis takes into account exchange rate pass-through in a global economy with two countries and two goods. Within each

[4]Campa & Goldberg (2002) interpret one quarter as short-run and four quarters as long-run.

country there exists a representative agent, a representative final good producer, a continuum of monopolistic competitive firms (owned by the representative agent), a continuum of local retailers that import goods, and a monetary authority. Intermediate firms face staggered price-setting, while importers do not. Local retailers import goods at a cost that follows the law of one price, but sell them at a price they choose according to the demand they face; in doing so, the law of one price is broken. Also, the model contemplates two different asset market structures: complete and incomplete asset markets. The difference between these asset market structures is found in how countries share risk; under incomplete asset markets countries have limited opportunities to do this. It is well known that complete asset markets, considering the case where the law of one price holds, cannot provide a solution to the Backus-Smith puzzle. On the other hand, some studies have been able to provide a solution to the puzzle by examining incomplete asset markets. Hence, it is important to see how the correlation between relative consumption and real exchange rate behaves when considering incomplete exchange rate pass-through and the mentioned asset market structures.

Monacelli (2005) first accounted for these facts and used this approach. Nonetheless, he does that in the environment of a small open economy and considering complete asset markets, with the objective of proposing a realistic representation of monetary policy in an open economy. Therefore, the two main differences between Monacelli (2005) and the model presented in this thesis are that, I consider a two-country model and two different asset market structures (i.e. complete and incomplete asset markets), with the objective of providing an avenue to resolve the Backus-Smith puzzle.

Selaive & Tuesta (2006) build a model considering non-traded goods, complete and incomplete asset markets and distribution services in non-traded goods in order to generate deviations from the law of one price; they also consider a low value for the trade elasticity. The authors successfully simulate a negative correlation between relative consumption and real exchange rate, hence providing a solution to the Backus-Smith puzzle. The key difference in my analysis relative to Selaive & Tuesta (2006) is the introduction of pass-through in local retailers as the main source that generates deviations from the law of one price.

The results of the thesis suggest that introducing incomplete pass-through in a two-country model provides an avenue for solving the Backus-Smith puzzle under both complete and incomplete asset markets. However, in order to achieve this it is important to consider non-separable preferences, because different degrees of pass-through affect the dynamics of the real wage for both countries, which in turn impacts the correlation between relative consumption and real exchange rate. In the particular case of incomplete asset markets, it was noted that real wages are affected by the behavior of the terms of trade of both countries. For low enough values of the trade elasticity κ, it is possible to observe that terms of trade depreciate up to a point where there is a negative correlation between relative consumption and real exchange rate. The model that is proposed in this thesis shows that the expected relative depreciation of the terms of trade plays a key role, given that the trade elasticity has a small value for the baseline model ($\kappa = 0.52$). Moreover, it is highlighted that the dynamics of this term affects the response of the real wage. In regard to the complete asset market case, it was pinpointed that even when analyzing the different variables that could affect the Backus-Smith correlation, a clear single effect could not be isolated. It was checked that the altogether outcome of the relative growth in the real marginal cost and the relative depreciation of the terms of trade affected the response of relative real wage growth. Overall, it is concluded that both the labor market and incomplete pass-through play a role in allowing to have variations in the relationship between relative consumption and real exchange rate. The sensitivity analysis shows that the elasticity of substitution between home and foreign intermediate goods is important in determining the sign of the correlation; lower values produce a lower, yet still positive correlation for the baseline pass-through level. High pass-through levels remain almost irresponsive when allowing for variations in the elasticity, while low degrees of pass-through allow for lower correlations as the elasticity increases. Also, it was noted that introducing incomplete exchange rate pass-through allows to have a wider interval of values for κ that resolve the Backus-Smith puzzle.

Other studies have approached the puzzle by generating deviations in the law of one price. However, most of the literature does not allow for these deviations. Selaive & Tuesta (2003) introduce incomplete asset markets and imperfect exchange rate pass-through in order to study the relationship between relative consumption and real exchange rate. While there are two different channels for real exchange rate fluctuations (deviations from the law of one price coming from traded goods and fluctuations in relative price of non-traded to traded goods), the authors decided to combine both. They find that asset market incompleteness is helpful to address the Backus-Smith puzzle; their model-derived correlations are very low (close to zero). However, they find that incomplete exchange rate pass-through provides no insight to the relationship between relative consumption and real exchange rate. In fact, intermediate levels of pass-through worsens the puzzle. The results of this thesis are different due to the way exchange rate pass-through is modelled (in a pricing-to-market setting). Selaive & Tuesta (2003) incorporate distribution costs as a way to give place to incomplete exchange rate pass-through and allow for a parameter representing the distribution margin to be closely related to the degree of pass-through. The pricing-to-market approach is more realistic, because it considers a continuum of degrees of pass-through that can account for the empirical evidence on exchange rate pass-through.

Corsetti et al. (2002) consider a standard open-economy model with distributive trade and manufacturers with monopoly power. Deviations from the law of one price arise from the monopolistic producers deciding to set different producer prices in the home and foreign countries. They find a correlation that is close to zero or negative. The authors argue that the relation between relative consumption and real exchange rate will depend on which sector receives a productivity shock. Shocks to the non-traded goods sector produce a positive comovement between the variables, while shocks to the traded goods sector generate a negative relationship. This thesis differs on how deviations from the law of one price are generated. The setting of Corsetti et al. (2002) implies that the trade elasticity can be country-specific, which is what allows to break the law of one price. Furthermore, they attribute their results to the imperfect sharing and the deviation from the law of one price. In contrast to this, the results of this thesis suggest that the effects of deviations caused by incomplete exchange rate pass-through and incomplete asset markets by themselves can resolve the Backus-Smith puzzle. Nonetheless, incomplete pass-through gives the opportunity to extend the possible values of the trade elasticity that can give a solution to the puzzle.

Itskhoki & Mukhin (2017) present a dynamic general equilibrium model of exchange rate determination with incomplete asset markets and a transmission mechanism that has four characteristics: 1) Significant home bias, 2) Pricing-to-market and deviations from the law of one price, 3) Low substitutability between home and foreign goods, and 4) Monetary policy that stabilizes domestic inflation. They argue that having a weak elasticity between home and foreign goods helps in resolving the Backus-Smith puzzle. Rather than focusing on risk sharing, they center on expenditure switching in the goods market and find that this is the force that dictates the relation between relative consumption and real exchange rate. Their results confirm this, as they find a negative correlation between these two variables. The results presented in this thesis go in line with the findings of these authors. A small elasticity between home and foreign intermediate goods provides a solution to the Backus-Smith puzzle for different degrees of exchange rate pass-through.

Corsetti et al. (2008) develop a two-country model with production that includes traded and non-traded goods. Deviations from the purchasing power parity (and hence from the law of one price) are generated through the distribution of traded goods, which require η units of the non-traded good. This feature generates a gap between producer and consumer prices, such that the law of one price does not hold at the consumer level. Technology shocks to the traded and non-traded sectors are considered. Their results depend on the value that is set for the price elasticity of traded goods; the authors considered two different calibrations (one low by using moment matching between the model and the data, and one high which was taken from the literature). Results shows that for low values of the trade elasticity, a negative correlation was observed between relative consumption and real exchange rate (although it was not as low as in the data). On the other hand, a high value of the trade elasticity additionally needed highly persistent productivity shocks in order to solve the Backus-Smith puzzle. Once again, it can be said that the shown results in this thesis go in line with the outcomes of these authors, as low values of the trade elasticity play an important role in solving the Backus-Smith puzzle. Moreover, they highlight the negative transmission effect as the mechanism through which an appreciation of the terms of trade, followed by a positive domestic productivity shock, accompanied with a low trade elasticity can address the Backus-Smith puzzle. This thesis shows that the expected relative depreciation of the terms of trade serves as a mechanism to solve the puzzle.

The thesis is organized in six chapters. In Chapter 2 I introduce a detailed literature review. Chapter 3 presents the baseline model. Chapter 4 describes the parameterization that is considered for the model, as well as the role that exchange rate pass-through has in generating fluctuations in the real exchange rate. In Chapter 5 I present the theoretical moments that the baseline model generates for different degrees of pass-through. Chapter 6 then performs a sensitivity analysis on two specific parameters of the model (home bias and the elasticity of substitution between domestic and foreign intermediate goods). Finally, Chapter 7 gives the conclusions. Appendix A contains a detailed description of the solution for both models that were contemplated and Appendix B displays the impulse response functions of selected variables.

Chapter 2

Literature Review

As it was mentioned in the previous Chapter, the Backus-Smith puzzle has been addressed considering different approaches. However, it should be stated that it is hard to find in the literature that a single approach is followed, which means that in many (if not all) cases, authors will try to combine some of them.

Chari et al. (2002) developed a two-country model with complete asset markets, local currency pricing, and nominal rigidity under a Taylor pricing rule. However, the correlation between real exchange rate and relative consumption remained positive and close to one. Different fixes were attempted, such as introducing shocks to productivity and government purchases, nominal wage stickiness, habit persistence in consumption, and incomplete asset markets. The results to all these approaches, except for nominal wage stickiness, were not successful due to the fact that there were no quantitative differences with respect to the benchmark model. Labor market frictions somewhat improved the baseline model, but it was not enough.

Adams & Barrett (2017) argue that asset market incompleteness can provide a solution to the Backus-Smith puzzle. However, the type of incompleteness is important, as most of the papers that take this approach omit, and therefore oversimplify financial markets, portfolio choice. The key mechanism that these authors introduce in their otherwise standard open-economy model is that households can hedge their income risk by only using asymmetric nominal foreign and domestic bonds. The model is driven by real productivity shocks and nominal shocks to prices of country-specific tradable intermediate goods. Considering this forgotten mechanism, they can successfully generate a negative correlation between relative consumption and real exchange rate.

Kollmann (2012) conveys that considering limited asset markets participation (i.e. a subset of households trade freely in financial asset markets), LAMP hereafter, solves the Backus-Smith puzzle. He includes this feature in a two-country, two-good model with investment that is driven by country-specific shocks to output, investment spending, and the share of GDP received by households that do not participate in financial markets. The setting of limited participation is relevant, because by doing this it is allowed to have within-country heterogeneity in risk hedging. In fact, the author motivates the use of this approach by saying that it has been empirically tested that a fraction of households do not hold financial assets and few households hold foreign assets.

Gao et al. (2014) adapt the model proposed by Backus et al. (1992, 1994), BKK hereafter, introducing three financial regimes (financial autarky, bond economy, and complete markets) and LAMP to study international business cycles. While they find that their LAMP models outperform the BKK models, the correlation between relative consumption and real exchange rate remains positive. In fact, introducing LAMP only reduces the correlation marginally.

Raffo (2010) incorporates investment-specific technology shocks, which she argues have a similar role as taste shocks, to a standard two-country BKK model with preferences that have no intertemporal substitution on labor efforts. The estimated results prove to deliver a solution to the Backus-Smith puzzle. Mandelman et al. (2011) also follow this approach and successfully address the puzzle. McKnight & Povoledo (2019) model a two-country economy with incomplete asset markets, sunspot shocks, and indivisble labor. They show that the last two mentioned features can induce a negative Backus-Smith correlation. Heathcote & Perri (2007) introduce taste shocks (i.e. shocks to the agent's utility function) to an extension of the BKK model as part of their sensitivity analysis. They find that a positive taste shock increases relative consumption, while it decreases the terms of trade and the real exchange rate. Therefore, the Backus-Smith puzzle is resolved.

Opazo (2006) introduces expectations on future productivity to a standard international real business cycle model, which are received through public signals, in order to generate consumption smoothing dynamics. When positive signals are observed, the mechanism leads to an appreciation of the real exchange rate combined with an increase in relative consumption. The correlation he derives proves to be similar to empirical data.

Benigno & Thoenissen (2008) incorporate non-traded goods to a two-country model under incomplete asset markets and allowing the law of one price to hold. They consider productivity shocks to the traded and non-traded goods sectors. The authors find that relative consumption and real exchange rate move in the same direction after a positive shock in the non-traded goods sector, similar to the complete asset market case they study. Contrary to this, these two variables move in opposite directions following a positive productivity shock in the traded sector. Nonetheless, this negative comovement is not strong enough, which is confirmed by the still positive, but small Backus-Smith correlation (0.10) they report.

Tuesta (2013) builds a model in line with Chari et al. (2002) and Stockman & Tesar (1995) with the objective of generating wealth effects in order to account for the Backus-Smith puzzle. There are three key features: 1) Incomplete asset markets with a stationary net foreign asset position, 2) Non-traded goods that help generating wealth effects, and 3) Distribution services for the non-traded goods sector, which give rise to deviations from the law of one price. His results provide a negative correlation between relative consumption and real exchange rate following a productivity shock in the traded sector. Moon (2016) proposes an international real business cycle model that considers incomplete asset markets, non-traded goods, and intermediate goods producers with fixed costs of entry. She finds that positive productivity shocks to the traded goods sector yield a negative Backus-Smith correlation.

Karabarbounis (2014) considers home produced and market purchased goods that enter the utility function in a non-separable way, and labor wedges in the model, features that help to match different facts of international business cycles and to simulate a negative correlation between real exchange rate and relative consumption. Thoenissen (2011) presents a two-country model with no deviations from the law of one price and incomplete asset markets, allowing for variations in the elasticity of traded goods. While his baseline model does not solve the puzzle, he argues that lower values for this elasticity can provide an answer through negative transmission. This mechanism suggests that a positive productivity shock leads the terms of trade and the real exchange rate to appreciate, while relative consumption increases, which simulates a negative Backus-Smith correlation.

Chapter 3

The Model

The model is a modification of McKnight (2011) allowing for local retailers, who import differentiated goods, which generates deviations from the law of one price depending on the degree of pass-through following Monacelli (2005). Moreover, this model contemplates two different asset market structures: complete and incomplete financial asset markets.

Consider a cashless global economy with two countries denoted as home (H) and foreign (F), where an asterisk denotes foreign variables. Within each country there exists a representative infinitely-lived agent, a representative final good producer, a continuum of monopolistic competitive firms (owned by the representative agent), a continuum of local retailers that import goods, and a monetary authority. The representative agent supplies labor and capital to the production process. Domestic intermediate firms use labor and capital as inputs to produce intermediate goods. Home producers sell to the home final good producer and the foreign importers, who then resell the good to the foreign final good producer. Intermediate firms have a staggered price-setting mechanism, whereas importers do not. Each representative final good producer is a competitive firm that bundles home and foreign intermediate goods into a non-tradable final good, which is consumed and used for investment purposes by the representative agent. The monetary authority implements monetary policy through the control of the nominal interest rate and adjusts it in response to changes in current inflation and output. Preferences and technologies are symmetric across both countries. Business cycles are generated by productivity shocks. The following presents the features of the model for the home country, where the foreign case can be analogously derived.

3.1 Final Good Producers

The home final good (Z_t) is produced by a competitive firm that uses domestic ($Z_{H,t}$) and imported ($Z_{F,t}$) inputs following a CES aggregation technology:

$$Z_t = \left[a^{\frac{1}{\kappa}} Z_{H,t}^{\frac{\kappa-1}{\kappa}} + (1-a)^{\frac{1}{\kappa}} Z_{F,t}^{\frac{\kappa-1}{\kappa}} \right]^{\frac{\kappa}{\kappa-1}} \tag{3.1}$$

where $\kappa > 0$ represents the constant elasticity of substitution between aggregate home and foreign intermediate goods. The relative share of domestic and imported intermediate goods is given by a, where $0 < a < 1$. The inputs $Z_{H,t}$ and $Z_{F,t}$ are defined as the quantity indices of domestic and imported intermediate goods respectively:

$$Z_{H,t} = \left[\int_0^1 z_{H,t}(i)^{\frac{\lambda-1}{\lambda}} di \right]^{\frac{\lambda}{\lambda-1}} \qquad Z_{F,t} = \left[\int_0^1 z_{F,t}(j)^{\frac{\lambda-1}{\lambda}} dj \right]^{\frac{\lambda}{\lambda-1}} \tag{3.2}$$

where $\lambda > 1$ represents the elasticity of substitution across domestic and foreign intermediate goods, and $z_{H,t}(i)$ and $z_{F,t}(j)$ are the respective quantities of the domestic and foreign type i and j intermediate goods. Profit maximization of the final good producer yields the aggregate demand conditions for the home and foreign intermediate goods:

$$Z_{H,t} = a\left(\frac{P_{H,t}}{P_t}\right)^{-\kappa} Z_t \qquad Z_{F,t} = (1-a)\left(\frac{P_{F,t}}{P_t}\right)^{-\kappa} Z_t \tag{3.3}$$

where the demand for individuals goods is given by:

$$z_{H,t}(i) = \left(\frac{p_{H,t}(i)}{P_{H,t}}\right)^{-\lambda} Z_{H,t} \qquad z_{F,t}(j) = \left(\frac{p_{F,t}(j)}{P_{F,t}}\right)^{-\lambda} Z_{F,t} \tag{3.4}$$

Furthermore, given that the final good producer is competitive, its price is set equal to marginal cost (it is assumed that the investment price is equal to the consumption price):

$$P_t = \left[a P_{H,t}^{1-\kappa} + (1-a) P_{F,t}^{1-\kappa} \right]^{\frac{1}{1-\kappa}} \tag{3.5}$$

where P_t is the consumer price index and $P_{H,t}$ and $P_{F,t}$ are the respective price indices of the home and foreign intermediate goods, all denominated in home currency. The price indices $P_{H,t}$ and $P_{F,t}$ are defined by:

$$P_{H,t} = \left[\int_0^1 p_{H,t}(i)^{1-\lambda} di \right]^{\frac{1}{1-\lambda}} \qquad P_{F,t} = \left[\int_0^1 p_{F,t}(i)^{1-\lambda} di \right]^{\frac{1}{1-\lambda}} \tag{3.6}$$

Let S_t be the nominal exchange rate, defined as the units of domestic currency needed to buy one unit of foreign currency, and $Q_t = \frac{S_t P_t^*}{P_t}$ the real exchange rate. Moreover, let $T_t \equiv \frac{P_{F,t}}{P_{H,t}}$ be the terms of trade of the home country and $T_t^* \equiv \frac{P_{H,t}^*}{P_{F,t}^*}$ the terms of trade of the foreign country.

3.2 Intermediate Goods Producers

3.2.1 Domestic Producers

There is a continuum of monopolistic competitive firms that are owned by households. Firms produce goods using capital and labor services. A firm of type i has a production technology:

$$y_t(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha} \tag{3.7}$$

where A_t represents the technology level, $K_t(i)$ and $L_t(i)$ represent the capital and labor usage respectively, and the input share is $0 < \alpha < 1$. The level of technology expressed in log-deviations, $\hat{A}_t = \frac{A_t - A}{A}$, evolves according to an exogenous AR(1) process given by:

$$\hat{A}_t = \rho \hat{A}_{t-1} + \varepsilon_t \tag{3.8}$$

where $\rho \in [0, 1]$ is the persistence of productivity growth and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$ is an i.i.d. shock. Given competitive prices of labor and capital, cost minimization yields:

$$w_t = mc_t(1-\alpha)A_t\left(\frac{P_{H,t}}{P_t}\right)\left(\frac{K_t}{L_t}\right)^{\alpha} \tag{3.9}$$

$$rr_t = mc_t \alpha A_t\left(\frac{P_{H,t}}{P_t}\right)\left(\frac{L_t}{K_t}\right)^{1-\alpha} \tag{3.10}$$

where w_t and rr_t represent the real wage rate and the capital rental cost respectively, and $mc_t = \frac{MC_t}{P_{H,t}}$ is the real marginal cost[1].

Simultaneously, each home firm i wants to set a price to maximize its profits by selecting an optimum price, which will be the same for both home and foreign markets. Firms set prices under the Calvo-Yun pricing rule, where $\theta_H \in [0, 1]$ is the constant random price signal that firms receive. Hence, each domestic firm i wants to solve the following problem:

$$\begin{aligned} \max_{p_{H,t}^{new}(i)} \quad & E_t\left\{\sum_{k=0}^{\infty} \beta^k \Lambda_{t,t+k} \theta_H^k \left[p_{H,t}^{new}(i) - MC_{t+k}(i)\right]\left[z_{H,t+k}(i) + z_{H,t+k}^*(i)\right]\right\} \\ \text{s.t} \quad & z_{H,t+k}(i) + z_{H,t+k}^*(i) = \left(\frac{p_{H,t}^{new}(i)}{P_{H,t+k}}\right)^{-\lambda}\left[Z_{H,t+k} + Z_{H,t+k}^*\right] \end{aligned} \tag{3.11}$$

where the firm's stochastic discount factor is given by:

$$\beta^k \Lambda_{t,t+k} = \frac{U_c(C_{t+k}, L_{t+k})}{U_c(C_t, L_t)} \frac{P_t}{P_{t+k}} \tag{3.12}$$

[1]Given that $P_t w_t$ and $P_t rr_t$ are common to all intermediate home firms, the nominal marginal cost must be the same across all intermediate home firms such that $MC_t(i) = MC_t$. Hence, it follows that $mc_t(i) = mc_t$.

and θ_H^k is the probability that price $p_{H,t}^{new}(i)$ still holds k periods ahead. The solution yields the following price:

$$p_{H,t}^{new}(i) = P_{H,t}^{new} = \left(\frac{\lambda}{\lambda-1}\right)\frac{E_t\Big\{\sum_{k=0}^{\infty}\beta^k\Lambda_{t,t+k}\theta_H^k P_{H,t+k}^{\lambda} MC_{t+k}\Big(Z_{H,t+k}+Z_{H,t+k}^*\Big)\Big\}}{E_t\Big\{\sum_{k=0}^{\infty}\beta^k\Lambda_{t,t+k}\theta_H^k P_{H,t+k}^{\lambda}\Big(Z_{H,t+k}+Z_{H,t+k}^*\Big)\Big\}} \tag{3.13}$$

This optimal price-setting condition says that the optimal price set is a markup, $\frac{\lambda}{\lambda-1} > 1$, over the weighted average of current and future nominal marginal costs. The weights depend on future demand and how quickly the firm discounts profits. The evolution of the aggregate price index is given by:

$$P_{H,t}^{1-\lambda} = \theta_H P_{H,t-1}^{1-\lambda} + (1-\theta_H)P_{H,t}^{new 1-\lambda} \tag{3.14}$$

3.2.2 Local Retailers

Local retailers in the home country import good j at a cost $S_t p_{F,t}^*(j)$. Following Monacelli (2005), a local retailer will solve the following problem:

$$\begin{aligned} \max_{p_{F,t}^{new}(j)} \quad & E_t\left\{\sum_{k=0}^{\infty}\beta^k\Lambda_{t,t+k}\theta_F^k(p_{F,t}^{new}(j) - S_{t+k}p_{F,t+k}^*(j))z_{F,t+k}(j)\right\} \\ \text{s.t} \quad & z_{F,t+k}(j) = \left(\frac{p_{F,t}^{new}(j)}{P_{F,t+k}}\right)^{-\lambda} Z_{F,t+k} \end{aligned} \tag{3.15}$$

where $p_{F,t}^*(j)$ is the foreign currency price of the imported good, $\theta_F \in [0,1]$ is the probability that the price $p_{F,t}^{new}(j)$ set for good j at time t still holds k periods ahead, and $\beta^k\Lambda_{t,t+k}$ is the stochastic discount factor of the local retailer (which is the same as for domestic firm i). The first order condition of this problem yields:

$$p_{F,t}^{new}(j) = P_{F,t}^{new} = \left(\frac{\lambda}{\lambda-1}\right)\frac{E_t\Big\{\sum_{k=0}^{\infty}\beta^k\Lambda_{t,t+k}\theta_F^k S_{t+k}P_{F,t+k}^* z_{F,t+k}(j)\Big\}}{E_t\Big\{\sum_{k=0}^{\infty}\beta^k\Lambda_{t,t+k}\theta_F^k z_{F,t+k}(j)\Big\}} \tag{3.16}$$

The aggregate import price evolves according to:

$$P_{F,t} = P_{F,,t-1}^{\theta_F} P_{F,t}^{new(1-\theta_F)} \tag{3.17}$$

where θ_F is the parameter that governs the degree of exchange rate pass-through. When $\theta_F > 0$, pass-through is incomplete and the law of one price does not hold, which in turn produces deviations from the purchasing power parity.

The optimal price-setting condition (3.16) says that the optimal price set is a markup, $\frac{\lambda}{\lambda-1} > 1$, over the weighted average of the current and future world price (in domestic currency) of the imported good j. Let $\theta_F = 0$. It follows from equation (3.16) that:

$$P_{F,t}^{new} = \frac{\lambda}{\lambda - 1} S_t P_{F,t}^{*} \tag{3.18}$$

which indicates that local retailers set a price equal to a constant markup over the price they pay in the world market. Combining this result with equation (3.17) yields:

$$P_{F,t} = \frac{\lambda}{\lambda - 1} S_t P_{F,t}^{*} \tag{3.19}$$

When $\theta_F = 0$, it is said that pass-through is complete. It is possible to see that equation (3.19) has a similar resemblance to the well known law of one price. However, the log-linear version of this equation transforms into a simple law of one price.

3.3 Representative Agent

The representative agent is infinitely lived and chooses real consumption (C_t) and labor (L_t) to maximize expected discounted utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\rho} C_t^{1-\rho} (1 - L_t)^{\eta} \right] \tag{3.20}$$

where E_t denotes expectations conditional on the information set at date t, β is the discount factor with $0 < \beta < 1$, $\rho > 0, \rho \neq 1$ is the relative risk aversion in consumption, and $\eta < 0$ is the inverse of the intertemporal elasticity of substitution in leisure.

The representative agent owns the capital stock K_t and makes all investment decisions I_t according to the law of motion:

$$K_{t+1} = (1 - \delta) K_t + I_t \tag{3.21}$$

where $0 < \delta < 1$ is the depreciation rate of capital. The representative agent supplies labor and capital to intermediate good producing firms, receives real income from wages w_t, a rental return on capital rr_t, and nominal profits from the ownership of domestic firms Π_t. The agent then divides its resources to purchase consumption C_t and investment I_t. The thesis looks at two common specifications for the international financial market: complete (CAM) and incomplete financial asset markets (IAM).

3.3.1 Complete Asset Markets

Under CAM, it is assumed that the representative agent in both countries has access to a complete set of Arrow-Debreu securities which can be traded both domestically and internationally. The period budget constraint is given by:

$$P_t(C_t + I_t) + E_t\{\Gamma_{t,t+1}B_{t+1}\} \leq B_t + P_t w_t L_t + P_t rr_t K_t + \int_0^1 \Pi(i)di \tag{3.22}$$

where $E_t\{\Gamma_{t,t+1}\} \equiv \frac{1}{1+i_t}$ is the gross nominal yield on a one-period discount bond and $\Gamma_{t,t+1}$ denotes the price of a state-contingent nominal bond B_{t+1} that pays one unit of domestic currency in period $t+1$, given a specific realized state in period t. The first order conditions from the agent's maximization problem yield:

$$\beta E_t\left\{\frac{U_c(C_{t+1}L_{t+1})}{U_c(C_t, L_t)}\frac{P_t}{P_{t+1}}\right\} = E_t\{\Gamma_{t,t+1}\} \tag{3.23}$$

$$U_c(C_t, L_t) = \beta E_t\Big\{U_c(C_{t+1}, L_{t+1})(1 - \delta + rr_{t+1})\Big\} \tag{3.24}$$

$$-\frac{U_L(C_t, L_t)}{U_c(C_t, L_t)} = w_t \tag{3.25}$$

where $U_c(C_t, L_t) = C_t^{-\rho}(1 - L_t)^{\eta}$ and $U_L(C_t, L_t) = -\frac{1}{1-\rho}C_t^{1-\rho}\eta(1 - L_t)^{\eta-1}$. Equation (3.23) is the Euler equation with state-contingent assets. Equations (3.24) and (3.25) are the respective optimal investment and labor supply conditions. Analogous conditions apply to the foreign agent. The transversality condition is given by:

$$\lim_{T\to\infty} E_t\left\{\Gamma_{t,t+T}\left(\frac{B_{t+T}}{P_{t+T}} + K_{t+1+T}\right)\right\} = 0 \tag{3.26}$$

From the first order conditions for the home and foreign agent, the following conditions can be derived:

$$(1 + i_t)E_t\{\Gamma_{t,t+1}\} = (1 + i_t^*)E_t\left\{\Gamma_{t,t+1}\frac{S_{t+1}}{S_t}\right\} \tag{3.27}$$

$$Q_t = q_0\frac{U_c(C_t^*, L_t^*)}{U_c(C_t, L_t)}, \qquad q_0 \equiv Q_0\frac{U_c(C_0, L_0)}{U_c(C_0^*, L_0^*)} \tag{3.28}$$

where equation (3.27) represents the uncovered interest rate parity condition and equation (3.28) is the risk sharing condition associated with complete asset markets. The latter equation shows that the marginal rate of substitution between home and foreign consumption is equated to the relative price of the aggregate consumption baskets.

3.3.2 Incomplete Asset Market

Under IAM, it is assumed that home individuals are able to trade two nominal risk-less bonds B_H and B_F denominated in the domestic and foreign currency respectively. On the other hand, foreign residents can only purchase bonds B_F^* denominated in the foreign currency. Home households face a transaction cost when they take a position in the foreign bond market. The period budget constraint of the domestic agent is given by:

$$P_t(C_t + I_t) + \frac{B_{H,t+1}}{1+i_t} + \frac{S_t B_{F,t+1}}{(1+i_t^*)\Theta\left(\frac{S_t B_{F,t+1}}{P_t}\right)} \leq B_{H,t} + S_t B_{F,t} + P_t w_t L_t + P_t rr_t K_t + \int_0^1 \Pi_t(i)di \tag{3.29}$$

where $\Theta(\cdot)$ represents the cost function that drives a wedge between the return on foreign currency denominated bonds received by domestic and by foreign residents. In the specification of incomplete asset markets, there is a bond-holding cost which allows to eliminate the unit root in the foreign bond holdings, following Benigno (2009). This cost function assumes the value of 1 only when the net foreign asset position is at its steady state level such that $\Theta(B_F) = 1$, and is a differentiable decreasing function in the neighbourhood of B_F. On the other hand, the foreign agent budget constraint is given by:

$$P_t^*(C_t^* + I_t^*) + \frac{B_{F,t+1}^*}{1+i_t^*} \leq B_{F,t}^* + P_t^* w_t^* L_t^* + P_t^* rr_t^* K_t^* + \int_0^1 \Pi_t^*(j)dj \tag{3.30}$$

The first order conditions from the home agent's maximization problem yield:

$$U_c(C_t, L_t) = \beta(1+i_t)E_t\left\{U_c(C_{t+1}, L_{t+1})\frac{P_t}{P_{t+1}}\right\} \tag{3.31}$$

$$U_c(C_t, L_t) = (1+i_t^*)\Theta\left(\frac{S_t B_{F,t+1}}{P_t}\right)\beta E_t\left\{U_c(C_{t+1}, L_{t+1})\frac{S_{t+1}P_t}{S_t P_{t+1}}\right\} \tag{3.32}$$

$$U_c(C_t, L_t) = \beta E_t\left\{U_c(C_{t+1}, L_{t+1})(1 - \delta + rr_{t+1})\right\} \tag{3.33}$$

$$-\frac{U_L(C_t, L_t)}{U_c(C_t), L_t} = w_t \tag{3.34}$$

where $U_c(C_t, L_t) = C_t^{-\rho}(1-L_t)^\eta$ and $U_L(C_t, L_t) = -\frac{1}{1-\rho}C_t^{1-\rho}\eta(1-L_t)^{\eta-1}$. Equations (3.31) and (3.32) are the Euler equations for the holdings of domestic and foreign bonds respectively. Equations (3.33) and (3.34) are the corresponding optimal investment and labor supply conditions (which are the same as under complete asset markets). The transversality condition of the home agent is given by:

$$\lim_{T\to\infty} E_t\left\{\frac{B_{H,t+T}/P_{t+T} + K_{t+1+T}}{\prod_{j=1}^T(1+i_{t+j})} + \frac{S_t B_{F,t+T}/P_{t+T}}{\Theta\left(\frac{S_t B_{F,t+1}}{P_t}\right)\prod_{j=1}^T(1+i_{t+j}^*)}\right\} = 0 \tag{3.35}$$

The first order conditions from the foreign agent's maximization problem yield:

$$U_c(C_t^*, L_t^*) = \beta(1 + i_t^*)E_t\Big\{U_c(C_{t+1}^*, L_{t+1}^*)\frac{P_t^*}{P_{t+1}^*}\Big\} \tag{3.36}$$

$$U_c(C_t^*, L_t^*) = \beta E_t\Big\{U_c(C_{t+1}^*, L_{t+1}^*)(1 - \delta + rr_{t+1}^*)\Big\} \tag{3.37}$$

$$-\frac{U_L(C_t^*, L_t^*)}{U_c(C_t^*, L_t^*)} = w_t^* \tag{3.38}$$

where $U_c(C_t^*, L_t^*) = C_t^{*-\rho}(1 - L_t^*)^\eta$ and $U_L(C_t^*, L_t^*) = -\frac{1}{1-\rho}C_t^{*1-\rho}\eta(1 - L_t^*)^{\eta-1}$. Equation (3.36) is the Euler equation for the holdings of foreign bonds. Equations (3.37) and (3.38) are the respective optimal investment and labor supply conditions.

From the first order conditions of the home and foreign agent, the following interest rate parity condition can be derived:

$$\begin{aligned}(1 + i_t^*)\Theta\Big(\frac{S_t B_{F,t+1}}{P_t}\Big)E_t\Big\{U_c(C_{t+1}, L_{t+1})\frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}\Big\} = \\ (1 + i_t)E_t\Big\{U_c(C_{t+1}, L_{t+1})\frac{P_t}{P_{t+1}}\Big\}\end{aligned} \tag{3.39}$$

An important implication of IAM is that it is possible to derive the equation for the current account. Under CAM this is not possible given that the budget constraint of the representative agent is not an equilibrium condition, since it is replaced by the risk sharing condition. The current account of the home agent is given by:

$$\frac{S_t B_{F,t+1}}{P_t(1 + i_t^*)}\frac{1}{\Theta\Big(\frac{S_t B_{F,t+1}}{P_t}\Big)} - \frac{S_t B_{F,t}}{P_t} = \frac{P_{H,t}}{P_t}Y_t - Z_t \tag{3.40}$$

3.4 Monetary Policy

Monetary policy is specified as a Taylor rule, where the monetary authority adjusts the nominal interest rate to changes in current inflation and output:

$$1 + i_t = (1 + i)\Big(\frac{\pi_t}{\pi}\Big)^{\mu_\pi}\Big(\frac{Y_t}{Y}\Big)^{\mu_y} \tag{3.41}$$

where π is the steady state inflation, Y is the steady state output, i is the steady state nominal interest rate, $\mu_\pi \geq 0$ is the inflation response coefficient, and $\mu_y \geq 0$ is the output response coefficient.

3.5 Market Clearing and Equilibrium

Total home demand must equal the supply of the final good:

$$Z_t = C_t + I_t \tag{3.42}$$

Market clearing for the domestic goods market requires:

$$Y_t = Z_{H,t} + Z^*_{H,t} \tag{3.43}$$

and the labor and capital markets both clear. In the case of complete asset markets, market clearing requires:

$$B_t + B^*_t = 0 \tag{3.44}$$

and under incomplete asset markets, the bond market clears when:

$$B_{F,t} + B^*_{F,t} = 0 \qquad B_{H,t} = 0 \tag{3.45}$$

Rational Expectations Equilibrium. A rational expectations equilibrium for the world economy consists of a sequence of home $\{Q_t, T_t, \Psi_{F,t}\}$ and foreign $\{T^*_t, \Psi^*_{H,t}\}$ relative prices, a sequence of home $\{i_t, mc_t, w_t, rr_t, P_t, P_{H,t}, P^{new}_{H,t}, P_{F,t}, P^{new}_{F,t}\}$ and foreign $\{i^*_t, mc^*_t, w^*_t, rr^*_t, P^*_t, P^*_{F,t}, P^{*new}_{F,t}, P^*_{H,t}, P^{*new}_{H,t}\}$ prices, and (a) under CAM a sequence of home $\{C_t, L_t, K_t, I_t, Y_t, Z_t, Z_{H,t}, Z_{F,t}\}$ and foreign $\{C^*_t, L^*_t, K^*_t, I^*_t, Y^*_t, Z^*_t, Z^*_{F,t}, Z^*_{H,t}\}$ allocations; and (b) under IAM a sequence of home $\{C_t, L_t, K_t, I_t, B_{H,t}, B_{F,t}, Y_t, Z_t, Z_{H,t}, Z_{F,t}\}$ and foreign $\{C^*_t, L^*_t, K^*_t, I^*_t, B^*_{F,t}, Y^*_t, Z^*_t, Z^*_{F,t}, Z^*_{H,t}\}$ allocations that satisfy: (i) the final good producer's optimality conditions (3.3) and (3.5); the domestic intermediate firm's first order conditions (3.9) and (3.10), the price-setting rules (3.13) and (3.14), and the aggregate version of the production function (3.7); (iii) the local retailers' price-setting rules (3.16) and (3.17); (iv) the optimality conditions of the representative agent (a) under CAM (3.23) to (3.25) and (b) under IAM (3.31) to (3.34), (b) under IAM the current account equation (3.40), and the capital accumulation equation (3.21); (v) the representative agent's budget constraint (a) under CAM (3.22) and (b) under IAM (3.29); (vi) the monetary policy rule (3.41); (vii) all markets clear (3.42), (3.43), (a) under CAM (3.44) and (b) under IAM (3.45); along with the foreign counterparts for (i) to (vii), and conditions (a) under CAM (3.27) and (3.28) and (b) under IAM (3.39).

Chapter 4

Log-Linearized Model and Parameterization

In order to analyze the equilibrium dynamics, I log-linearize around the steady state to obtain the equations that describe the model. The steady state that is considered for the log-linearization is a zero inflation one, where the law of one price holds. This implies that $P = P_H = P_F = P^* = P_H^* = P_F^* = 1$. Then, by definition $S = Q = T = 1$. In what follows, a variable $\hat{X}_t$ denotes the log-deviations of X_t with respect to its steady state value X (i.e. $\hat{X}_t = \frac{X_t - X}{X}$). Table 4.1 presents the log-linear equations of the home country under complete and incomplete asset markets. The key difference in the log-linear model between the considered asset market structures lies on the risk sharing condition. Under IAM, risk sharing is achieved in terms of expected first differences, and not in levels as under the CAM case. Also, under IAM it is possible to characterize the current account dynamics, whereas under CAM this is not needed. The equilibrium conditions for the foreign country are described in Appendix A.

4.1 Parameterization

The time interval is assumed to be a quarter. The benchmark parameterization is summarized in Table 4.2. I assume that the home and foreign countries are of equal size and parameter values are chosen in a symmetric manner. Following Dotsey & Duarte (2006), parameters α, β, and δ were chosen. Parameters a and ρ were set following Nam & Wang (2010), λ following Rotemberg & Woodford (1998), κ following Boehm et al. (2019), L following Hansen & Wright (1992), η following Stockman & Tesar (1995), ε following Rabanal & Tuesta (2006), μ_π and μ_y following Gali (2015), θ_H following McKnight (2011), and θ_F following Gopinath & Rigobon (2006).

The discount factor β is set to 0.99. This is a common value in the IRBC literature, which implies an annual real interest rate of around 4%. Also, the coefficient of risk aversion $\rho = 2$ is common within literature. The utility function that I used follows Stockman & Tesar (1995), which implies that consumption and leisure are non-separable. Hence, I set the inverse elasticity of substitution in leisure η at the same value they do.

Table 4.1. Log-Linearized Equations for the Home Country

Common Equations	
Domestic demand of home intermediate goods:	$\hat{Z}_{H,t} = (1-a)\kappa\hat{T}_t + \hat{Z}_t$
Domestic demand of foreign intermediate goods:	$\hat{Z}_{F,t} = -a\kappa\hat{T}_t + \hat{Z}_t$
CPI inflation:	$\hat{\pi}_t = a\hat{\pi}_{H,t} + (1-a)\hat{\pi}_{F,t}$
Production function:	$\hat{Y}_t = \hat{A}_t + \alpha\hat{K}_t + (1-\alpha)\hat{L}_t$
Optimal labor demand condition:	$\hat{w}_t = \hat{mc}_t + \hat{A}_t - (1-a)\hat{T}_t + \alpha(\hat{K}_t - \hat{L}_t)$
Optimal capital demand condition:	$\hat{rr}_t = \hat{mc}_t + \hat{A}_t - (1-a)\hat{T}_t + (1-\alpha)(\hat{L}_t - \hat{K}_t)$
New Keynesian Phillips curve	$\hat{\pi}_{H,t} = \beta E_t\hat{\pi}_{H,t+1} + \kappa_H\hat{mc}_t$
Imported inflation:	$\hat{\pi}_{F,t} = \beta E_t\hat{\pi}_{F,t+1} + \lambda_F\Psi_{F,t}$
Law of motion of capital:	$\hat{K}_{t+1} = (1-\delta)\hat{K}_t + \delta\hat{I}_t$
Euler equation:	$\rho E_t\hat{C}_{t+1} + \eta\frac{L}{1-L}E_t\hat{L}_{t+1} = \rho\hat{C}_t + \eta\frac{L}{1-L}\hat{L}_t + \hat{i}_t - E_t\hat{\pi}_{t+1}$
Optimal investment condition:	$\rho E_t\hat{C}_{t+1} + \eta\frac{L}{1-L}E_t\hat{L}_{t+1} - (\beta rr)E_t\hat{rr}_{t+1} = \rho\hat{C}_t + \eta\frac{L}{1-L}\hat{L}_t$
Optimal labor supply condition:	$-\hat{C}_t + \hat{w}_t = \frac{L}{1-L}\hat{L}_t$
Monetary policy rule:	$\hat{i}_t = \mu_\pi\hat{\pi}_t + \mu_y\hat{Y}_t$
Law of one price gap:	$\Psi_{F,t} = \hat{Q}_t - (1-a)\hat{T}^*_t - a\hat{T}_t$
Terms of trade:	$\hat{T}_t - \hat{T}_{t-1} = \hat{\pi}_{F,t} - \hat{\pi}_{H,t}$
Total home demand:	$\hat{Z}_t = \frac{C}{Z}\hat{C}_t + \frac{I}{Z}\hat{I}_t$
Total domestic goods demand:	$\hat{Y}_t = \frac{Z_H}{Y}\hat{Z}_{H,t} + \frac{Z^*_H}{Y}\hat{Z}^*_{H,t}$
Complete Asset Markets	
Risk sharing condition:	$\hat{Q}_t = -\rho(\hat{C}^*_t - \hat{C}_t) + \eta\left(\frac{L}{1-L}\hat{L}_t - \frac{L^*}{1-L^*}\hat{L}^*_t\right)$
Incomplete Asset Markets	
UIP condition:	$E_t(\hat{Q}_{t+1} - \hat{Q}_t) = \hat{i}_t - E_t\hat{\pi}_{t+1} - (\hat{i}^*_t - E_t\hat{\pi}^*_{t+1}) + \varepsilon\tilde{b}_{t+1}$
Current account:	$\beta\tilde{b}_{t+1} - \tilde{b}_t = \hat{Y}_t - (1-a)\hat{T}_t - \frac{Z}{Y}\hat{Z}_t$

Nam & Wang (2010) set the share of domestic intermediate goods in the final consumption good (a) at 0.85, in order to make it match to the ratio of export to GDP (which is around 85%) in the United States. In regard to the elasticity of substitution between domestic and foreign intermediate goods (κ), the literature provides different estimates depending on whether micro or macro data is used. Micro-based studies, such as Harrigan (1993) and Baier & Bergstrand (2001), report higher estimates, ranging from 5 to 12, whereas macro-based studies, such as Hooper et al. (1998) and Deardorff & Stern (1990), report estimates ranging from 0.3 to 2 for the United States. However, recent estimates by Boehm et al. (2019) suggest a value in the range of 0.42 to 0.62. I set this elasticity in the mid-point of this range (0.52). Given that this elasticity is a key parameter, I will consider alternative values of κ in the sensitivity analysis.

Table 4.2. Baseline Parameters

Aggregates	
Share of domestic inputs (a)	0.85
Elast. of subst. Z_H and Z_F (κ)	0.52
Elast. of subst. individual varieties (λ)	7.66
Production and Adjustment Functions	
Capital share (α)	1/3
Degree of price rigidity (θ_H)	0.75
Depreciation rate (δ)	0.025
Bond holdings (ε)	0.007
Local Retailers	
Pass-through domestic imports (θ_F)	0.78
Preferences	
Discount factor (β)	0.99
Coefficient of risk aversion (ρ)	2
Inverse elast. of subst in leisure (η)	-3.17
Time spent working (L)	1/3
Monetary Policy	
Inflation response coefficient (μ_π)	1.5
Output response coefficient (μ_y)	0.125
Productivity Shocks	
Autocorrelation coefficients (ρ)	0.85

The share of capital input in the intermediate good production, α in the Cobb-Douglas production function is 1/3, which is a standard value. This implies that capital services receive one third of payments to factors of production. The capital depreciation rate is 10% per annum, equilavent to 2.5% per quarter, which is also standard in the IRBC literature. Following Hansen & Wright (1992), the steady state level of hours worked is set to 1/3. This value is line with empirical studies such as Juster & Stafford (1991) and Rudebusch & Swanson (2012).

The degree of pass-through is governed by θ_F, where $0 \leq \theta_F \leq 1$. Using monthly data on

U.S. import and export prices at-the-dock from 1994 to 2005, Gopinath & Rigobon (2006) find that the exchange rate pass-through into U.S. import prices is of $\gamma = 22\%$. They define complete pass-through when $\gamma = 1$ and incomplete when $\gamma < 1$. Given that my model defines complete pass-through when $\theta_F = 0$, I set $\theta_F = 0.78$ in order for this measure to match the finding of Gopinath & Rigobon (2006). The analysis will also contemplate different values of pass-through in order to study the effects of this key parameter in the economy. I assume $\theta_H = 0.75$ following McKnight (2011). This value implies an average price duration of four quarters, a value that is common in the literature.

For the specification of incomplete markets, the bond-holding cost is of 0.7% per quarter, such that $\varepsilon = -\Theta(B)\bar{Y} = 0.007$ according to estimations of Rabanal & Tuesta (2006). Furthermore, I assume that the steady state ratio of net foreign assets to GDP, B/Y, is equal to zero. The parameters of the nominal interest rate rule are taken from Gali (2015) for the United States ($\mu_\pi = 1.5$ and $\mu_y = 0.125$). Taylor (1993) was the first one to propose these parameters to describe the conduct of monetary policy in the U.S.

Technology level follows a first-order autoregressive process, where the persistence of productivity growth is set to 0.85 at a quarterly frequency. Nam & Wang (2010) estimated this coefficient through an AR(1) process using data of the U.S. multifactor productivity index from 1949 to 2008. Evidence shows that productivity shocks are highly persistent in the U.S. For example, Baxter & Crucini (1995), Gruber (2002), and Basu et al. (2004) fail to reject a unit root for the productivity time series. Similarly, Dotsey & Duarte (2006) mention that persistence coefficients are close to one. Hence, this parameter is in line with empirical evidence.

4.2 The Role of Incomplete Pass-Through

It is of interest to analyze the dynamics of the real exchange rate in the presence of incomplete pass-through, as it depends on the value of a (i.e. degree of home bias) and the deviation from the law of one price. The log-linearized real exchange rate is described by:

$$\hat{Q}_t = \Psi_{F,t} + (1-a)\hat{T}_t^* + a\hat{T}_t \tag{4.1}$$

In the presence of home bias (i.e. $a > 0.5$), the impact that the domestic terms of trade have on the real exchange rate will be higher than the one coming from the foreign terms of trade, ceteris paribus.

A second source that affects the real exchange rate comes from the term Ψ_F. This term is defined as $\Psi_{F,t} \equiv \hat{S}_t + \hat{P}_{F,t}^* - \hat{P}_{F,t}$, and hence measures the deviation of the price paid in the foreign market from the home currency price local retailers set on imported goods. This means that in the presence of incomplete pass-through, the gap that is generated in the law of one price (l.o.o.p. gap) will contribute to the volatility of the real exchange rate.

It is clear to see that when the law of one price holds, then $\Psi_F = 0$. Consequently, the latter log-linear equation for the real exchange rate can be expressed only in terms of the terms of trade of the home country[1]:

$$\hat{Q}_t = (2a - 1)\hat{T}_t \tag{4.2}$$

This means that the only way to directly affect the real exchange rate is through the home bias channel (i.e. assigning different values to parameter a). Note that if $a < 0.5$, then there is a negative relationship between the terms of trade and the real exchange rate.

A second equation that is related is the one that describes the dynamics of the imported inflation:

$$\hat{\pi}_{F,t} = \beta E_t \hat{\pi}_{F,t+1} + \lambda_F \Psi_{F,t} \tag{4.3}$$

where $\lambda_F = \frac{(1-\theta_F)(1-\beta\theta_F)}{\theta_F}$. This equation allows us to see that generated inflation in imported prices is affected by the law of one price gap. In other words, when the price paid in the foreign market by the local retailers exceeds the local currency price they apply, import price inflation rises; this would happen when observing a depreciation of the nominal exchange rate. The wedge that is generated makes the marginal cost to increase, resulting in a higher imported inflation. Note that λ_F, the impact of the l.o.o.p. gap, depends on structural parameters β and θ_F.

The parameter θ_F is of particular interest, as it governs the degree of exchange rate pass-through. Understanding that the exchange rate pass-through [2] is the percentage change in the local currency import prices resulting from a 1% change in the exchange rate between the exporting and importing country, a decrease in θ_F (higher pass-through) increases λ_F. This means that, when importers need to absorb more of the exchange rate pass-through, they decide to place more weight on the current law of one price gap and hence less weight on the future gap, as they have a better opportunity to modify prices today. Notice that when $\theta_F = 0$ the pass-through is said to be complete, while $0 < \theta_F < 1$ means that pass-through is incomplete. On the other hand, when $\theta_F = 1$ there is zero pass-through.

The main objective in this thesis is to depict the relationship between the real exchange rate and relative consumption, as these two variables are involved in the Backus-Smith

[1]When the l.o.o.p holds, we have that $\hat{P}_{H,t} = \hat{S}_t + \hat{P}^*_{H,t}$ and $\hat{P}^*_{F,t} = \hat{P}_{F,t} - \hat{S}_t$. The terms of trade of the foreign country are defined as $\hat{T}^*_t = \hat{P}^*_{H,t} - \hat{P}^*_{F,t}$. Substituting the l.o.o.p. log-linear equations in the expression for the terms of trade, it is possible to see that $\hat{T}^*_t = -\hat{T}_t$.

[2]See p. 19 of Gopinath & Rigobon (2006).

puzzle. In this case, the expression will be different under each asset market structure. Consider the incomplete asset markets case first. Recall that the UIP condition, in log-linear terms, is expressed as:

$$E_t(\hat{Q}_{t+1} - \hat{Q}_t) = \hat{i}_t - E_t\hat{\pi}_{t+1} - (\hat{i}^*_t - E_t\hat{\pi}^*_{t+1}) + \varepsilon\tilde{b}_t \tag{4.4}$$

The right-hand side of the equation can be substituted using the Euler log-linear equations of both home and foreign agents:

$$\rho E_t\hat{C}_{t+1} + \eta\frac{L}{1-L}E_t\hat{L}_{t+1} - \rho\hat{C}_t - \eta\frac{L}{1-L}\hat{L}_t = \hat{i}_t - E_t\hat{\pi}_{t+1} \tag{4.5}$$

$$\rho E_t\hat{C}^*_{t+1} + \eta\frac{L^*}{1-L^*}E_t\hat{L}^*_{t+1} = \rho\hat{C}^*_t + \eta\frac{L^*}{1-L^*}\hat{L}^*_t + \hat{i}^*_t - E_t\hat{\pi}^*_{t+1} \tag{4.6}$$

and the optimal labor supply conditions of both agents:

$$\frac{L}{1-L}\hat{L}_t = -\hat{C}_t + \hat{w}_t \tag{4.7}$$

$$\frac{L^*}{1-L^*}\hat{L}^*_t = -\hat{C}^*_t + \hat{w}^*_t \tag{4.8}$$

Consequently, the log-linear equation for the implied risk sharing condition can be expressed as:

$$E_t(\hat{Q}_{t+1} - \hat{Q}_t) = (\rho - \eta)\Big[E_t\hat{C}^R_{t+1} - \hat{C}^R_t\Big] + \eta\Big[E_t(\hat{w}_{t+1} - \hat{w}_t) - E_t(\hat{w}^*_{t+1} - \hat{w}^*_t)\Big] + \varepsilon\tilde{b}_{t+1} \tag{4.9}$$

where $\hat{C}^R = \hat{C} - \hat{C}^*$ denotes relative consumption. This equation indicates that the real exchange rate will be affected by the behavior of the wage rate and the deviation of foreign currency denominated bond holdings from their steady state relative to domestic output. However, given that ε is assumed to take a very small value, the volatility that the term $\tilde{b}_{t+1}$ can provide is not significant. There is something important to note here: the form this condition takes is the consequence of having a utility function with non-separability between consumption and leisure (which is standard in the literature). Otherwise, the risk sharing equation would only involve the real exchange rate and relative consumption. This fact leads to highlight that non-separability plays an important role in the Backus-Smith puzzle.

The above equation might at first give the impression that the relationship between real exchange rate and relative consumption is dependant on the parameter values of ρ and η, and whether the $\rho - \eta$ is greater or less than zero. It is important to recall that η being the inverse elasticity of substitution in leisure, it is expected to take a negative value. Hence, the term $\rho - \eta$ is always greater than zero. This would then suggest that there is a positive relationship between the variables of interest. Nonetheless, equation (4.9) indicates that the dynamics real wage rate follow for both countries play a role in determining the correlation of real exchange rate and relative consumption. Let us build the case for this statement. Recall that parameter η is always negative, so the sign of the term associated to it will depend on the behavior of domestic and foreign wage rates. If the domestic expected growth rate of wage is relatively higher than the foreign expected wage growth rate, then the term will produce a negative correlation between relative consumption and real exchange rate. In contrast, when the foreign expected growth rate is relatively higher than the domestic expected growth rate, then the correlation will be positive. Therefore, in order to solve the Backus-Smith puzzle, it is sufficient to see a positive expected relative growth in wage rates, when considering non-separable preferences.

This model allows for exchange rate pass-through to be a mechanism that can generate a negative correlation between real exchange rate and relative consumption. This particular feature of the model affects the behavior of wages, which then impacts the Backus-Smith correlation. Therefore, the combination of having incomplete asset markets, non-separability between consumption and leisure, and exchange rate pass-through affecting real wages is what suggests an avenue to resolve the puzzle. As it is observed in Figure 5.4 in Chapter 5, there is a threshold value for θ_F that leads the Backus-Smith correlation to be negative (which is around $\theta_F = 0.425$). In order to yield evidence of the intuition that was exposed above, Figure 4.1 shows the average expected relative growth rate of real wage. Recall that it was stated that a positive relative growth leads to a negative correlation between real exchange rate and relative consumption. On average, this relative growth rate remains positive up to $\theta_F = 0.455$, which coincides with the previously mentioned threshold value for θ_F. Hence, following the provided intuition that the risk sharing condition gives and analyzing Figure 4.1 offers evidence that different levels of pass-through allow relative growth rates of domestic and foreign real wages to be either positive or negative, producing a negative or positive correlation between real exchange rate and relative consumption, as it is presented in the results of Chapter 5.

There is a second thing that is important to highlight. Under the case when the law of one price holds it is also possible to solve the Backus-Smith puzzle. This would then suggest that the mechanism that can generate a negative correlation is different in that case. Nonetheless, an important factor that needs to be considered is the elasticity between home and foreign intermediate goods (κ), as the value this parameter takes gives shape to the Backus-Smith correlation (even when the law of one price holds). Indeed, when $\kappa = 0.80$, there is a positive correlation (0.39) between relative consumption and real exchange rate when the law of one price holds, while this correlation is considerably negative (-0.91), and hence solving the puzzle, under incomplete exchange rate pass-through. Standard theory argues that lower values of κ generate larger responses of the terms of trade to a positive productivity shock,

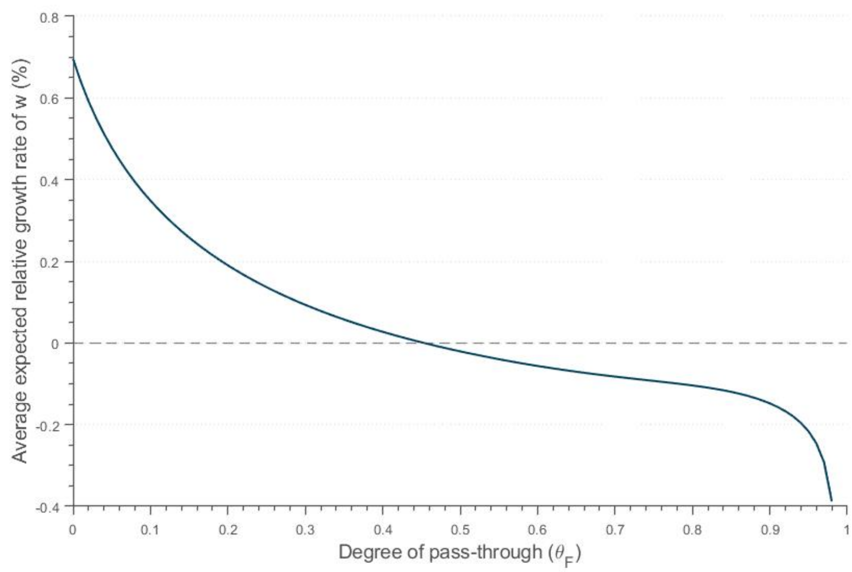

Figure 4.1. Average Expected Relative Growth Rate of Real Wage

such that for sufficiently small values of this parameter, the terms of trade can depreciate up to the point of allowing a negative correlation between relative consumption and real exchange rate.

Consider equation (4.9). The term of the expected relative growth of wages can be reexpressed by using the optimal labor demand conditions for both countries:

$$\hat{w}_t = \hat{mc}_t + \hat{A}_t - (1-a)\hat{T}_t + \alpha(\hat{K}_t - \hat{L}_t) \tag{4.10}$$

$$\hat{w}_t^* = \hat{mc}_t^* + \hat{A}_t^* - (1-a)\hat{T}_t^* + \alpha(\hat{K}_t^* - \hat{L}_t^*) \tag{4.11}$$

such that:

$$\begin{aligned} E_t(\hat{w}_{t+1} - \hat{w}_t) - E_t(\hat{w}_{t+1}^* - \hat{w}_t^*) = E_t\Big\{ &\hat{mc}_{t+1} - \hat{mc}_t - (\hat{mc}_{t+1}^* - \hat{mc}_t^*) \\ &+\hat{A}_{t+1} - \hat{A}_t - (\hat{A}_{t+1}^* - \hat{A}_t^*) - (1-a)\Big[\hat{T}_{t+1} - \hat{T}_t - (\hat{T}_{t+1}^* - \hat{T}_t^*)\Big] \\ &+\alpha\Big[\hat{K}_{t+1} - \hat{K}_t - (\hat{K}_{t+1}^* - \hat{K}_t^*) - (\hat{L}_{t+1} - \hat{L}_t) + \hat{L}_{t+1}^* - \hat{L}_t^*\Big]\Big\} \end{aligned} \tag{4.12}$$

This allows one to see that the expected relative depreciation of the terms of trade is involved in the behavior that the expected relative growth rate of real wages follows. Reviewing the idea that was mentioned in the previous paragraph, for the model proposed in this thesis, it can be tested that the expected relative depreciation of the terms of trade, not the depreciation alone, is what gives shape to the negative correlation between relative consumption and real exchange rate, according to a specific value for the elasticity of substitution between home and foreign intermediate goods. Indeed, by inspecting Figure 4.2, it is possible to conclude that the threshold expected rate of depreciation to resolve the Backus-Smith puzzle is -0.275%. This result also shows that including incomplete pass-through allows a wider range of κ values to solve the Backus-Smith puzzle. This will be further discussed in Chapter 6.

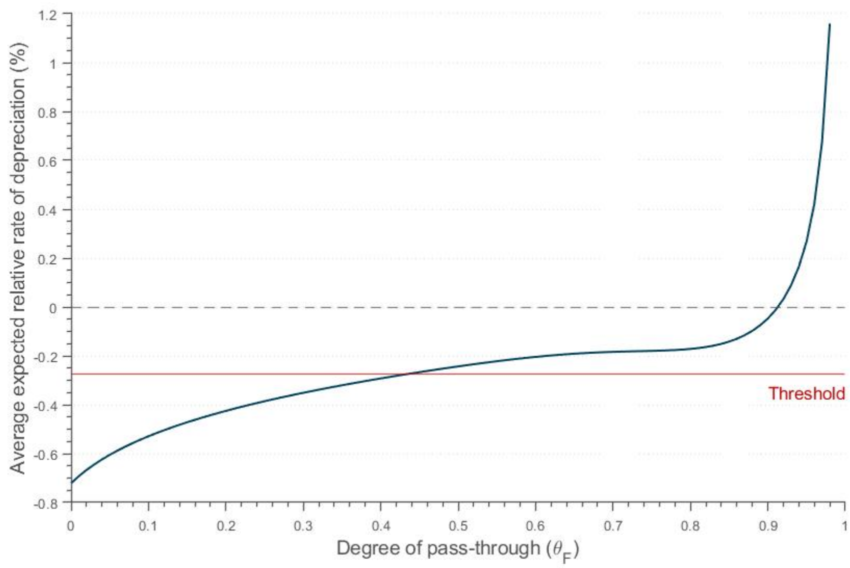

Figure 4.2. Average Expected Relative Rate of Depreciation of the Terms of Trade

Now, let us look at the case of complete asset markets. Recall that the risk sharing condition, in log-linear terms, is given by:

$$\hat{Q}_t = -\rho(\hat{C}_t^* - \hat{C}_t) + \eta\left(\frac{L}{1-L}\hat{L}_t - \frac{L^*}{1-L^*}\hat{L}_t^*\right) \tag{4.13}$$

The terms that include labor on the right-hand side of the equation can be substituted using the optimal labor supply conditions of both agents to obtain:

$$\hat{Q}_t = (\rho - \eta)\hat{C}_t^R + \eta(\hat{w}_t - \hat{w}_t^*) \tag{4.14}$$

Considering the optimal labor demand conditions of the home and foreign agents, the risk sharing condition can be expressed as:

$$\begin{aligned}\hat{Q}_t = (\rho - \eta)\hat{C}_t^R + \eta\Big[&\hat{mc}_t - \hat{mc}_t^* + \hat{A}_t - \hat{A}_t^* - (1-a)(\hat{T}_t - \hat{T}_t^*) \\ &+\alpha(\hat{K}_t - \hat{L}_t) - \alpha(\hat{K}_t^* - \hat{L}_t^*)\Big]\end{aligned} \tag{4.15}$$

In this case, if one is to contrast IAM and CAM, the most obvious difference lies on the fact that neither equations (4.14) nor (4.15) include any expected terms. That is to say, the relationship between relative consumption and real exchange rate will solely depend on the behavior of the involved variables at time t. In this case (just like under IAM), exchange rate pass-through gives shape to the dynamics of the real wage, which in turn is characterized by the differences in variables that are observed in equation (4.15). In fact, the higher pass-through is, the higher the initial response of the relative real wage growth rate is, which then causes a positive correlation between the variables of interest. This is also reflected in the labor market, given that as part of the adjustment process after the domestic productivity shock, when the Backus-Smith puzzle is present, it is initially appreciated that labor in the home country increases more than in the foreign country. It is important to say that this is altogether caused by the effects of the relative growth in the real marginal cost and the relative depreciation of the terms of trade. Therefore, the sufficient condition to solve the Backus-Smith puzzle under complete asset markets, with non-separable preferences, is that there must be an initial negative relative growth rate of wages, which is accompanied by a lower growth in labor of the home country relative to the foreign country, given that exchange rate pass-through is incomplete.

Two more things are worthwhile mentioning. Under CAM, the model when the law of one price holds cannot provide a negative correlation between real exchange rate and relative consumption. This is consistent with the literature. However, introducing incomplete exchange rate pass-through allows to solve the Backus-Smith puzzle, which then indicates that this feature is important in studying this anomaly. The second thing that is important to mention, as it will be discussed in Chapter 6, is that including incomplete exchange rate pass-through allows a wider range of κ values to resolve the puzzle.

Chapter 5

Model Performance

In this Chapter I analyze the second moments that are generated by the proposed model, using the parameter values presented in Table 4.2. Tables 5.1 and 5.2 display the second moments from the data and compares them with the moments that are generated by the model under the different asset market structures[1]. All data that is presented is of quarterly frequency.

The column headed as *Data* contains selected second moments that were taken from Gao et al. (2014). The data considers the period of 1973:1 to 2007:4, where the home country is the U.S. and the foreign country includes different combinations of the aggregate of European countries. The data for the autocorrelations contemplate the aggregate of Canada, Japan, and 19 European countries following the calculations by McKnight & Povoledo (2019).

Before seeing the computed second moments for each asset market structure, it is possible to discuss the simulated results by first analyzing the impulse response functions following a positive domestic productivity shock. The graphs are displayed in Appendix B. The model under complete asset markets (CAM) and incomplete asset markets (IAM) showed similar dynamics in general. However, there are some differences that are highlighted. In this model and for these parameters, an increase in domestic productivity raises relative consumption, while generating a depreciation of the real exchange rate caused by the depreciation of the terms of trade and the increase in the law of one price gap. An observed difference is that under IAM, relative consumption remained positive, while under CAM this variable only increased temporarily. Interestingly, there is an initial disaccumulation of assets (under IAM), because total home demand proved to be greater than domestic output. Foreign consumption increases as well, but in a lower magnitude than domestic, allowing for a positive relative consumption. Imported inflation decreased, even though there was an increase in

[1]The software Dynare was used to compute the model-derived moments

the law of one price gap. This can be explained by thinking that, while at the beginning the price that local retailers paid for the imported good was higher than the local currency price applied in the domestic market, agents' expectations that the l.o.o.p gap was going to close in the future were higher than the effect this gap itself had. Hence, this led to observe a fall in the imported inflation. The fall in domestic prices leads to a depreciation of the terms of trade.

5.1 Complete Asset Markets

Table 5.1 presents the second moments results for the model under different degrees of pass-through. The data shows that the volatility of both terms of trade and real exchange rate is high. However, the baseline model under different degrees of pass-through fails to match this fact. In fact, it is only observed a somewhat high volatility of the terms of trade accompanied with a very weak standard deviation of the real exchange rate. One can pinpoint that moderate high values of pass-through yield a higher volatility for the terms of trade. This is in opposite direction to what is observed with the standard deviation of the real exchange rate, as higher levels of pass-through generate a higher coefficient.

In regard to the first-order autocorrelations, the most noticeable fact is that the generated moment for output is fairly stable across all levels of pass-through and that it is somewhat close to the data (0.87). The autocorrelation for the real exchange rate follows an increasing trend as pass-through decreases. The best fits two fits with the data are when $\theta_F = 0.78, 0.95$. Hence, the baseline model provides a good estimate for the real exchange rate.

Observing the results of correlations with output, the baseline model yields close moments to the data, except for terms of the terms of trade. The baseline correlations between output and employment are slightly above the data (0.97 and 0.96 vs. 0.82 and 0.85 respectively). A pass-through level of 0.50 seems to be appropriate to almost match the data (0.85 and 0.88 respectively). The baseline model generates a perfect match of the correlation between output and investment. A fact that is observed in the data is that there is negative correlation between output and the terms of trade (-0.16). None of the models are able to simulate this fact. However, it is appreciated that higher pass-through levels generate a lower coefficient, the lowest being reached when $\theta_F = 0.95$ (0.18).

The modelled cross-country correlations fail to match what the data displays, as they are not high enough. The correlation for output achieves a more matching value for high levels of pass-through (i.e. θ_F in the range of 0.05 and 0.25), while this happens for consumption for moderate high values of pass-through (i.e. θ_F between 0.25 and 0.50). For investment, almost all models present a negative cross-country correlation, which is in sharp contrast

Table 5.1. **Second Moments: Model Under Complete Asset Markets**

			Model with different degrees of pass-through				
	Data[1]	Baseline model	$\theta_F = 0$	$\theta_F = 0.05$	$\theta_F = 0.25$	$\theta_F = 0.5$	$\theta_F = 0.95$
Standard deviations relative to output							
Consumption	0.62	0.34	0.59	0.50	0.33	0.30	0.38
Investment	2.92	4.66	3.86	2.94	3.20	4.14	4.69
Employment	0.68	0.25	0.65	0.52	0.25	0.20	0.27
Terms of trade	1.77	0.66	1.08	1.11	1.10	0.95	0.51
Real exchange rate	2.38	0.49	0.00	0.10	0.26	0.37	0.50
First-order autocorrelations							
Output	0.87*	0.68	0.70	0.73	0.70	0.68	0.67
Real exchange rate	0.82*	0.81	-0.01	0.16	0.55	0.74	0.82
Correlations with output							
Consumption	0.82	0.97	0.56	0.53	0.63	0.85	0.99
Investment	0.94	0.94	0.71	0.78	0.82	0.87	0.96
Employment	0.85	0.96	0.44	0.37	0.48	0.88	0.94
Terms of trade	-0.16	0.36	0.48	0.55	0.58	0.50	0.18
Cross-country correlations							
Output	0.58	-0.01	0.11	0.41	0.88	0.38	-0.09
Consumption	0.43	0.18	-0.77	-0.62	0.08	0.68	-0.03
Investment	0.41	-0.47	-0.15	0.58	0.51	-0.22	-0.53
Employment	0.45	0.00	-0.89	-0.80	-0.27	0.43	-0.36
Correlation between real exchange rate							
Relative consumption	-0.17	0.76	0.85	-1.00	-0.97	-0.40	0.90

[1] The estimated moments for the data were taken from Gao et al. (2014), except for the values denoted by *, which were taken from McKnight & Povoledo (2019)

to the data; in this case, high values of pass-through help to simulate a better coefficient. Employment shows a similar behavior as investment[2]. However, in this case when $\theta_F = 0.50$ the correlation almost matches the data, and is in fact the only one that is in line with the data for all values of θ_F.

The most important fact to highlight considering the Backus-Smith puzzle is that a

[2] This is what Baxter (1995) dubbed as the "international comovement puzzle".

negative correlation between relative consumption and real exchange rate is only achieved when the law of one price does not hold. Indeed, under complete asset markets, if one wants to solve the puzzle, it is strictly necessary, but not sufficient, to break the law of one price. A second thing that can be noted is that the baseline model shows a lower correlation (0.76) than the case where the law of one price holds (0.85). A third thing that can be appreciated is that moderate to high values of pass-through generate a strong negative correlation. Figure 5.1 helps one to better see the behavior of this correlation for θ_F going from 0 to 0.97. Looking at this Figure, it is possible to see more explicitly how for some values of pass-through, the puzzle can be solved. In fact, Figure 5.1 also emphasizes how when the law of one price holds, there is a positive correlation between real exchange rate and relative consumption. Most importantly, this Figure displays that a θ_F in the range of 0.52 to 0.55 can replicate a similar correlation to the one yielded by the data. Therefore, it can be concluded that under complete asset markets it is possible to solve the Backus-Smith puzzle, and get a similar result to the one produced by the data, for moderate levels of pass-through (i.e. θ_F between 0.52 and 0.55). Unfortunately, these values are not empirically possible for the U.S.

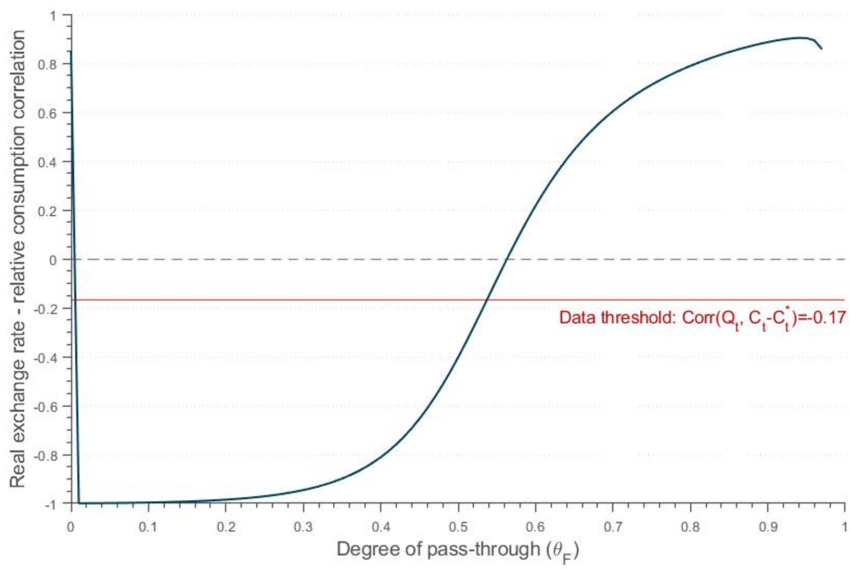

Figure 5.1. Correlation Between Real Exchange Rate and Relative Consumption for Different Pass-Through Levels Under CAM

Figures 5.2 and 5.3 show the impulse response functions of relative consumption and real exchange rate respectively, following a 1% positive productivity shock in the domestic goods sector for different pass-through values. Analyzing Figure 5.2 first, it is possible to highlight that for a very high level of pass-through ($\theta_F = 0.05$) and for the case where the law of one price holds, the fall in relative consumption shows its greatest magnitude across the different values for θ_F. For the case where $\theta_F = 0$, this fall is short timewise, as in quarter 2 there is a very steep recovery going from -34.18% to -0.36%. Differently, when $\theta_F = 0.05$, the initial fall in relative consumption is somewhat smaller (-23.36%), and the recovery is also somewhat smoother in contrast to the case where the law of one price, as it takes three periods to get back closer to the zero-line. Interestingly, after observing this recovery, the dynamic of relative consumption is fairly stable around the initial steady state for both values of θ_F. When $\theta_F = 0.25$ and $\theta_F = 0.50$, there is also an initial fall in relative consumption, but it is much lower magnitude. In addition, the response of this variable after the fall is similar to that of higher degrees of pass-through, as it remains stable for the rest of the considered quarters. When pass-through is low, it is appreciated that relative consumption somewhat increases at the beginning, but then it starts to smoothly decrease. It is worthwhile noting that only when $\theta_F = 0.95$, the deviation of this variable does not recover from the fall, but remains in the negative area. Overall, it can be concluded that the initial response of relative consumption depends on the degree of pass-through.

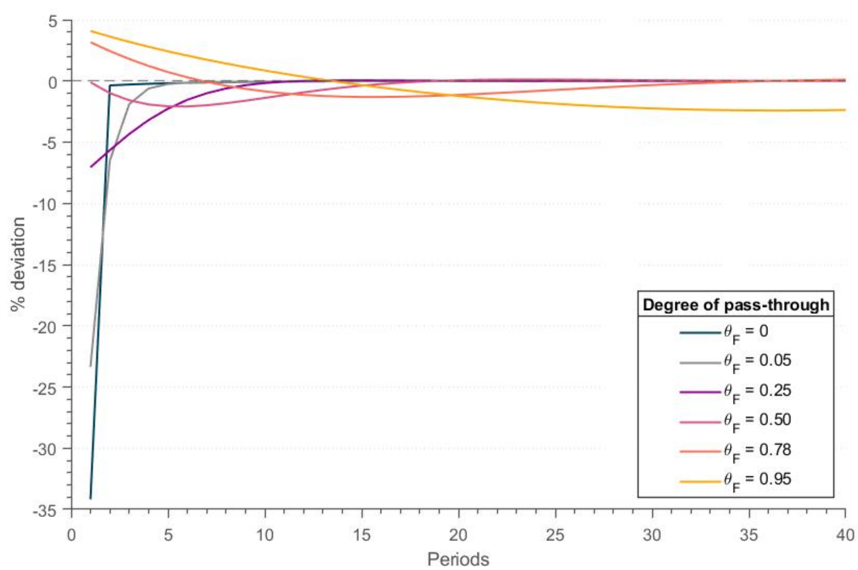

Figure 5.2. Impulse Response Functions of Relative Consumption Under CAM

Figure 5.3 shows that the response of the real exchange rate to a positive domestic productivity shock is almost null when the law of one price holds, in contrast to the case where incomplete pass-through is present. In fact, the mean deviations of real exchange rate when $\theta_F = 0$ is of 1.0894E-16. The clearest trend that can be appreciated is that as pass-through decreases, the initial response of real exchange rate is higher. Indeed, when $\theta_F = 0.95$, this variable increases by 3.07%. A second pattern that can be noted is that when pass-through is lower, it takes longer to the real exchange rate to go back to its original steady state. In regard to this, when $\theta_F = 0.05$ it is very noticeable an immediate return of the real exchange rate to the initial steady state, and digging in the data, it remains fluctuating around zero. For $\theta_F = 0.25$, the increase in the real exchange rate lasts approximately 10 quarters, while the posterior fall lasts approximately 15 quarters before it goes back to the original stead state. It is interesting to note that when $\theta_F = 0.78$ and $\theta_F = 0.95$, the initial increase in the real exchange rate is very similar (3.01% and 3.07% respectively). Nonetheless, there is a divergent behavior as time goes by, since the deviation of real exchange rate from the steady state lasts two more quarters when $\theta_F = 0.95$ in contrast to $\theta_F = 0.78$. Overall, it can be concluded that the initial depreciation of the real exchange rate heavily depends on the degree of pass-through.

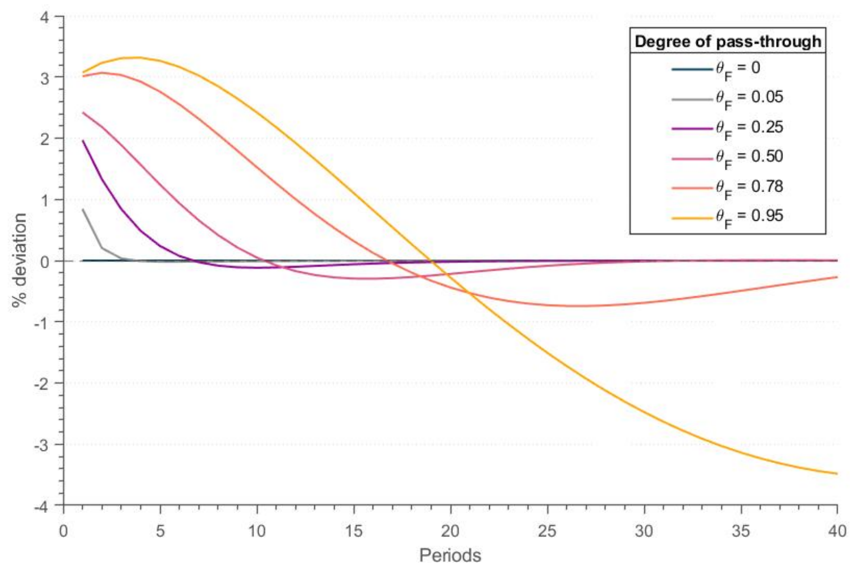

Figure 5.3. Impulse Response Functions of Real Exchange Rate Under CAM

5.2 Incomplete Asset Markets

Table 5.2 presents the second moments results for the model under different degrees of pass-through. The column headed as *Baseline* displays the second moments generated by the model under the parameter values presented in Table 4.2. The generated volatilities in both terms of trade and real exchange rate are not high enough. Something that is interesting to note is that the volatility of the terms of trade does not differ much across different levels of pass-through, while the volatility of the real exchange increases as pass-through decreases.

Observing the results of persistence, the model comes reasonably close to what the data explains. The baseline model under incomplete asset markets estimates an autocorrelation coefficient of 0.67 for output and 0.82 for the real exchange rate, while the data yields 0.87 and 0.82 respectively. One result that stands out is when $\theta_F = 0.05$, because the modelled autocorrelation for the real exchange rate attains the lowest value among all results (0.19), while when $\theta_F = 0$ this autocorrelation is not lower, but the highest reported value (0.87). Overall, comparing these results with variations in pass-through, one can only say there are only marginal changes.

Table 5.2. Second Moments: Model Under Incomplete Asset Markets

			Model with different degrees of pass-through				
	Data[1]	Baseline model	$\theta_F = 0$	$\theta_F = 0.05$	$\theta_F = 0.25$	$\theta_F = 0.5$	$\theta_F = 0.95$
Standard deviations relative to output							
Consumption	0.62	0.36	0.40	0.37	0.33	0.33	0.37
Investment	2.92	4.49	3.05	2.94	3.40	4.01	4.64
Employment	0.68	0.23	0.35	0.29	0.20	0.20	0.27
Terms of trade	1.77	0.57	0.64	0.66	0.68	0.66	0.54
Real exchange rate	2.38	0.44	0.00	0.05	0.15	0.25	0.66
First-order autocorrelations							
Output	0.87*	0.67	0.72	0.71	0.68	0.67	0.67
Real exchange rate	0.82*	0.82	0.87	0.19	0.58	0.76	0.80
Correlations with output							
Consumption	0.82	0.99	0.79	0.82	0.90	0.96	1.00
Investment	0.94	0.95	0.95	0.98	0.94	0.92	0.97
Employment	0.85	0.95	0.51	0.55	0.75	0.90	0.96
Terms of trade	-0.16	0.40	0.61	0.62	0.59	0.51	0.17
Cross-country correlations							
Output	0.58	0.02	0.41	0.59	0.61	0.28	-0.06
Consumption	0.43	0.13	-0.27	0	0.74	0.81	-0.09
Investment	0.41	-0.41	0.50	0.68	0.24	-0.19	-0.49
Employment	0.45	0.10	-0.65	-0.45	0.25	0.56	-0.26
Correlation between real exchange rate							
Relative consumption	-0.17	0.86	-0.27	-0.99	-0.96	0.53	0.75

[1] The estimated moments for the data were taken from Gao et al. (2014), except for the values denoted by *, which were taken from McKnight & Povoledo (2019).

The modelled corrrelations with output are close to the data, except for the terms of trade. Allowing for variations in the degree of pass-through show that intermediate levels of pass-through (i.e. θ_F between 0.25 and 0.50) provide the best fit to the data in employment. Similarly, lower levels of pass-through (i.e. θ_F between 0.78 and 0.95) yield the smallest correlation between output and the terms of trade. However, the data displays a negative correlation, while the lowest value that is achieved through the model is of 0.17 when $\theta_F = 0.95$.

In regard to the cross-country correlations, the model fails to match the observed fact in investment, as the model-derived coefficient is of opposite sign to the one that the data yields. A possible explanation to this is that the productivity shock in the domestic country is sufficiently persistent to allow capital to flow from the foreign to the home country in order to exploit the higher return of capital. The model-derived coefficients for output, consumption, and employment fall below to those observed in the data. The cross-country correlations of output and investment show more consistency with the data when pass-through is very high. In general, examining these results under different pass-through levels leads one to observe that most of the derived coefficients that best fit the data are related to high degrees of pass-through (i.e. θ_F between 0.05 and 0.25).

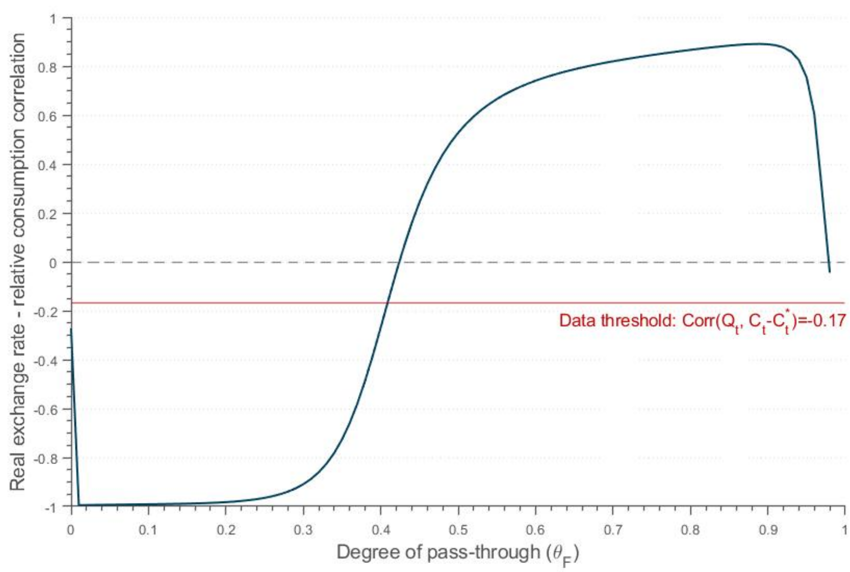

Figure 5.4. Correlation Between Real Exchange Rate and Relative Consumption for Different Pass-Through Levels Under IAM

Considering the Backus-Smith puzzle, it is evident that the baseline model (0.86), contemplating a pass-through degree of 0.78, fails in matching the observed correlation between relative consumption and the real exchange rate (-0.17). Nonetheless, for

$0 < \theta_F \leq 0.78$ there is a very clear trend of how this correlation falls as pass-through increases. Indeed, this correlation goes from 0.53 to -0.96 when θ_F decreases from 0.50 to 0.25. It is also worthwhile noting the case when the law of one price holds, because that model better matches the data (-0.27). Notwithstanding, Figure 5.4 shows the behavior of this correlation for values of θ_F ranging from 0 to 0.98, and it allows one to better appreciate that it is possible to observe that in fact, when $\theta_F < 0.425$ a negative moment is generated. Nonetheless, the admitted values of exchange rate pass-through are not compatible with the empirical results for the U.S. A second result to observe is that when $\theta_F = 0.41$, there is a perfect match with the data. Consequently, the generated results support the idea that incomplete pass-through can provide a reasonable solution to the Backus-Smith puzzle for intermediate pass-through levels (i.e. θ_F in the range of 0.405 and 0.415).

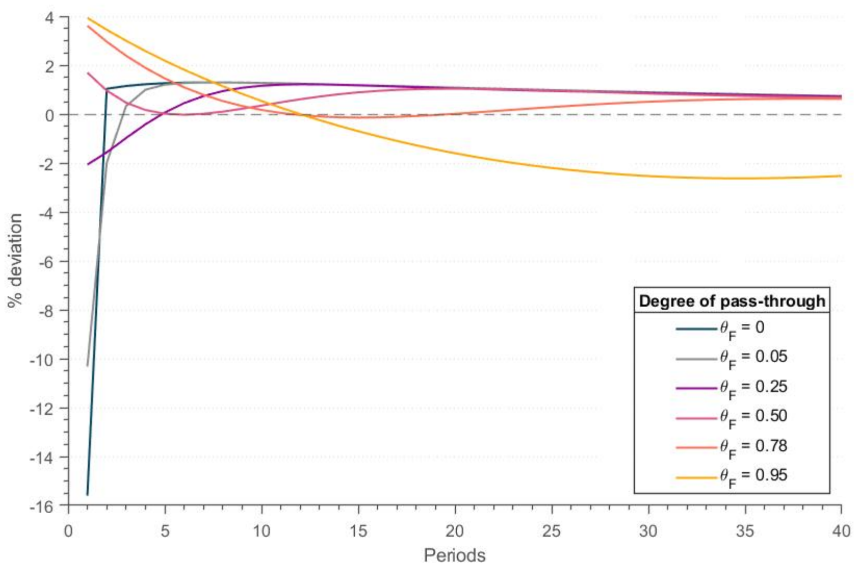

Figure 5.5. Impulse Response Functions of Relative Consumption Under IAM

Figures 5.5 and 5.6 show the impulse response functions of relative consumption and real exchange rate respectively, following a 1% positive productivity shock in the domestic goods sector for different values of pass-through. Observing Figure 5.5 first, two clear patterns are depicted for high levels of pass-through (i.e. $\theta_F < 0.25$): 1) There is an initial fall in relative consumption, which means that foreign consumption in response to the domestic productivity shock is greater than domestic consumption and 2) The trajectories relative consumption follows are similar across these pass-through values. However, relative consumption starts increasing and remains above the zero-line for more than 40 quarters. Conversely, low degrees of pass-through make domestic consumption to be greater in response to a positive domestic productivity shock. The dynamic that this variable follows are evidently dependant on the degree of pass-through. For example, when $\theta_F = 0.95$, there is a positive relative consumption only for the first 12 quarters. From this point on, this variable falls below the zero-line smoothly across time. On the other hand, when $\theta_F = 0.50$ and $\theta_F = 0.78$ it is possible to note that even though there is a decreasing trend in relative consumption, it slightly crosses the threshold for $\theta_F = 0.78$ and touches the zero-line for $\theta_F = 0.50$, but actually recovers smoothly and remains positive for the rest of the periods.

Figure 5.6 shows a very interesting dynamic for the real exchange rate when the law of one price holds: it barely moves away from the initial steady state in contrast to the trajectory that real exchange rate follows under incomplete pass-through. Going through the data, it is appreciated that there are fluctuations in this variable, but on average these deviations are basically zero (-9.0365E-16). In fact, this marks the trend that each response function follows: the lower pass through is (i.e. $\theta_F \to 1$), the larger the deviations from the steady state are. Indeed, the more volatile trajectory is observed when $\theta_F = 0.95$. It also can be pinpointed that high values of pass-through (θ_F in the range from 0.05 to 0.25) do not generate strong dynamics for the real exchange rate. The more interesting behaviors of this variable are observed for $\theta_F = 0.78$ and $\theta_F = 0.95$, as these are the cases where fluctuations are perceived. Notwithstanding, if one wants to compare these dynamics with the complete asset market structure, it is also possible to mention that the initial depreciation of the real exchange rate lasts longer than under incomplete asset markets.

To conclude this Chapter, comparing Figures 5.1 and 5.4 it is possible to appreciate that both asset market structures are capable of successfully solving the Backus-Smith puzzle for a wide range of incomplete pass-through levels. The most notorious difference is that under CAM, the correlation between relative consumption and real exchange rate is positive when the law of one price holds (which is precisely what Backus & Smith, 1993 originally pointed out), while under IAM it is possible to reach a negative correlation between the variables of interest. Additionally, it can be noted that the range of values for θ_F, that generates a negative correlation between relative consumption and real exchange rate, is very similar under both asset market structures ($\theta_F \in (0, 0.56)$ under CAM and $\theta_F \in [0, 0.42)$ under IAM). However, the CAM case proves to provide a somewhat wider range, which includes moderate levels of pass-through.

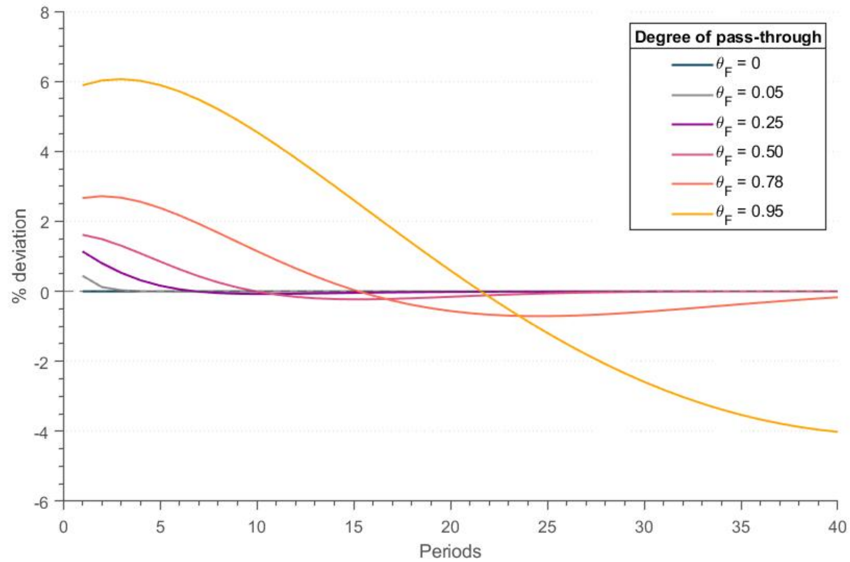

Figure 5.6. Impulse Response Functions of Real Exchange Rate Under IAM

Chapter 6

Sensitivity Analysis

In this Chapter, I perform a sensitivity analysis[1] on the home bias and the elasticity of substitution between home and foreign intermediate goods parameters for the two asset market structures that are presented.

6.1 Complete Asset Markets

Table 6.1 reports the correlation between real exchange rate and relative consumption for alternative values of a (the home bias parameter) and κ (the elasticity of substitution between domestic and foreign intermediate goods), and for different exchange rate pass-through levels. In particular, a is set at 0.55 and 0.70 and κ is set at 0.20, 0.40, 0.60, 0.80, 1, and 1.50. In order to make the sensitivity analysis comparable to the results presented in the previous Chapter, the same degrees of pass-through were chosen. Nonetheless, when $a = 0.70$, setting $\theta_F = 0.95$ generates indeterminancy. For this reason, the upper bound of θ_F was modified to 0.94 instead.

The degree of home bias seem not to affect the observed correlation between real exchange rate and relative consumption for the case when the law of one price holds, as it is possible to observe for the different tested values that this correlation is positive, and hence does not solve the Backus-Smith puzzle. In addition, it can be highlighted that this correlation is consistently negative (and very close to the unit) for values of θ_F up to 0.50. A special case that is worthwhile noting is when $a = 0.55$ and $\theta_F = 0.78$, as it yields a correlation of -0.23, which is very close to the data (-0.17). In this sense, a low value of home bias favors to observe a similar correlation between real exchange rate and relative consumption

[1] This analysis was also done for the degree of price rigidity. However, results presented marginal changes with respect to the baseline estimations. Consequently, these results are not included.

to the data for the empirical pass-through level (i.e. $\theta_F = 0.78$ as estimated by Gopinath & Rigobon, 2006). Overall, it can be concluded that in the presence of complete asset market, it is possible to solve the Backus-Smith puzzle for moderate low values of pass-through, which is translated in observing values between 0.50 and 0.78 for θ_F.

One surprising result for the Backus-Smith puzzle is that a sufficiently low value of the elasticity of substitution is capable of reproducing a negative correlation between relative consumption and real exchange (which is of -0.23 when $\kappa = 0.20$). In regard to the case where the law of one price holds, it is not clear the effect this elasticity has on the Backus correlation, as it appears only that every other correlation is negative. Also, it is interesting to highlight that high levels of pass-through consistently simulate a very high negative correlation. Moreover, it can be noted that in general, the correlation that better fits the data can be found for moderate low values of pass-through (i.e. θ_F between 0.50 and 0.78). Overall, these results point to the fact that with incomplete pass-through it is possible to solve the Backus-Smith puzzle, even under a complete asset market structure and for different values of the elasticity of substitution between home and foreign intermediate goods that are in line with the estimates of Boehm et al. (2019).

Table 6.1. Robustness of the Correlation Between Real Exchange Rate and Relative Consumption Under Complete Asset Markets

	Degree of pass-through					
	$\theta_F = 0$	$\theta_F = 0.05$	$\theta_F = 0.25$	$\theta_F = 0.5$	$\theta_F = 0.78$	$\theta_F = 0.94$
Home bias:						
$a = 0.55$	0.33	-0.99	-0.99	-0.96	-0.23	0.53
$a = 0.70$	0.03	-1.00	-0.99	-0.91	0.37	0.87
Trade elasticity:						
$\kappa = 0.20$	-0.23	-1.00	-0.97	-0.74	0.64	0.93
$\kappa = 0.40$	0.37	-1.00	-0.97	-0.57	0.73	0.92
$\kappa = 0.60$	-0.37	-1.00	-0.97	-0.27	0.77	0.88
$\kappa = 0.80$	0.12	-1.00	-0.97	0.13	0.79	0.75
$\kappa = 1.00$	-0.57	-1.00	-0.96	0.45	0.80	0.44
$\kappa = 1.50$	-0.49	-0.97	0.04	0.74	0.79	0.35

6.2 Incomplete Asset Markets

Table 6.2 shows the correlation between real exchange rate and relative consumption for alternative values of a and κ, and for different exchange rate pass-through levels. In particular, a is set at 0.55 and 0.70 and κ is set at 0.20, 0.40, 0.60, 0.80, 1, and 1.50. In order to make the sensitivity analysis comparable to the results presented in the previous Chapter, the same degrees of pass-through were chosen. Nonetheless, when $a = 0.70$, setting $\theta_F = 0.95$ generates indeterminancy. For this reason, the upper bound of θ_F was modified to 0.94 instead.

Considering the Backus-Smith puzzle, it is clear that in both cases it is possible to observe a majority of negative correlations with different magnitudes. The selected lower of values of a provide lower correlations up to $\theta_F = 0.50$; this is also observed in Table 5.2. This might suggest that breaking the law of one price is a sufficient condition to solve this puzzle. What is of interest as well is that, with lower values of a, the correlation between the real exchange rate and relative consumption remains negative for more values of pass-through. One thing that can be concluded is that the value of a is relevant in the behavior of the Backus-Smith puzzle. As a matter of fact, in the baseline calibration ($a = 0.85$), in order to match the data, θ_F lies in the interval (0.25, 0.50); when $a = 0.70$, a similar result to the data would be observed when θ_F is between 0.50 and 0.78; when $a = 0.50$, this would happen when θ_F belongs between 0.78 and 0.95.

A low value of κ (specifically when it is set at 0.20) generates a negative correlation between real exchange rate and relative consumption similar to the data for moderate low levels of pass-through (i.e. θ_F between 0.50 and 0.78). Something that is interesting to highlight is that for all tested values for the trade elasticity, a strong negative correlation was consistently produced for high degrees of pass-through ($\theta_F = 0.05, 0.25$). Contrary to this, it is clear that regardless of the κ value that is used, the correlation between relative consumption and real exchange rate remains positive high for low degrees of pass-through (i.e. θ_F between 0.78 and 0.94). In fact, a particular pattern is observed with these two degrees of pass-through: when $\theta_F = 0.78$, this correlation becomes more positive as κ increases, while the opposite seems to happen when $\theta_F = 0.94$. For values of $\kappa > 1$, it is also appreciated that a negative correlation between relative consumption and real exchange rate is only achieved through very high values of pass-through (i.e. $\theta_F = 0.94$). In general, it can be concluded that low values of κ simulate lower correlations between the variables of interest, and hence are able to resolve the Backus-Smith puzzle.

In Chapter 4 it was argued that under incomplete asset markets, it is very clear to see that the mechanism that helps solving the Backus-Smith puzzle is given by the expected

Table 6.2. Robustness of the Correlation Between Real Exchange Rate and Relative Consumption Under Incomplete Asset Markets

	Degree of pass-through					
	$\theta_F = 0$	$\theta_F = 0.05$	$\theta_F = 0.25$	$\theta_F = 0.5$	$\theta_F = 0.78$	$\theta_F = 0.94$
Home bias:						
$a = 0.55$	-0.39	-0.99	-0.99	-0.96	-0.50	0.56
$a = 0.70$	-0.60	-1.00	-1.00	-0.92	0.32	0.85
Trade elasticity:						
$\kappa = 0.20$	0.00	-1.00	-0.98	-0.69	0.59	0.76
$\kappa = 0.40$	-0.70	-1.00	-0.98	0.00	0.82	0.79
$\kappa = 0.60$	-0.78	-0.98	-0.90	0.70	0.87	0.70
$\kappa = 0.80$	0.39	-0.91	-0.09	0.83	0.88	0.34
$\kappa = 1.00$	0.13	-0.64	0.56	0.85	0.88	-0.38
$\kappa = 1.50$	-0.41	0.56	0.75	0.81	0.82	-0.62

relative depreciation of the terms of trade for complete and incomplete exchange rate pass-through. After the discussion in this Chapter and the presented results, rather than saying that incomplete pass-through seems irrelevant in solving the puzzle, it is important to note that the introduction of this feature allows to have a wider range of κ values to resolve the Backus-Smith puzzle for both CAM and IAM.

Chapter 7

Conclusions

In this thesis the model of McKnight (2011) has been extended to incorporate incomplete exchange rate pass-through in order to generate deviations from the law of one price. The objective is to address the Backus-Smith puzzle for two asset market structures: 1) Complete asset markets (CAM) and 2) Incomplete asset markets (IAM). This puzzle refers to the positive relationship between real exchange rate and relative consumption that is observed in open-economy macroeconomic models, while the data yields a negative correlation.

Empirical evidence shows that there is exchange rate pass-through in traded goods. This means that the law of one price only holds at the dock, implying that pass-through is incomplete or partial (Campa & Goldberg, 2002). Therefore, in order to try to account for better economic fluctuations, the proposed model incorporates incomplete pass-through by considering local retailers, following Monacelli (2005). Local retailers enter the model by being the agents responsible of importing goods at a cost that follows the law of one price. Nonetheless, they decide to set a different price, according to the downward sloping demand they face, which allows to break the law of one price and have incomplete exchange rate pass-through.

Second moments (standard deviations, first-order autocorrelations, correlations with output, cross-country correlations, and the correlation between relative consumption and real exchange rate) were computed considering CAM and IAM. A common fact that was observed under both asset market structures is that the model yielded somewhat higher volatility in investment. Also, under CAM the model failed to yield strong enough standard deviations for both the terms of trade and the real exchange rate. This was translated in that the model only produced somewhat high volatilities for the terms of trade, but accompanied with very low standard deviations in the real exchange rate. Overall, higher levels of pass-through proved to provide results that are more in line with the data. The computed standard deviations under IAM display different values in the coefficients for the terms of trade and the real exchange rate, if one is to contrast the results that CAM provided. It is also observed that the volatility of both the terms of trade and the real exchange rate is not as high as in the data. A difference between both asset market structures though, is that the standard deviation of the terms of trade is lower for higher values of pass-through. Hence, it can be said that market completeness generate higher volatility in the terms of trade only for high levels of pass-through. In general, the baseline model provided somewhat close moments to the data.

The generated cross-country correlations were some similar and others different under complete and incomplete asset market structures and for specific values of exchange rate pass-through. Coefficients for output are an example of similar observed results under both asset market structures. One thing to note in the baseline model for complete and incomplete asset markets is that the cross-country correlation of investment was negative and persisted that way for high and low levels of pass-through. In general, it can be said that the model generated moments that fell somewhat below the data threshold.

Results successfully show that introducing incomplete pass-through can be a part of the solutions for the Backus-Smith puzzle, considering either complete or incomplete asset markets, since negative correlations between real exchange rate and relative consumption were observed. One important fact that the model replicated was that under CAM and allowing the law of one price to hold, the computed correlation between these two variables was positive; this goes in line with previous findings (for example Chari et al., 2002). On the other hand, the model provided evidence that under incomplete asset markets it was also possible to simulate a negative correlation between the real exchange rate and relative consumption. It was analyzed that exchange rate pass-through affects the dynamics of real wage for both countries, which in turn impacts the correlation between relative consumption and real exchange rate. Under IAM, it was noted that the average expected relative growth rate of real wages played an important role in the fluctuations of relative consumption. In particular, when the relative growth rate of domestic wages is higher than the foreign one, a negative correlation was observed. Furthermore, it was pinpointed that a decisive variable that determines the behavior of real wages is the terms of trade of both countries. In particular, the expected relative depreciation rate of the terms of trade is what shapes the real wages. Whenever expected foreign terms of trade depreciate more than the home terms of trade, the Backus-Smith puzzle is solved. Under CAM, the risk sharing condition shows that the relative real wage growth helps in determining the sign of the correlation between real exchange rate and relative consumption. Nonetheless, it was not possible to isolate whether there is a particular variable that has a preponderant effect on real wages, but it was concluded that the joint effect of the real marginal cost and the depreciation of terms of trade affect relative real wage growth.

In order to help having a better notion of how this correlation behaves under different exchange rate pass-through levels, Figures 5.1 and 5.4 show the dynamics of such correlation for a continuum of values for pass-through (i.e. θ_F going from 0 to 0.97 under complete asset markets and from 0 to 0.98 for incomplete markets). For both asset market structures it was possible to see that introducing incomplete pass-through resolved the Backus-Smith puzzle. The first thing that can be noted is that moderate to high exchange rate pass-through levels are needed in order to produce a negative correlation between the variables of interest. Allowing $\theta_F = 0$ mean that pass-through is complete, the mentioned range is for θ_F between 0.01 and 0.41 under complete asset markets and from 0 to 0.56 under incomplete asset markets. Nonetheless, in order to observe a correlation similar to the data (-0.17 for the U.S. in this thesis), pass-through needs to be between 0.52 and 0.55 under complete asset markets and around 0.41 under incomplete asset markets, which is higher than the estimates Gopinath & Rigobon (2006) and Campa & Goldberg (2002) give. Overall, the performance of the model is analogous, as both asset market structures solve the Backus-Smith puzzle by introducing incomplete pass-through.

Impulse response functions to a 1% positive productivity shock in the domestic goods sector of relative consumption and real exchange rate were computed for the model considering complete and incomplete asset markets, and different levels of pass-through. The same pattern was observed under both asset market structures, although of different magnitude. High levels of exchange rate pass-through generate an initial fall in relative consumption. On the other hand, when pass-through is low, the initial response of this variable is positive. Therefore, the degree of pass-through is crucial in determining the initial response of relative consumption.

The impulse response function of the real exchange rate shows as well that the degree of pass-through plays a key role in the dynamics this variable is to follow under both asset market structures. When the law of one price holds, the model simulated an almost null response of real exchange rate in contrast to the cases where incomplete pass-through was present. Also, it was noted that lower degrees of pass-through provoked a longer initial depreciation of the real exchange rate. At the same time, the lower pass-through is, the greater and long-lasting appreciation was observed after the initial depreciation.

Finally, a robustness analysis was performed on two parameters: 1) Home bias and 2) The elasticity of substitution between domestic and foreign intermediate goods. Regarding the Backus-Smith puzzle, under complete asset markets it was possible to observe that lower values of home bias allowed lower levels of pass-through to reach a lower correlation between real exchange rate and relative consumption. For example, when a was set at 0.55, a correlation of -0.23 was produced under the baseline pass-through level (i.e. $\theta_F = 0.78$). The same pattern can be observed for the different tested values of κ. Notwithstanding, the decrease in the correlation for lower levels of pass-through was marginal even for the lowest κ value that was tested. In the case of incomplete asset markets, lower values of home bias also allow lower levels of pass-through to achieve a lower correlation between real exchange rate and relative consumption. A key difference from the complete asset market case is that the effect is larger, as when $a = 0.55$ the generated correlation for the baseline pass-through level was of -0.50. Therefore, in order to observe a correlation that is close to the data, a would need to be between 0.55 and 0.70. In the case of the elasticity of substitution between domestic and foreign intermediate goods, it is also easy to see that lower values of κ help the correlation between relative consumption and real exchange rate to be smaller for low levels of pass-through. However, the lowest correlation coefficient that is reached for the baseline pass-through degree is of 0.59 when $\kappa = 0.20$. A second important result from the sensitivity analysis is that for both asset market structures, introducing incomplete exchange rate pass-through allows to have a wider range of values for the elasticity of substitution between home and foreign intermediate goods that can resolve the Backus-Smith puzzle.

Appendix A

System of Equilibrium Conditions

In this Appendix I describe the equilibrium conditions of both countries, under complete and incomplete asset markets, that were used to simulate the results presented in this document. I present the pair of home and foreign equations.

A.1 Final Good Producer

The domestic demand of home and foreign intermediate goods for the home country are given by:

$$\hat{Z}_{H,t} = (1-a)\kappa\hat{T}_t + \hat{Z}_t \tag{H1}$$

$$\hat{Z}_{F,t} = -a\kappa\hat{T}_t + \hat{Z}_t \tag{H2}$$

and for the foreign country:

$$\hat{Z}^*_{F,t} = (1-a)\kappa\hat{T}^*_t + \hat{Z}^*_t \tag{F1}$$

$$\hat{Z}^*_{H,t} = -a\kappa\hat{T}^*_t + \hat{Z}^*_t \tag{F2}$$

CPI inflation for the home and foreign country is given by:

$$\hat{\pi}_t = a\hat{\pi}_{H,t} + (1-a)\hat{\pi}_{F,t} \tag{H3}$$

$$\hat{\pi}^*_t = a\hat{\pi}^*_{F,t} + (1-a)\hat{\pi}^*_{H,t} \tag{F3}$$

A.2 Intermediate Goods Producers

The production function for the home and foreign country is given by:

$$\hat{Y}_t = \hat{A}_t + \alpha\hat{K}_t + (1-\alpha)\hat{L}_t \tag{H4}$$

$$\hat{Y}^*_t = \hat{A}^*_t + \alpha\hat{K}^*_t + (1-\alpha)\hat{L}^*_t \tag{F4}$$

The optimal labor and capital demands conditions for the home country are given by:

$$\hat{w}_t = \hat{mc}_t + \hat{A}_t - (1-a)\hat{T}_t + \alpha(\hat{K}_t - \hat{L}_t) \tag{H5}$$

$$\hat{rr}_t = \hat{mc}_t + \hat{A}_t - (1-a)\hat{T}_t + (1-\alpha)(\hat{L}_t - \hat{K}_t) \tag{H6}$$

and for the foreign country:

$$\hat{w}^*_t = \hat{mc}^*_t + \hat{A}^*_t - (1-a)\hat{T}^*_t + \alpha(\hat{K}^*_t - \hat{L}^*_t) \tag{F5}$$

$$\hat{rr}^*_t = \hat{mc}^*_t + \hat{A}^*_t - (1-a)\hat{T}^*_t + (1-\alpha)(\hat{L}^*_t - \hat{K}^*_t) \tag{F6}$$

The New Keynesian Phillips Curve for the home and foreign country is given by:

$$\hat{\pi}_{H,t} = \beta E_t \hat{\pi}_{H,t+1} + \kappa_H \hat{mc}_t \tag{H7}$$

$$\hat{\pi}^*_{F,t} = \beta E_t \hat{\pi}^*_{F,t+1} + \kappa^*_F \hat{mc}^*_t \tag{F7}$$

where $\kappa_H = \frac{(1-\theta_H)(1-\beta\theta_H)}{\theta_H}$ and $\kappa^*_F = \frac{(1-\theta^*_F)(1-\beta\theta^*_F)}{\theta^*_F}$.
Imported inflation for the home and foreign country is given by:

$$\hat{\pi}_{F,t} = \beta E_t \hat{\pi}_{F,t+1} + \lambda_F \Psi_{F,t} \tag{H8}$$

$$\hat{\pi}^*_{H,t} = \beta E_t \hat{\pi}^*_{H,t+1} + \lambda^*_H \Psi^*_{H,t} \tag{F8}$$

where $\lambda_F = \frac{(1-\theta_F)(1-\beta\theta_F)}{\theta_F}$ and $\lambda^*_H = \frac{(1-\theta^*_H)(1-\beta\theta^*_H)}{\theta^*_H}$.

A.3 Representative Agent

The law of motion of capital for the home and foreign country is given by:

$$\hat{K}_{t+1} = (1-\delta)\hat{K}_t + \delta\hat{I}_t \tag{H9}$$

$$\hat{K}^*_{t+1} = (1-\delta)\hat{K}^*_t + \delta\hat{I}^*_t \tag{F9}$$

The Euler equation, and the optimal investment and labor supply conditions for the home are given by:

$$\rho E_t \hat{C}_{t+1} + \eta \frac{L}{1-L} E_t \hat{L}_{t+1} = \rho \hat{C}_t + \eta \frac{L}{1-L} \hat{L}_t + \hat{i}_t - E_t \hat{\pi}_{t+1} \tag{H10}$$

$$\rho E_t \hat{C}_{t+1} + \eta \frac{L}{1-L} E_t \hat{L}_{t+1} - \beta rr E_t \hat{rr}_{t+1} = \rho \hat{C}_t + \eta \frac{L}{1-L} \hat{L}_t \tag{H11}$$

$$-\hat{C}_t + \hat{w}_t = \frac{L}{1-L} \hat{L}_t \tag{H12}$$

and for the foreign country:

$$\rho E_t \hat{C}^*_{t+1} + \eta \frac{L^*}{1-L^*} E_t \hat{L}^*_{t+1} = \rho \hat{C}^*_t + \eta \frac{L^*}{1-L^*} \hat{L}^*_t + \hat{i}^*_t - E_t \hat{\pi}^*_{t+1} \tag{F10}$$

$$\rho E_t \hat{C}^*_{t+1} + \eta \frac{L^*}{1-L^*} E_t \hat{L}^*_{t+1} - (\beta r r^*) E_t \hat{rr}^*_{t+1} = \rho \hat{C}^*_t + \eta \frac{L^*}{1-L^*} \hat{L}^*_t \tag{F11}$$

$$-\hat{C}^*_t + \hat{w}^*_t = \frac{L^*}{1-L^*} \hat{L}^*_t \tag{F12}$$

A.4 Monetary Policy

The monetary policy rule for the home and foreign country is given by:

$$\hat{i}_t = \mu_\pi \hat{\pi}_t + \mu_y \hat{Y}_t \tag{H13}$$

$$\hat{i}^*_t = \mu_\pi \hat{\pi}^*_t + \mu_y \hat{Y}^*_t \tag{F13}$$

A.5 Market Clearing Conditions

The total home demand for the home and foreign country is given by:

$$\hat{Z}_t = \frac{C}{Z} \hat{C}_t + \frac{I}{Z} \hat{I}_t \tag{H14}$$

$$\hat{Z}^*_t = \frac{C^*}{Z^*} \hat{C}^*_t + \frac{I^*}{Z^*} \hat{I}^*_t \tag{F14}$$

The total domestic goods demand for the home and foreign country is given by:

$$\hat{Y}_t = \frac{Z_H}{Y} \hat{Z}_{H,t} + \frac{Z^*_H}{Y} \hat{Z}^*_{H,t} \tag{H15}$$

$$\hat{Y}^*_t = \frac{Z^*_F}{Y^*} \hat{Z}^*_{F,t} + \frac{Z_F}{Y^*} \hat{Z}_{F,t} \tag{F15}$$

A.6 Other Equations

The terms of trade for the home and foreign country are given by:

$$\hat{T}_t - \hat{T}_{t-1} = \hat{\pi}_{F,t} - \hat{\pi}_{H,t} \tag{H16}$$

$$\hat{T}^*_t - \hat{T}^*_{t-1} = \hat{\pi}^*_{H,t} - \hat{\pi}^*_{F,t} \tag{F16}$$

The law of one price gap for the home and foreign country is given by:

$$\Psi_{F,t} = \hat{Q}_t - (1-a)\hat{T}^*_t - a\hat{T}_t \tag{H17}$$

$$\hat{\Psi}^*_{H,t} = -\hat{Q}_t - a\hat{T}_t - (1-a)\hat{T}^*_t \tag{F17}$$

A.7 Complete Asset Markets

The risk-sharing condition is given by:

$$\hat{Q}_t = -\rho(\hat{C}_t^* - \hat{C}_t) + \eta\left(\frac{L}{1-L}\hat{L}_t - \frac{L^*}{1-L^*}\hat{L}_t^*\right) \tag{H18}$$

A.8 Incomplete Asset Markets

The bond market clearing conditions is given by:

$$\tilde{b}_t = -\tilde{b}_t^* \tag{H18}$$

The Uncovered Interest Rate Parity (UIP) condition is given by:

$$E_t(\hat{Q}_{t+1} - \hat{Q}_t) = \hat{i}_t - E_t\hat{\pi}_{t+1} - (\hat{i}_t^* - E_t\hat{\pi}_{t+1}^*) + \varepsilon\tilde{b}_{t+1} \tag{H19}$$

The current account equation for the home country is given by:

$$\beta\tilde{b}_{t+1} - \tilde{b}_t = \hat{Y}_t - (1-a)\hat{T}_t - \frac{Z}{Y}\hat{Z}_t \tag{H20}$$

A.9 Steady State Ratios

The steady state ratios are computed mainly through market clearing conditions. All values are symmetrical for each country. I present the ratios in Table A.1.

Table A.1. Steady State Ratios

Home Country	Foreign Country
$\frac{Z}{Y} = 1$	$\frac{Z^*}{Y^*} = 1$
$\left(\frac{K}{L}\right)^{1-\alpha} = \alpha\frac{\lambda-1}{\lambda}\frac{\beta}{1-\beta(1-\delta)}$	$\left(\frac{K^*}{L^*}\right)^{1-\alpha} = \alpha\frac{\lambda-1}{\lambda}\frac{\beta}{1-\beta(1-\delta)}$
$\frac{K}{Y} = \left(\frac{K}{L}\right)^{1-\alpha}$	$\frac{K^*}{Y^*} = \left(\frac{K^*}{L^*}\right)^{1-\alpha}$
$\frac{C}{Z} = 1 - \delta\frac{K}{Y}\frac{Y}{Z}$	$\frac{C^*}{Z^*} = 1 - \delta\frac{K^*}{Y^*}\frac{Y^*}{Z^*}$
$\frac{I}{Z} = 1 - \frac{C}{Z}$	$\frac{I^*}{Z^*} = 1 - \frac{C^*}{Z^*}$
$\frac{Z_H}{Y} = a$	$\frac{Z_F^*}{Y^*} = a$
$\frac{Z_H^*}{Y} = 1 - a$	$\frac{Z_F}{Y^*} = 1 - a$

Appendix B

Impulse Response Functions

This Appendix contains the impulse response functions (IRF) following a 1% positive productivity shock of selected variables for both countries (consumption, labor, investment, and terms of trade) and for different degrees of exchange rate pass-through.

B.1 Complete Asset Markets

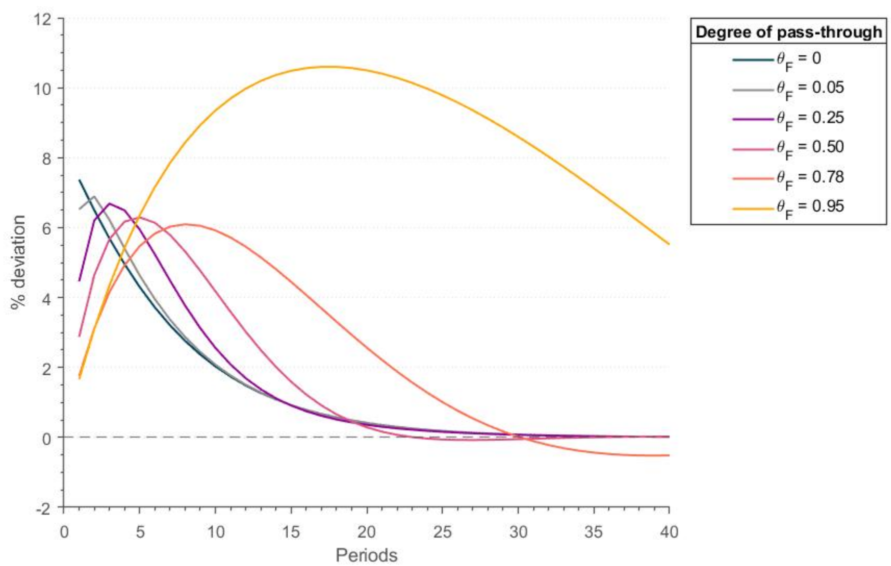

Figure B.1. Impulse Response Function of Domestic Terms of Trade Under CAM

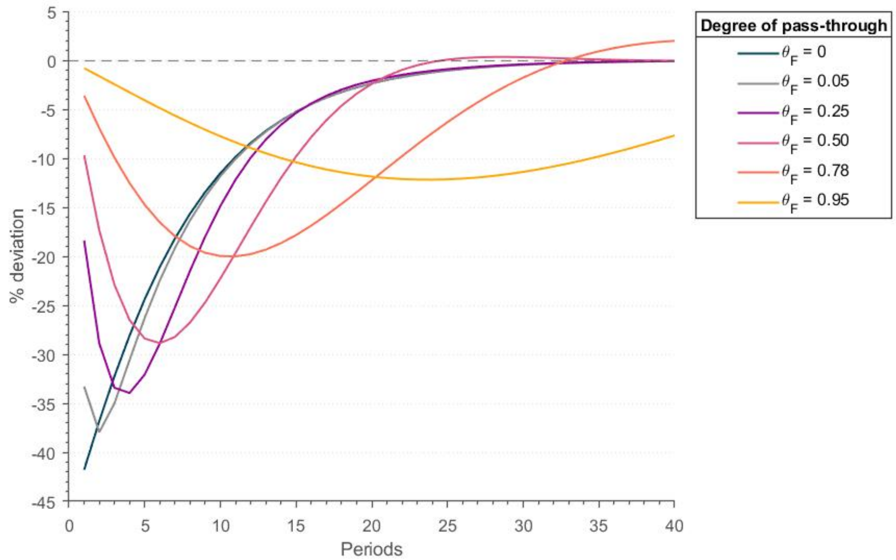

Figure B.2. Impulse Response Function of Foreign Terms of Trade Under CAM

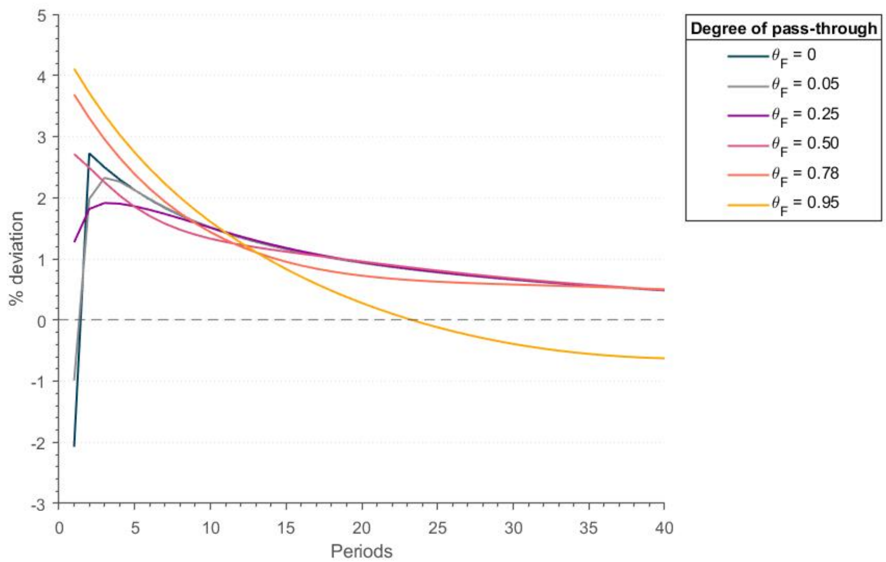

Figure B.3. Impulse Response Function of Domestic Consumption Under CAM

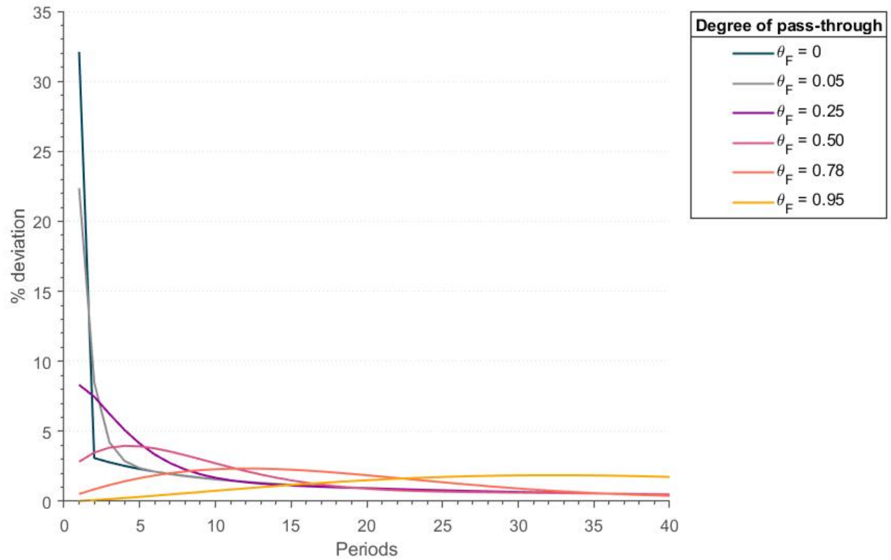

Figure B.4. Impulse Response Function of Foreign Consumption Under CAM

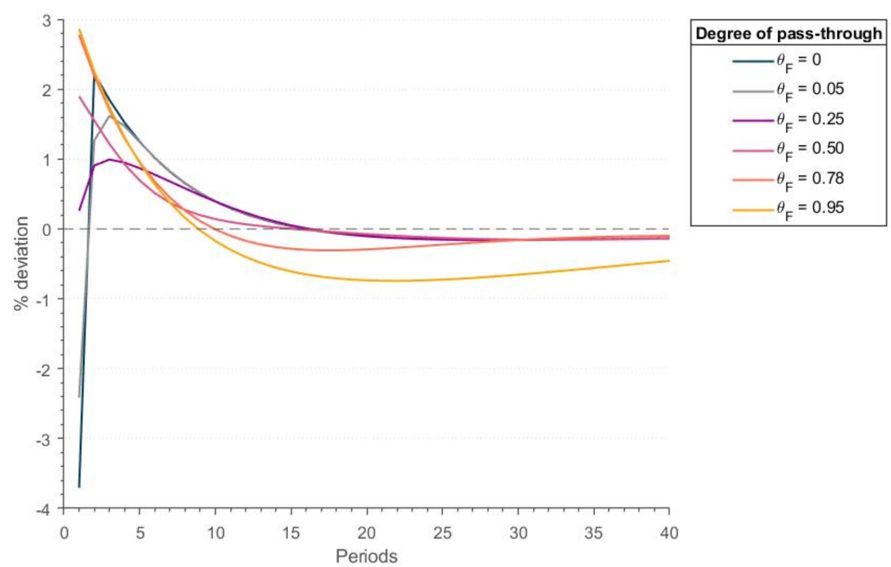

Figure B.5. Impulse Response Function of Domestic Labor Under CAM

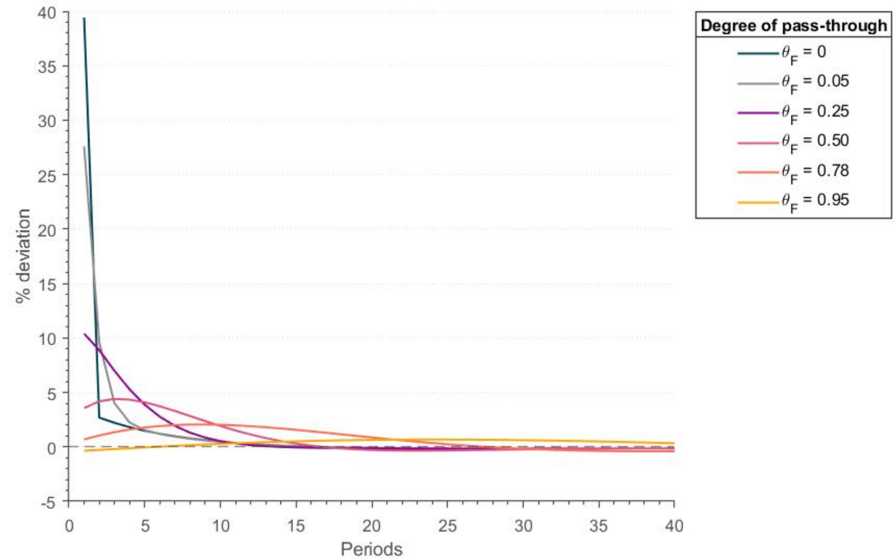

Figure B.6. Impulse Response Function of Foreign Labor Under CAM

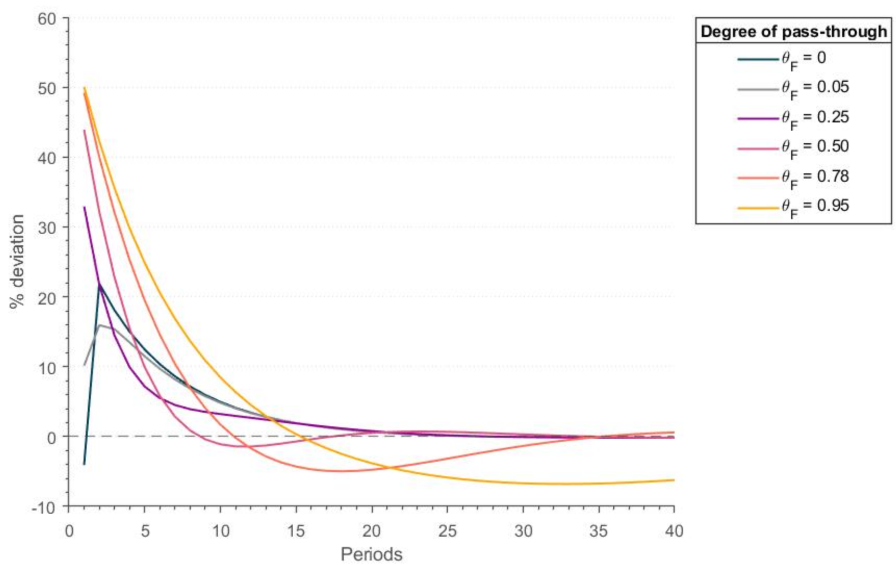

Figure B.7. Impulse Response Function of Domestic Investment Under CAM

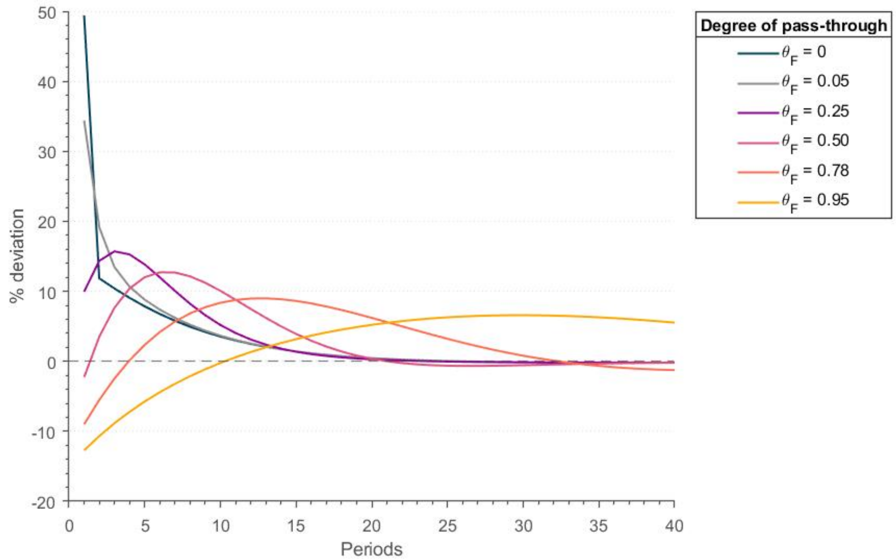

Figure B.8. Impulse Response Function of Foreign Investment Under CAM

B.2 Incomplete Asset Markets

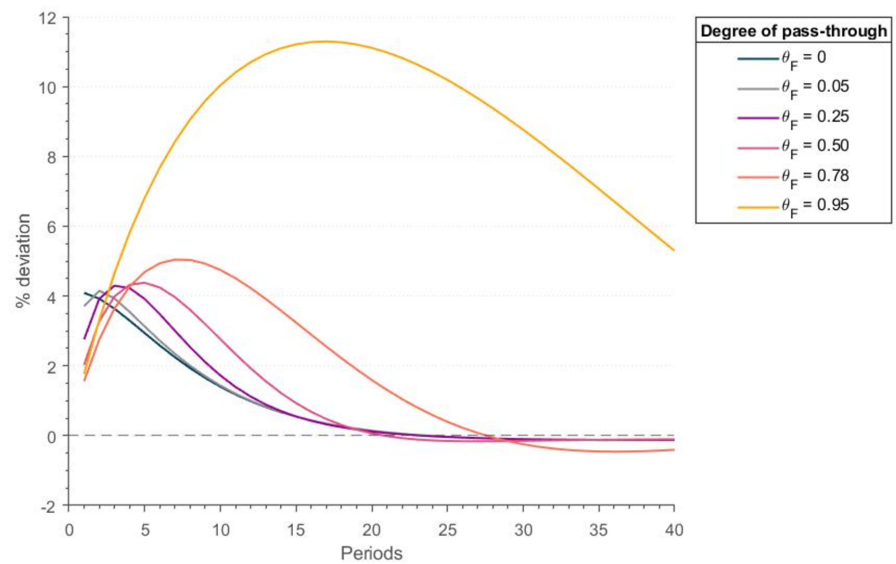

Figure B.9. Impulse Response Function of Domestic Terms of Trade Under IAM

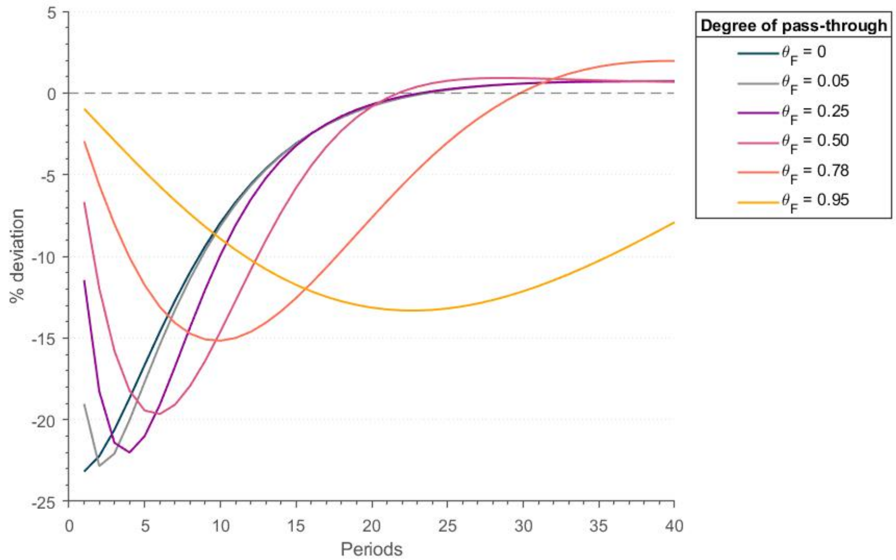

Figure B.10. Impulse Response Function of Foreign Terms of Trade Under IAM

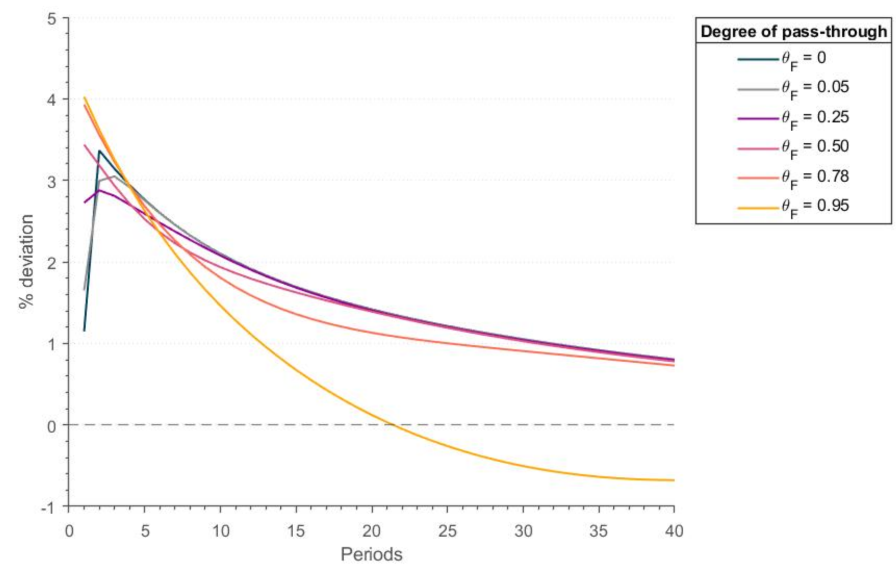

Figure B.11. Impulse Response Function of Domestic Consumption Under IAM

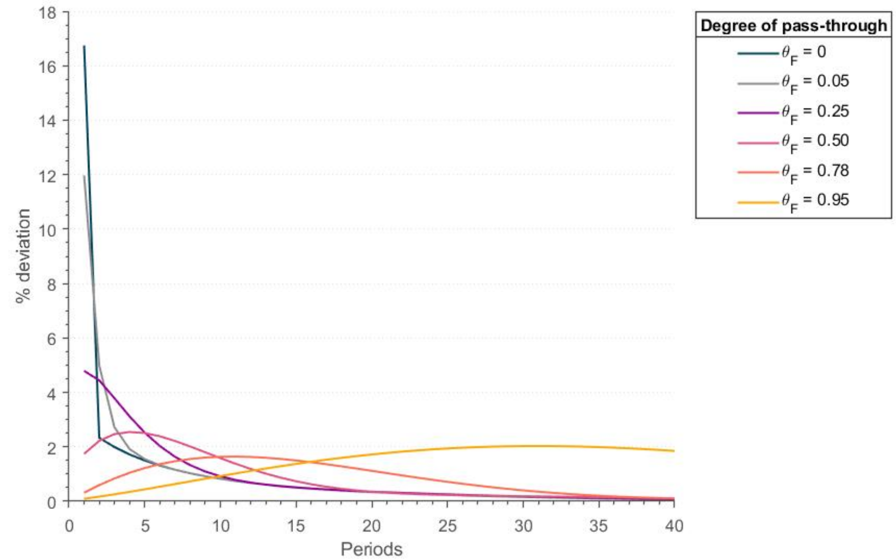

Figure B.12. Impulse Response Function of Foreign Consumption Under IAM

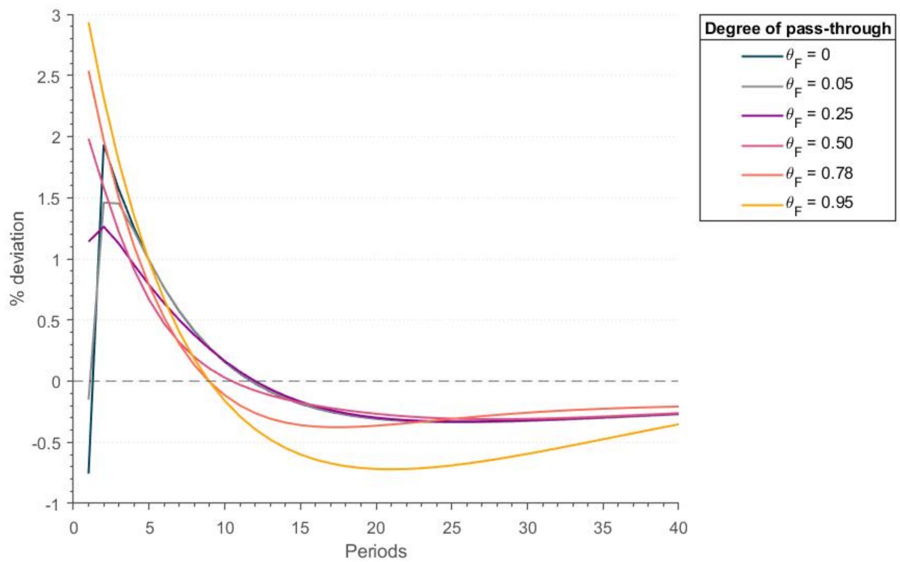

Figure B.13. Impulse Response Function of Domestic Labor Under IAM

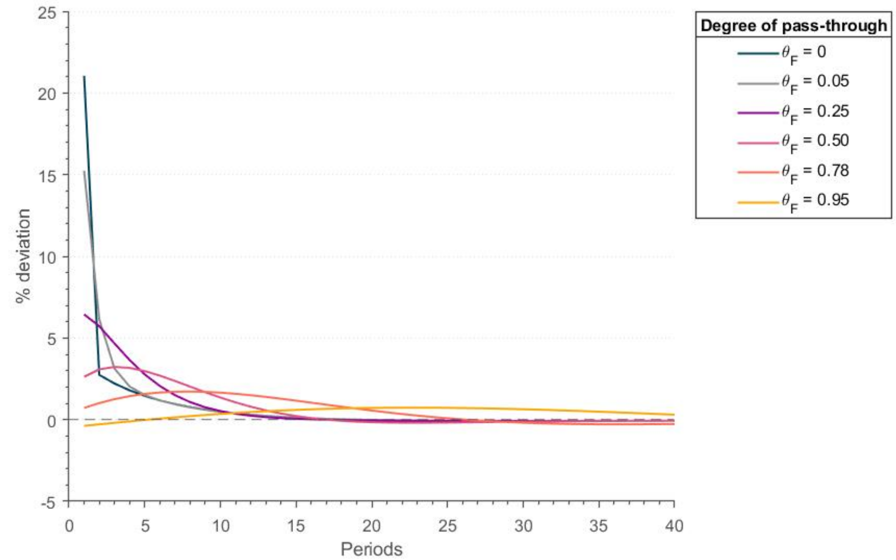

Figure B.14. Impulse Response Function of Foreign Labor Under IAM

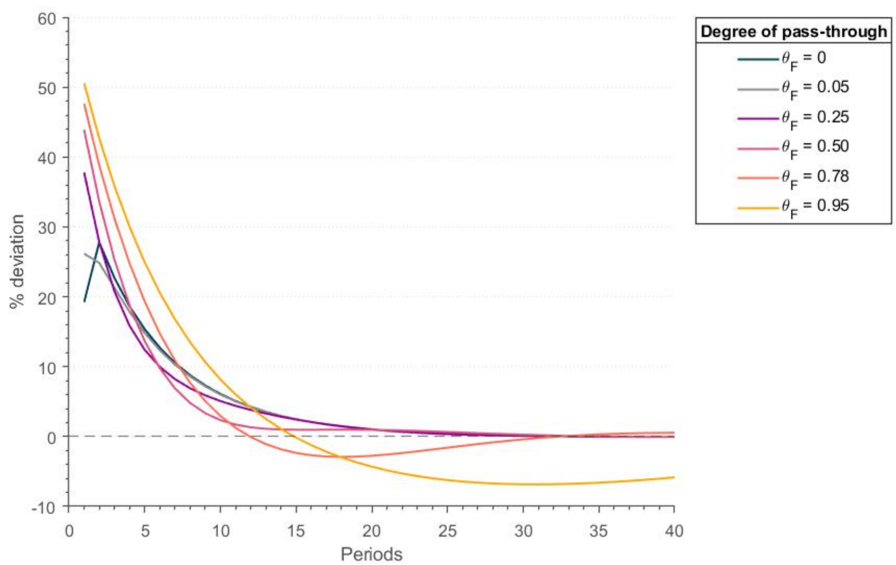

Figure B.15. Impulse Response Function of Domestic Investment Under IAM

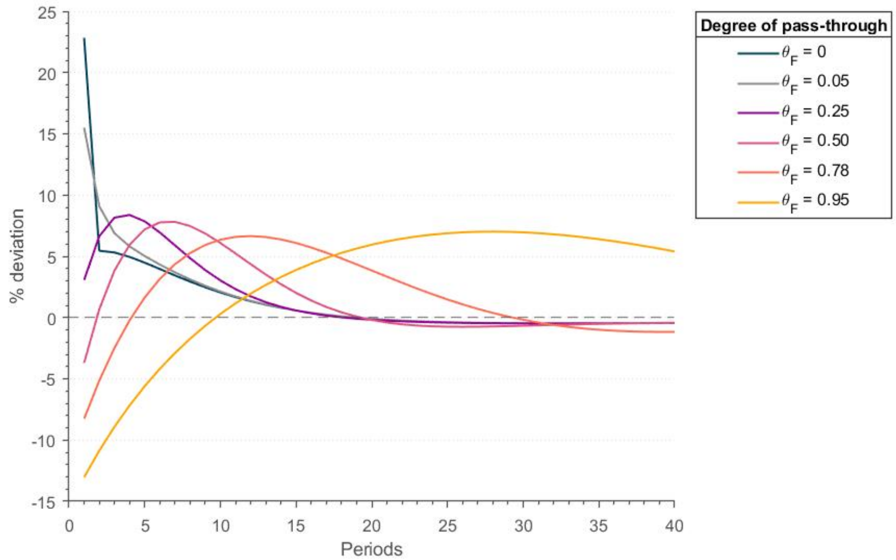

Figure B.16. Impulse Response Function of Foreign Investment Under IAM

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