Understanding volatility shocks in real models∗

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Abstract

This paper studies the role of endogenous markups in the transmission of volatility shocks in real models. I design a variant of a small open economy model with volatility shocks and firm dynamics that gives rise to endogenous markups. I calibrate this model to match the business cycle facts in emerging economies and show that the impact of volatility shocks is substantially amplified if markups are endogenously time-varying. I study three variants of the model: one in which volatility shocks affect the stochastic process of technology, one in which volatility shocks affect the stochastic process of the interest rate spread and one augmented with working capital constraints. I find that volatility shocks increase savings, due to precautionary motives, and markups. The increase in markups acts as a wedge that endogenously decreases the TFP and induces a fall in real wages, decreasing labor supply with further negative aggregate dynamics that are absent in the models with constant markups.

Keywords: Volatility shocks, firm dynamics, endogenous markups.


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1 Introduction

The objective of this paper is to understand the channels behind the transmission of volatility shocks in real business cycle models. Specifically, I develop a real general equilibrium model for a small open economy with stochastic volatility and monopolistic competition, and use it to study the role of endogenously time-varying markups in the amplification and persistence of volatility shocks.

A “volatility shock” is a shock to the standard deviation of exogenous random variables. Even though the attention to volatility shocks as driving forces of the business cycle has recently increased because of the Great Moderation and the “good luck” versus “good policy” debate, the understanding of these shocks is still evolving.\(^1\) The main reason for the limited understanding of volatility shocks is that these disturbances are of a very different nature compared to any other shock commonly used in the macroeconomics’ literature. Specifically, volatility shocks do not affect the level of real nor nominal innovations, but only the risk associated to future realizations. For example, consider a standard real business cycle model with stochastic volatility technology shocks (TFP). Here, a change in the volatility of TFP does not affect the level of TFP, hence any real impact of this change is not a consequence of a current change in productivity but, instead, a consequence of a change in the risk associated to future values of the TFP.\(^2\) Given the nature of volatility shocks, their transmission channels are different from those of other shock. Even though volatility shocks attracted a great deal of attention, the literature that studied them in pure real models has so far assumed fixed markups, however, markups are endogenously time-varying.

In this paper, I contribute to the understanding of volatility shocks in dynamic economies.

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\(^1\)The Great Moderation refers to the period 1984-2007 during which the volatility of macroeconomic variables in US experienced a statistically significant drop compared to the pre-1984 sample. See McConnell and Perez-Quiros (2000) and Stock and Watson (2003). The “good luck” versus “good policy” debate was the one that intended to find the roots of the “Great moderation”. Specifically, this debate inquires whether the decrease in aggregate volatility occurred due to an exogenous drop in the volatility of shocks, i.e. the “good luck” scenario, or because policy-makers had designed appropriate policy instruments to deal with exogenous disturbances, the “good policy” scenario.

\(^2\)Additionally note that a volatility shock is also different from a news shock. Changes in volatility do not imply future changes in the level of random variables whereas news shocks do.
I study the way time-varying markups, Frisch elasticity, adjustment costs of capital and different assumptions about the utility functions affect the sign, magnitude and persistence of the response of endogenous variables to volatility shocks in pure real models, i.e. models in which nominal variables do not play a role.

First, I study the dynamics of markups observed in the data for 10 small open emerging economies. Using annual data from UNIDO Indstat2, that includes information on 28 manufacturing industries during the period 1963-2010, I show that markups volatility is substantial. In particular, the volatility of markups relative to the volatility of GDP goes from 15%, for the case of Bolivia, to 130% for South-Africa, with a cross country average of about 45%. Additionally, I show that on average it tends to be negatively correlated with output. This evidence suggests that markups variability can potentially be an important factor in the transmission of volatility shocks and, moreover, the appropriate model to take markups variability into account should be one with countercyclical markups.

Then, I introduce a model to study the role of endogenously time-varying markups in a pure real economy. The baseline model is a version of real business cycle small open economy model along the lines of Mendoza (1991) and Schmitt-Grohé and Uribe (2003), with GHH preferences, as in Greenwood et al. (1988), and stochastic volatility shocks. The baseline specification of the model assumes monopolistic competition in a setup that I borrow from Jaimovich (2007) and allows for entry and exit of firms, which gives rise to countercyclical markups as firm dynamics affect the degree of competition. Besides the firm dynamics, the model is an otherwise simple real business cycle small open economy model. This model, hence, allows us to study the role of endogenously time-varying markups without assuming price frictions or nominal disturbances and, consequently, allows us to isolate the effects of markups from those of nominal frictions, something that is impossible in New-Keynesian sticky prices models.

I find that endogenously time-varying markups induce a substantial amplification in the responses of endogenous variables to a TFP volatility shock because they exacerbate the
response of real wages. Specifically, an increase in volatility triggers a consumption drop because of precautionary savings motives. Additionally, it negatively affects investment because it makes investment returns more risky. These two effects decrease the demand side of the economy. In the open economy, the trade balance improves, imports drop and the domestic economy increases savings in foreign debt. Given the assumptions of monopolistic competitive firms, the drop in demand forces the exit of firms which lowers the degree of competition and drives markups up. The increase in markups operates as inducing a drop in the technology and decreases the real wage inducing a drop in labor supply. The joint drop in labor and technology through the increase in markups induces an extra negative impact on output which subsequently reinforces the drop in demand. This channel is absent without time-varying markups. This analysis is followed by a battery of robustness exercises and sensitivity analysis to provide further insights on the mechanisms behind the dynamics of the model. I study the role of Frisch elasticity, adjustment costs of investment, the degree of financial frictions and the role of GHH preferences. \(^3\) I find that the results for the baseline model are robust but the magnitude of the responses can be significantly affected by the parameters regulating them. Additionally, I find that the assumption of GHH utility function matters. If separable utility functions are assumed, wealth effect might easily compensate the substitution effect and induce a counter-factual increase in hours worked following a volatility shock. However, the right dynamics can be restored at the cost of a small Frisch elasticity.

Fernández-Villaverde et al. (2011b) studies spread shocks and spread volatility shocks and show they have quantitatively important effects in the dynamics of emerging economies. For this reason, in Section 6 I study the role of endogenous markups in the transmission of

\(^3\)I study to what extent the results depend on the Frisch elasticity given that Fernández-Villaverde et al. (2011b) point out the response of labor supply to volatility shocks is of major importance. Then, I study the role of investment adjustment costs, following the findings in Bloom et al. (2007). Seoane (2012) discusses the importance of the risk premium elasticity, hence in this paper I study whether the main dynamics are affected by different degrees of responsiveness of the interest rate spread to foreign debt, that is usually considered a measure of financial frictions. Finally, it is well known that a feature of GHH preferences is that they eliminate the wealth effect and make labor supply only dependent on the real wage. For this reason, I study whether and how dynamics change when using a separable utility function.
volatility shocks to the interest rate spread. This section considers two variants of the model, with working capital constraints and without working capital constraints as in Neumeyer and Perri (2005). The findings in this section reinforces our previous results, I find that the impact of spread volatility shocks to output is twice as large when the markup dynamics are considered than in the model with fixed markups. When firms are subject to working capital constraints the differences between the model with and without endogenous markups are even larger.

The focus on open economies is not by chance. One of the main stylized facts in the literature of volatility shocks is that increases in volatility are negatively related to output. In order to generate these dynamics, the set of financial assets that can be used for saving matters. Specifically, volatility shocks trigger precautionary savings, in the close economy with only capital, agents would increase their savings using capital that will rent to the firms. In this case, volatility shock increases capital and induces and increase in output, rather than an output fall. The open economy provides with an extra asset available in infinite supply which is foreign debt. For instance, an option to deal with this issue in the closed economy would be to model a government that issues sovereign debt. Even though this is a valid direction, it makes results dependent on the fiscal policy behavior. Fernández-Villaverde et al. (2011a) studies volatility shocks and fiscal policy in a model with sticky prices.

The economic mechanism in the baseline model relies on firm dynamics. For this reason, I provide some stylized evidence on dynamics of firms in different countries using the database constructed by Bartelsman et al. (2009) that includes annual variables for entry and exit of firms at industry level for several open economies. I find evidence suggesting that the dynamic of firms is roughly in line with the implications of the model. Additionally, in the online appendix I study the role of endogenous markups in a variant of the small open economy in which markups change because of deep habits, as in Ravn et al. (2006) assuming no firm dynamics and, as can be seen, the main results are robust to this alternative specification.
This paper is related to the literature that studies the role and importance of volatility shocks over the business cycle such as Bloom et al. (2007), Bloom (2009), Cogley and Sargent (2005), Justiniano and Primiceri (2008), Fernández-Villaverde and Rubio-Ramírez (2007) and Fernández-Villaverde et al. (2011b). This literature has grown substantially during the last years and currently expanded to the study of the effect of changes in the volatility of technology, the volatility of fiscal and monetary policies, such as Fernández-Villaverde et al. (2011a) and Fernández-Villaverde et al. (2010) as well as changes in the volatility of foreign interest rates in open economy models, as in Fernández-Villaverde et al. (2011b), among several additional specifications. A recent review of this literature is in Fernández-Villaverde and Rubio-Ramírez (2013). However, all real models in this literature assume fixed markups, while endogenous markups have only been studied together with sticky prices in New Keynesian models.

There is substantial evidence supporting the time-variation of markups over the business cycle. To my best knowledge, among the first references are Rotemberg and Woodford (1991) and Rotemberg and Woodford (1999), who find evidence supporting countercyclical markups, i.e. they tend to increase together with output drops. However, there is a large list of references that study the impact of volatility shocks in models in which prices equal marginal costs, for instance, Fernández-Villaverde et al. (2011b), Gruss and Mertens (2009) and Plante and Traum (2011). Given the evidence I present here, the results in these articles might substantially underestimate the impact of volatility shocks.

This paper is also related to a growing literature studying the role of endogenous markups in the dynamics of general equilibrium models. For instance, Jaimovich (2007) develop models with endogenous markups to study firm dynamics and business cycle fluctuations. Additionally, Ravn et al. (2004b), Ravn et al. (2006) and Ravn et al. (2004a) study a generalization of Abel (1990)’s “Keeping up with the Joneses” external habit formation at the aggregate consumption level, to a framework in which this kind of habit formation occurs at the individual goods variety level and in this way affects markups endogenously. My paper
differs from those in this literature in that they do not consider the case of time-varying volatility and hence, do not study how considering endogenous markups might affect the transmission channels following a volatility shock nor the economics behind it.

As mentioned above, in models with sticky prices, some attention has been devoted to the interaction of volatility shocks and markups as in Basu and Bundick (2011) and Fernández-Villaverde et al. (2011a). The contribution of my paper is that I study this interaction in a pure real model. Hence, this paper contributes to help disentangling the role of time-varying markups from the one of sticky prices in the amplification of volatility shocks.

The remainder of the paper goes as follows. In Section 2, I study the dynamics of markups over the business cycle in small open economies in order to provide evidence of their substantial variability and their comovement with output. Then in Section 3, I present the baseline real business cycle model with TFP stochastic volatility and firm dynamics. Section 4 discusses the empirical strategy I follow to take this model to the data. Section 5 studies the dynamic behavior of endogenous variables after volatility shocks and provides a sensitivity analysis. In Section 6 I present, calibrate and study the version of the model with volatility shocks to the real interest rate spread. The economic mechanism in the model relies on firm dynamics, hence, Section 7 provides two sources of evidence supporting the mechanism behind the model, first I study firms entry and exit over the business cycle for 7 emerging economies using data from Bartelsman et al. (2009) and show that the dynamics of firms are strongly related to the business cycle; then I present a literature review on firm dynamics in open economies. Section 8 concludes and provides a discussion of the potential implications of the main result.4

4Additional exercises are available in an online appendix. In particular, the appendix studies the transmission of volatility shocks in models with deep habits following Ravn et al. (2004b), Ravn et al. (2006) and Ravn et al. (2004a). Deep habits are an alternative way to induce endogenous markups in real models. I show that endogenous markups in this setup have also similar amplification power to the one in the model with firm dynamics. This allows me to provide a more general result about the role of endogenous markups in the transmission of volatility shocks, in the sense that the amplification that endogenous markups generate is observed regardless the setup that gives rise to time-varying markups. Additional exercises in the online appendix include the impact of different sizes of volatility shocks and different calibrations.
2 Markups in the open economy

This section explores the relationship between markups and the business cycle in small open economies. The main objective is to inquire whether markups exhibit a significant volatility and whether they are procyclical or countercyclical in various open economies. To this end, this section exploits the industrial data from 10 small open economies in Latin America, Asia and Africa.

<table>
<thead>
<tr>
<th>Country</th>
<th>Linear</th>
<th>Quadratic</th>
<th>H. P. ($\lambda = 100$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>48</td>
<td>36</td>
<td>47</td>
</tr>
<tr>
<td>Bolivia</td>
<td>15</td>
<td>21</td>
<td>36</td>
</tr>
<tr>
<td>Chile</td>
<td>20</td>
<td>32</td>
<td>45</td>
</tr>
<tr>
<td>Colombia</td>
<td>26</td>
<td>52</td>
<td>43</td>
</tr>
<tr>
<td>Ecuador</td>
<td>51</td>
<td>69</td>
<td>110</td>
</tr>
<tr>
<td>Israel</td>
<td>20</td>
<td>32</td>
<td>46</td>
</tr>
<tr>
<td>Mexico</td>
<td>48</td>
<td>35</td>
<td>58</td>
</tr>
<tr>
<td>Peru</td>
<td>48</td>
<td>35</td>
<td>58</td>
</tr>
<tr>
<td>South-Africa</td>
<td>130</td>
<td>120</td>
<td>72</td>
</tr>
<tr>
<td>Turkey</td>
<td>43</td>
<td>45</td>
<td>68</td>
</tr>
</tbody>
</table>

Note: Relative volatility between markups and GDP for different detrending methods in percentage terms. “Linear”, “Quadratic” and “H. P. ($\lambda = 100$)” denote results or a linear, a quadratic and Hodrick-Prescott detrending methods. Details on data sources and management are available in the Online Appendix.

I use the definition of markups as in Braun and Raddatz (2012), that is, Price Cost Margin defined as $M_{kt} = \frac{V_{At} - W_{t}}{Ouptut_{t}}$, where $V_{At}$ denotes aggregate value added for the 28 industries at 2-digits level ISIC Revision 3, $W_{t}$ total wages in these 28 industries and $Ouptut_{t}$ denotes total output for these industries. The reason for using this definition of markups is based on data availability in UNIDO database and by the fact that this database contains harmonized data for the economies considered. Raw data is annual from UNIDO Indstat2 database which
contains annual data from 1963 to 2010. As discussed by Braun and Radclatz (2012), if the production function is Cobb-Douglas, this measure of markups captures its variability in the absence of direct markup calculations. In the following tables, I also use GDP for each economy from World Development Indicator database from World Bank measured in dollars at fixed 2005 prices.

The first question to answer is whether markups exhibit a significant variability in the open economies. Table 1 presents the relative volatility between markups and GDP in 10 emerging economies around the world in percentage terms. Markups and GDP are detrended accordingly in order to remove any trend that might appear due to the small sizes of annual data samples. As seen in the table, the volatility of markups substantially depends on the specific country we study, but overall, its variability is on average about one half of the output variability, with Bolivia being the less variable and South-Africa being the most variable. The findings in this table are robust to different detrending methods. Arguably, the variability of markups is strong, which would suggest it can potentially be an important variable to take into account when studying the impact of different aggregate shocks. A second question is about the behavior of markups over the business cycle, Table 2 presents the correlations between markups and GDP using the same economies.

As seen in the table, there are significant differences in the sign of the correlation as well as in sizes between different economies. However, on average, correlation is negative regardless the detrending method. This implies that there is evidence that markups are significantly countercyclical in many emerging economies at annual frequency. In other words, although significant country heterogeneity, 8 out of 10 economies using linear detrending (and 7 out of 10 using other detrending methods) have countercyclical markups. This is important because, even though there has been substantial discussion regarding markups in US, there is less evidence on markups behavior for the rest of the world.
Table 2: Markups and GDP in Small Open Economies

<table>
<thead>
<tr>
<th>Country</th>
<th>Linear</th>
<th>St Err</th>
<th>Quadratic</th>
<th>St Err</th>
<th>H. P. (100)</th>
<th>St Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>-24</td>
<td>5.5</td>
<td>-19</td>
<td>4.3</td>
<td>-35</td>
<td>8</td>
</tr>
<tr>
<td>Bolivia</td>
<td>-62</td>
<td>11</td>
<td>-59</td>
<td>10</td>
<td>-28</td>
<td>5</td>
</tr>
<tr>
<td>Chile</td>
<td>-17</td>
<td>3</td>
<td>16</td>
<td>2.8</td>
<td>-34</td>
<td>6</td>
</tr>
<tr>
<td>Colombia</td>
<td>-31</td>
<td>4.4</td>
<td>14</td>
<td>2</td>
<td>37</td>
<td>5.3</td>
</tr>
<tr>
<td>Ecuador</td>
<td>-44</td>
<td>6.5</td>
<td>-3.5</td>
<td>0.52</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Israel</td>
<td>11</td>
<td>1.5</td>
<td>27</td>
<td>4</td>
<td>-20</td>
<td>2.9</td>
</tr>
<tr>
<td>Mexico</td>
<td>-26</td>
<td>6.3</td>
<td>-19</td>
<td>4.5</td>
<td>-24</td>
<td>5.9</td>
</tr>
<tr>
<td>Peru</td>
<td>-36</td>
<td>9.1</td>
<td>-22</td>
<td>5.6</td>
<td>-36</td>
<td>9.3</td>
</tr>
<tr>
<td>Southafrica</td>
<td>-20</td>
<td>2.9</td>
<td>-17</td>
<td>2.5</td>
<td>5</td>
<td>0.73</td>
</tr>
<tr>
<td>Turkey</td>
<td>15</td>
<td>2.2</td>
<td>-18</td>
<td>2.6</td>
<td>-24</td>
<td>3.5</td>
</tr>
<tr>
<td>Average</td>
<td>-23.4</td>
<td>-10</td>
<td>-14.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Correlation between markups and GDP for different detrending methods in percentage terms. “Linear” denotes linear trend, “Quadratic” denotes quadratic trend and “H P” denotes Hodrick-Prescott trend. Details on data sources and management are available in the Online Appendix.

3 A real model with endogenous markups

The baseline model in this paper is an extension of the simple small open economy real business cycle model, as in Mendoza (1991), including firm dynamics, as in Jaimovich and Floetotto (2008), and shocks to the volatility of stochastic processes such as those in Justiano and Primiceri (2008), Fernández-Villaverde and Rubio-Ramirez (2007) and Fernández-Villaverde et al. (2011b).

Households have access to international asset markets where they trade a non-contingent asset under full commitment. Besides to foreign debt issuing, households consume a unique final good, supply labor and accumulate capital. On the other hand, the modeling of firms is slightly different to the standard competitive firms modeled in the RBC literature, I assume firms operate in a monopolistic competitive market and produce intermediate differentiated goods. Given this assumption, firms have monopolistic power that allows them to set prices
above their marginal costs. Additionally, there is a final good producer that buys inter-
mediate inputs to produce the final good that can be used for consumption, investment or
international trade. I now turn to a detailed description of the economic environment.

3.1 The households

Assume the economy is populated by a large number of identical households that maxi-
mize the present discounted value of future expected utility streams given by the following
expression,

\[ E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, H_t), \]

where \( \beta \) denotes a time-invariant discount factor, \( C_t \) denotes final consumption, \( H_t \) de-
notes hours worked. Households face a sequence of budget constraints,

\[ D_t = D_{t-1} - w_t H_t - r^k_t K_t + C_t + I_t - \Pi_t. \]

Here, \( D_t \) denotes non-contingent debt issued in international asset markets. Households
rent labor and capital services at competitive prices, \( w_t \) and \( r^k_t \). Additionally, households
own the firms and get any profits derived from their operation, \( \Pi_t \). Foreign debt is also
subject to a No-Ponzi game constraint. \( I_t \) denotes investment and the law of motion of
capital is given by,

\[ K_{t+1} = (1 - \delta)K_t + \Phi(I_t, I_{t-1})I_t, \]

where \( \delta \) denotes a constant depreciation rate and \( \Phi(I_t, I_{t-1}) \) is an adjustment cost on
investment. Additionally, I follow Garcia-Cicco et al. (2010) and Aguiar and Gopinath (2007)
and assume that the interest rate is a function of the level of debt,

\[ R_t = R^* + \Psi(D_t - D). \]
Here $R^*$ denotes the gross risk free rate, assumed constant, $D$ is the steady state of debt, and $\hat{D}_t$ is the aggregate level of debt that is non-internalized by the households. Alternatively, it could be possible to introduce different assumptions for the interest rate, such as adjustment costs of debt or endogenous discount factors in order to induce stationarity. As shown in Seoane (2012), when studying nonlinear emerging economy models, the inducing stationarity device matters. However, I keep this assumption here in order to make my model as close as possible to existing references in the literature.

3.2 Firms and market structure

This paper considers an economy with a single final good that can be consumed, used for investment purposes, or traded in the world market. The final good is produced by a competitive firm that combines differentiated inputs using a constant returns to scale technology given by,

$$Y_t = \left( \int_0^1 Q_t(j) \omega dj \right)^{\frac{1}{\omega}}.$$

Here, $Y_t$ denotes the production of the final good and $Q_t(j)$ denotes input $j$ used in production at period $t$. This $Q_t(j)$ is the output from industry $j$, and $\omega \in (0,1)$ regulates the elasticity of substitution between inputs. Specifically, $1/(1 - \omega)$ is the elasticity of substitution between inputs produced by any two different sectors. Note that we use an infinite number of inputs to produce $Y_t$, which means that the model assumes a continuum of industries.

Additionally, each $Q_t(j)$ is produced by combining a finite number of intermediate inputs, denoted by $x_t(j,i)$, each of which is ultimately produced by combining labor and capital with a Cobb-Douglas technology. Hence, each industry has a finite number of firms operating in it, denoted by $N_t$. Output in industry $j$ is given by,
\[ Q_t(j) = N_t^{\frac{\tau+1}{\tau}} \left[ \sum_{i=1}^{N_t} x_t(j,i)^\tau \right]^{\frac{1}{\tau}}, \]

where \( 0 < \tau < 1 \) regulates the elasticity of substitution between inputs \( i \), which is given by \( 1/(1 - \tau) \). Here \( x_t(j,i) \) denotes the output of firm \( i \) used in industry \( j \). Each firm produces differentiated goods. Hence, firms have monopolistic power and are able to set prices. Additionally, firms hire labor and capital in competitive factor markets that are combined using a Cobb-Douglas technology given by,

\[ x_t(j,i) = \exp(a_t) k_t(j,i)^\alpha h_t(j,i)^{1-\alpha} - \phi. \]  

Here, \( a_t \) is a common stationary technology shock and \( \phi \) denotes overhead costs. \( k_t(j,i) \) and \( h_t(j,i) \) are capital and labor services rented by firm \( i \) in industry \( j \) and \( \alpha \) denotes the capital share.

Under these assumptions, the demand and the price of industrial goods are given by,

\[ Q_t(j) = \left[ \frac{P_t(j)}{P_t} \right]^{\frac{\tau+1}{\tau}} Y_t, \]  

where \( P_t(j) \) is the price of input \( j \), and

\[ P_t = \left[ \int_0^1 p_t(j) \frac{1}{x_t(j,i)^\frac{\tau+1}{\tau}} dj \right]^{\frac{\tau+1}{\tau}} \]

is the price of the final good. Additionally, the demand and prices for intermediate inputs are given by,

\[ x_t(j,i) = \left[ \frac{p_t(j,i)}{p_t(j)} \right]^{\frac{1}{\tau-1}} Q_t(j) \frac{1}{N_t}, \]

where \( p_t(j,i) \) is the price of good \( i \) in industry \( j \), and
\[ p_t(j) = N_t^{1-\frac{1}{\tau}} \left[ \sum_{i=1}^{N_t} p_t(j,i) \tau^{-1} dj \right]^{\frac{\tau-1}{\tau}}. \]

Finally, we focus in a symmetric equilibrium, such that \( x_t(j,i) = x_t, \ k_t(i,j) = k_t, \ h_t(i,j) = h_t, \ p_t(i,j) = p_t(j) = P_t, \) which is normalized to 1. In the symmetric equilibrium, aggregate capital and hours are given by \( K_t = N_t k_t \) and \( H_t = N_t h_t. \) We impose a zero profit condition in each sector for every period,

\[ (\mu(N_t) - 1) x_t = \phi, \tag{4} \]

where \( \mu(N_t) \) stands for the markup.\(^5\) Notice that, given the symmetric equilibrium, using equations (2) and (3) it can be shown that \( N_t x_t = Y_t. \) Additionally, following Jaimovich and Floetotto (2008), the number of firms and a different expression for aggregate output can be found by combining (4) and (1)

\[ N_t = \exp(a_t) K_t^\alpha H_t^{1-\alpha} \left[ \frac{\mu(N_t) - 1}{\mu(N_t) \phi} \right], \tag{5} \]

\[ Y_t = \frac{\exp(a_t)}{\mu(N_t)} K_t^\alpha H_t^{1-\alpha}. \]

Notice that the TFP, the part of output not explained by labor and capital inputs, in this model is endogenous and can be defined as follows

\[ TFP_t = \frac{\exp(a_t)}{\mu(N_t)}. \]

Using the previous expressions, the rental rates of labor and capital can be expressed in familiar terms,

\(^5\)From solving the problem of the intermediate input producer, it can be shown that \( \mu_t \) is a function of \( N_t. \)
\[ w_t = (1 - \alpha) \frac{Y_t}{H_t}, \]

and

\[ r^k_t = \alpha \frac{Y_t}{K_t}. \]

Ultimately, notice that in the symmetric equilibrium the solution to this model is very similar to the one of standard real business cycle model with competitive firms. However, here we need to keep track of the number of firms and markups. In other words, equation 5 is required to characterize the equilibrium. The online appendix presents the full set of equations that characterize the equilibrium of this model.

### 3.3 Stochastic processes

I assume there are two driving forces in this economy, a shock to the level of technology and a shock to the volatility of the technology. Technology follows an auto-regressive process with stochastic volatility,

\[ a_t = \rho_a a_{t-1} + \sigma_a e^{v_{a,t}} \epsilon_{a,t}, \]

where

\[ v_{a,t} = \rho_{v,a} v_{a,t-1} + \sigma_{v,a} \eta_{a,t}, \]

Here, we assume that all stochastic processes are mean reverting, \(|\rho_a| < 1\) and \(|\rho_{v,a}| < 1\). Additionally, \(\epsilon_{a,t} \sim N(0, 1)\) and \(\eta_{a,t} \sim N(0, 1)\).

Hence, there is only one level shock, \(a_t\), that is purely technology shock, but in this setup it is different from the TFP, which is now endogenous due to the entry and exit of firms. As discussed in the introduction, the shock to the volatility of technology has no level effect; it
only increases the risk of future technology realizations.

4 Solution method, functional forms and calibration

As discussed in the introduction, the main objective of this paper is to study the transmission mechanisms behind the responses to volatility shocks in real models. It is still important to study these dynamics in an empirically plausible model, i.e. a model whose dynamics can represent observed dynamics. Consequently, before studying the main results of the paper, this section discusses some aspects of the empirical strategy, including the solution method, functional forms and the calibration.

4.1 Solution method

I use a third order perturbation method in logarithms to approximate the policy functions around the non-stochastic steady state. As it has been widely discusses in methodological references such as Aruoba et al. (2006) and also in Fernández-Villaverde et al. (2011b), perturbation method is a local solution method that makes use of the Taylor series expansion and might be applied for any desired order of approximation. A first order perturbation in logarithms is equivalent to a log-linear approximation and, as we know, this solution is certainty equivalent. This means that any change in the volatilities of the innovations does not have effect in the policy functions, i.e. agents do not respond to volatility changes up to first order. The approximation of second order captures a constant correction to the impact of volatility changes. Only for approximation of a third (or higher) order, changes in the volatility of stochastic processes appear in an autonomous way in the policy functions. This means that, in this case, agents respond directly to changes in volatilities even if all other shocks are zero. Hence, a third order of approximation is required to capture the first order effect of volatility shocks.\footnote{For details on the solution method, the reader is referred to the aforementioned references, Aruoba et al. (2006) and Fernández-Villaverde et al. (2011b).}
4.2 Functional forms

I assume utility function is GHH, as in Greenwood et al. (1988),

\[ u(C_t, H_t) = \left[ C_t - \theta \frac{H_t^\eta}{\eta} \right]^{1-\gamma} - 1 \]

Here \( \eta \) determines the Frisch elasticity which regulates the response of labor supply to wages while \( \gamma \) determines the curvature of the utility function. \( \theta \) in turn regulates the disutility of labor supply and does not affect the models dynamics but the steady state level of labor supply.

One of the properties of GHH utility functions is that it eliminates the wealth effect on labor and hence, labor only responds to changes in the real wage. This is a convenient property of the utility function to match the dynamics observed in the data. In section 5.1, I also consider the implications of the model when using a separable utility function.

I follow Fernández-Villaverde et al. (2011b) for the functional form of the adjustment costs of capital,

\[ \Phi(I_t, I_{t-1}) = 1 - \frac{\phi}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2, \]

where \( \phi > 0 \). In turn, I follow Aguiar and Gopinath (2007), Garcia-Cicco et al. (2010) and Seoane (2012) for the functional form of the risk premium,

\[ \Psi(\hat{D}_t - D) = \psi \left( e^{\hat{D}_t - D} - 1 \right), \]

where \( \psi \) determines the elasticity of the interest rate to debt. Notice that the risk premium depends on \( \hat{D}_t \), which is the aggregate level of debt and it is not internalized by the households.
4.3 Calibration

Here, set the deep parameters affecting preferences and technology to standard values in the small open economy literature. On the other hand, the remaining parameters, $\rho_a$, $\sigma_a$, $\rho_{v,a}$ and $\sigma_{v,a}$, are calibrated to match a set of moments observed in the data.\(^7\)

Table 3 presents the parameters that are determined following previous studies. For instance, $\alpha$ denotes the capital share and it is fixed to 0.32 as is common in the RBC literature. To set the depreciation rate, $\delta$, I follow Fernández-Villaverde et al. (2011b) who assume this parameter is equal to 0.008 for a monthly frequency specified model. Given that the model in this paper is specified at quarterly frequency, I fix it to 0.024, i.e. a quarterly depreciation rate of 2.4%. $\mu$ denotes the steady state level of markups, $\omega$ and $\tau$ determine the intra-sectoral and inter-sectoral elasticity of substitution, respectively. I set these parameters to the values in Jaimovich and Floetotto (2008).

$\rho^*$ denotes the risk free rate interest rate, which I set to 4% annualized level and $\phi_k$ denotes the capital adjustment costs that I fix to 5. This is an important parameter and the estimates in the literature range from very small up to large numbers, for instance in the monthly specification in Fernández-Villaverde et al. (2011b) the range depending on the country and model specification goes from 12 to 95. For this reason I devote one section of the robustness analysis to study how sensitive my results are to the values of this parameter. The same applies to $\psi$, the elasticity of interest rate to debt accumulation. I set it to 0.001 as in Aguiar and Gopinath (2007) but given that this matters for consumption and foreign debt dynamics, as pointed out in Seoane (2012), I study whether results are affected when this parameter takes different values.

In turn, $\eta$ and $\gamma$ are set in line with several papers in the small open economy literature. $\theta$ is fixed such that the model generates $H = 0.3$ in steady state, as in Jaimovich and Floetotto.

\(^7\)I calibrate these parameters by minimizing the distance of the moments implied by the model to those of the data. Hence, the parameterization is done by exploiting the dynamics within the model. This is a standard methodology in macroeconomics. Another strategy would be a direct estimation of the stochastic volatility model of the Solow residual. As discussed in Aguiar and Gopinath (2007), this type of exercise can lead to inconclusive results when using short samples.
Table 3: Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Capital share</td>
<td>0.32</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Quarterly depreciation rate</td>
<td>0.024</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Steady state markup</td>
<td>1.3</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Interest rate debt elasticity</td>
<td>0.001</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Preference parameter</td>
<td>2</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Preference parameter</td>
<td>1.6</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Preference parameter</td>
<td>2.7</td>
</tr>
<tr>
<td>$R^*$</td>
<td>Quarterly level risk free rate</td>
<td>$1.04^{1/4}$</td>
</tr>
<tr>
<td>$\omega$</td>
<td>Technology parameter</td>
<td>0.001</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Technology parameter</td>
<td>0.949</td>
</tr>
<tr>
<td>$\phi_k$</td>
<td>Capital adjustment costs</td>
<td>5</td>
</tr>
<tr>
<td>$d/y$</td>
<td>Debt to output ratio</td>
<td>10%</td>
</tr>
</tbody>
</table>

Note: These parameters are fixed to values in existing literature. The main text explains the details on the sources for each of them.

Finally, $d/y$ denotes the debt to output ratio which I set to 10% as in Aguiar and Gopinath (2007).

The average volatility of technology, $\sigma_a$, its persistence $\rho_a$ and the parameters that characterize the stochastic process of volatility, $\rho_{v,a}$ and $\sigma_{v,a}$ are used to match the nine moments in Table 4, which are key in the emerging economies: the output, consumption, investment and net exports to output volatility, the correlation between net exports to output ratio and output, and the first order autocorrelations of these variables, averaged for the four emerging economies discussed in Fernández-Villaverde et al. (2011b), Argentina, Brazil, Ecuador and Venezuela.

To target the moments in Table 4 I proceed by simulation as follows: first, randomly draw a proposal vector of parameters for $\rho_{v,a}$, $\sigma_{v,a}$ and $\sigma_a$; second, conditional on this draw, solve the model using third order perturbation; third, simulate 100 series of innovations with

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8Even though theoretical moments are available, the size of the model and the fact that we need a 3rd order approximation method to solve the model and the data is HP filtered still prevents us from using them.
Table 4: Moments to match

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Targets</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma(y_t)$</td>
<td>3.7</td>
<td>4.4</td>
</tr>
<tr>
<td>$\sigma(c_t)$</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>$\sigma(i_t)$</td>
<td>10.5</td>
<td>10.5</td>
</tr>
<tr>
<td>$\sigma(nxy_t)$</td>
<td>3.9</td>
<td>2.1</td>
</tr>
<tr>
<td>$\rho(y, nxy)$</td>
<td>-5.1</td>
<td>-7.1</td>
</tr>
<tr>
<td>$\rho(y_t, y_{t-1})$</td>
<td>50.4</td>
<td>66.9</td>
</tr>
<tr>
<td>$\rho(c_t, c_{t-1})$</td>
<td>69.4</td>
<td>69.1</td>
</tr>
<tr>
<td>$\rho(i_t, i_{t-1})$</td>
<td>76.6</td>
<td>95.9</td>
</tr>
<tr>
<td>$\rho(nxy_t, nxy_{t-1})$</td>
<td>75.8</td>
<td>91.5</td>
</tr>
</tbody>
</table>

Note: Average targets for Argentina, Brazil, Ecuador and Venezuela. Data is HP filtered at quarterly frequency. Moments are in percentage terms. $y_t$, $c_t$, $i_t$ and $nxy_t$ denote (respectively): quarterly log HP filtered output, consumption, investment; and quarterly HP filtered net exports to output ratio. $\sigma(\cdot)$ denotes standard deviations and $\rho(\cdot, \cdot)$ denote correlations.

A length of 20000 periods and keep the last 2000 simulated points to ensure convergence to the ergodic distribution; fourth, using the last 2000 periods construct a model counterpart of the observed data. I filter the series using a Hodrick-Prescott filter with smoothing parameter equal to 1600 and use the resulting series to compute the moments implied by the model. Finally, I repeat these steps to minimize the difference between observed and simulated moments.

Table 5: Matching moments parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_a$</td>
<td>Persistence of technology shock</td>
<td>0.97</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>Steady state volatility of technology shock</td>
<td>0.005</td>
</tr>
<tr>
<td>$\rho_{v,a}$</td>
<td>Persistence of stochastic volatility shock</td>
<td>0.74</td>
</tr>
<tr>
<td>$\sigma_{v,a}$</td>
<td>Standard deviation of stochastic volatility shock</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Note: These parameters are calibrated in order to match the moments on Table 4. The main text explains the details on this procedure.
As seen in Table 4, the model can account for the degree of variability observed in the
data and for the relative variability of the components of aggregate demand. Hence, even
though the main objective of the paper is not an empirical one, we have confidence this
model is able to represent dynamics in line to those observed in these economies.

Table 5 presents the calibrated parameters that minimize the distance between observed
and simulated moments. As seen in the table, the model requires a rather persistent tech-
nology shock with a mild average volatility to match the moments observed in the data.
Additionally, the standard deviation of volatility shocks is 0.95. This calibration implies
that one standard deviation shock to the volatility of TFP increases the TFP volatility from
steady state from 0.005 to $\exp(0.95) \times 0.005 = 0.0129$, that is, increases by a factor of 2.6, of
a similar order of magnitude as in Fernández-Villaverde et al. (2011b). In other words, one
standard deviation increase in volatility has a major impact on the uncertainty associated
to TFP shocks. As standard when studying the impact of exogenous shocks, I will take
1 standard deviation shocks to volatility as the benchmark for impulse response function
analysis.

5 Results

Figure 1 presents the impulse response functions of endogenous variables to 1 standard
deviation volatility shock, both for the model with monopolistic competition, denoted by
the solid line labeled as “Endogenous Markups” and the model with competitive markets,
denoted by the dashed line labeled as “Fixed Markups”.

As seen in the figure, the mechanism that generates time-varying markups substantially
amplifies the dynamics of endogenous variables following a shock to the volatility of technol-
ogy. The economics of these dynamics are as follows: after a volatility shock the precaution-
ary savings motive induces a drop in consumption and, given that future technology levels
become riskier and the returns to capital get more uncertain, investment falls. The drops in
consumption and investment explain a fall in domestic absorption. As a counterpart, households save more using foreign debt, that is, households decrease their liabilities or increase their assets against the rest of the world. The counterpart of this increase in savings is an improvement in the net exports, explained by a drop in imports.

The behavior of aggregate demand translates in a drop of production of final good inducing the exit of firms that produce inputs for intermediate goods. When firms exit the degree of competition falls and markups rise. Recall that as markups increase, wages and the return to capital falls accordingly to these expressions,

$$w_t = (1 - \alpha) \frac{\exp(a_t)}{\mu(N_t)} K_t^\alpha H_t^{-\alpha},$$
\[ r_t^k = \alpha \frac{\exp(a_t)}{\mu(N_t)} K_t^{\alpha-1} H_t^{1-\alpha}. \]

Hence, real wages also decrease. Recall that we assume a GHH utility function and that the property of this function is that it implies that labor responds only to changes in real wage and given that real wages drop, labor supply also decreases. On the other hand, the response of \( r_t^k \) exacerbates the fall in investment. Additionally, in our formulation the TFP is endogenous,

\[ TFP_t = \frac{\exp(a_t)}{\mu(N_t)}. \]

Hence, for the model with monopolistic competition, volatility shocks have a first order effect on the TFP, even when the exogenous component of technology is fixed at its ergodic mean. Note that, even though this exercise isolates the impact of volatility shock alone, we can highlight some interesting points. First, note that the dynamics of markups and output after a volatility shock is roughly in line with the evidence presented in Tables 1 and 2 because, as can be seen in the figure, markups are countercyclical and the response of markups is smaller than the one of output, suggesting that even though highly volatile, it is less volatile than output. Second, from this picture we can also infer that volatility shocks contribute to generate a consumption dynamics more volatile than output, here in particular, consumption response is about 1.5 times the one output. Moreover, volatility shocks also contribute to generate a volatile dynamic for investment. This does not seem to be the same for the model with fixed markups, suggesting that time-varying markups help the baseline model to capture the stylized facts observed in emerging economies.

In summary, the dynamics of the economy with time-varying markups are amplified compared to the one with fixed markups. The reason is that in the case of monopolistic competition, when aggregate demand falls, the number of firms operating in each industry falls too, the markets become less competitive and hence, the firms that stay are able to
charge larger markups. This is absent in the case of perfect competition. Moreover, if markups do not change, the only way to affect wages and the return to capital is through the level of factors used in production, leading to substantially smaller effects than in the case of endogenously time-varying markups.

5.1 Sensitivity analysis

I implement a battery of robustness exercises and sensitivity analysis to provide further insights on the mechanisms behind the dynamics of the model. First, I study to what extent the main results depend on the Frisch elasticity given that Fernández-Villaverde et al. (2011b) point out the response of labor supply to volatility shocks is of major importance. Then, I study the role of investment adjustment costs, following Bloom et al. (2007). Seoane (2012) discusses the importance of the risk premium elasticity, hence in this section I study whether the main dynamics are affected by different levels of responsiveness of the risk premium. Finally, it is well known a feature of GHH preferences is that eliminates the wealth effect and makes labor supply only dependent on the real wage. For this reason, I study whether the dynamics are affected if we assume separability in the utility function.

5.1.1 The role of the Frisch elasticity

As discussed above, the Frisch elasticity determines the response of labor supply to wages and through this channel regulates the response of labor to a volatility shock. In a model with GHH preferences, the Frisch elasticity is $\frac{1}{\eta-1}$. For the baseline calibration this equals 1.66, which implies that if the wage changes in 1%, the labor supply changes in 1.66%. This level of Frisch elasticity is standard in small open economy models, as discusses when introducing the baseline calibration.

This section considers two additional calibrations for the Frisch elasticity, a high Frisch elasticity of 2.5% and a low Frisch elasticity of 1%. Figure 2 presents the impulse responses functions for each of these cases. As seen in the figure, the Frisch elasticity has a major
Figure 2: Impulse responses to a volatility shock

Note: This figure plots the response to a 1std shock to the volatility of technology in percentage deviations of each variables with respect to their ergodic means at quarterly frequency for the following calibrations: “Benchmark Frisch” = 1.66, represented by the solid line; “Low Frisch” = 1, represented by the dotted line; and “High Frisch” = 2.5, represented by the dashed line.

importance on the size of the response of endogenous variables to a volatility shock. However, it does not affect the qualitative dynamics. As seen in the figure, a large Frisch elasticity of 2.5 amplifies the dynamics compared to the case of low Frisch elasticity equal to 1. The economic intuition behind this finding is that when a volatility shock hits the economy, the high Frisch elasticity implies that for a drop in the real wage of 1% the labor supply falls 2.5%. Given that labor supply is more responsive and this negatively affects the agents’ labor income, incentives to save are higher. Moreover, given a larger response of labor supply, the marginal product of capital also responds in a stronger way affecting the incentives to invest. This explains the amplification of the dynamics of investment and consumption. In the same way as for the baseline calibration, the impact on aggregate demand affects the number of
firms, which increases markups, decreases the TFP and amplifies the dynamics.

5.1.2 Adjustment costs of capital

It is well known that the size of the adjustment costs can affect the dynamics of the trade balance given that it affects the degree of response of capital to innovations. Figure 3 shows the responses to a volatility shock when the adjustment costs of capital are 0.25, 2.5, 25.

![Figure 3: Impulse responses to a volatility shock](image)

Note: This figure plots the response to a 1std shock to the volatility of technology in percentage deviations of each variables with respect to their ergodic means at quarterly frequency for the following calibrations: “Benchmark $\phi$” = 2.5, represented by the solid line; “High $\phi$” = 25, represented by the dotted line; and “Low $\phi$” = 0.25, represented by the dashed line.

Note that conditional on these calibrations, there are noticeable differences both in size of response and in persistence, but not in terms of the qualitative implications of the model. Specifically the smaller the cost, the larger the improvement in the trade balance given that the larger is the deterioration of investment. Additionally, in this case the responses are
less short lived as all adjustments occur faster; specifically investment recovers faster, which pushes output, employment and TFP up. On the other hand, when adjustment costs of capital are high, the responses of investment are milder, as expected, but more persistent given that investment decisions are taken over a larger time span.

5.1.3 Interest rate elasticity

As discussed in Seoane (2012), the dynamics of small open economy models are greatly amplified by the dynamics of the interest rate. Specifically, Figure 4 plots the responses of endogenous variables to a volatility shock for different elasticity of the interest rate to debt.

![Graph showing impulse responses to a volatility shock](image)

Figure 4: Impulse responses to a volatility shock

Note: This figure plots the response to a 1std shock to the volatility of technology in percentage deviations of each variables with respect to their ergodic means at quarterly frequency for the following calibrations: “Benchmark $\psi$” = 0.001, represented by the solid line; “High $\psi$” = 0.01, represented by the dotted line; and “Low $\psi$” = 0.0001, represented by the dashed line.

As seen in the figure, the smaller the elasticity, the greater the response of endogenous
variables. The reason is that this elasticity operates as an adjustment cost on foreign debt which prevents large changes in the foreign debt position and in the trade balance. Notice that when the cost of changing the debt position is very small, $\psi = 0.0001$, the response of trade balance to output ratio, consumption and investment are much larger than in the case of high cost. Here the incentives to save are larger and this explains the amplifications in the dynamics of aggregate demand.

Notice that when $\psi = 0.01$, the figures suggest that the cost of changing the debt position is high compared to the cost of capital accumulation. In this case, the domestic economy reduces consumption but the savings in foreign debt are small, as can be seen from the small response of the trade balance. Instead the economy slightly increases capital accumulation. This generates a slow but significant and persistent increase in the capital stock that induces an increase in output, in contrast to the baseline calibration.

5.1.4 Separable preferences

A key element of our analysis is the GHH preferences. It is well known that this type of preferences eliminates the wealth effect in the response of hours to any disturbance.

To capture the stylized facts of volatility shocks, a small or nil wealth effect is an important feature because when volatility increases, the wealth decreases and this might have a positive effect in labor supply, which is at odds with the data. In this section, I compare the responses under GHH and the responses under the following separable utility function,

$$u(C_t, H_t) = \frac{C_t^{1-\sigma} - 1}{1 - \sigma} + \theta \frac{(1 - H)^{1-\eta} - 1}{1 - \eta}.$$

This utility function is the one in Ravn et al. (2006). I calibrate it such that it is comparable to the one in the baseline model. I assume a Frisch elasticity of 1.66, as in the benchmark case and $\theta$ is calibrated to match the $H = 0.3$ while $\sigma = 2$. Figure 5 presents the impulse responses for the baseline economy with GHH together with the ones assuming separability.

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Figure 5: Impulse responses to a volatility shock

Note: This figure plots the response to a 1std shock to the volatility of technology in percentage deviations of each variables with respect to their ergodic means at quarterly frequency assuming separable preferences.

Note two interesting findings. First, under this calibration, wealth effect is stronger than substitution effect when using separable utility function. This explains the increase in hours after a volatility shock and the remaining dynamics for investment and output. Consumption drop is much smaller given that now the model generates a counter factual increase in output. Second, incentives to save are smaller too and the amplification of endogenous markups are also smaller than under GHH given that the response of labor increases output and this represents a pressure to decrease savings rather than increasing it.

Under utility functions of this sort, the standard approach is to impose a large $\eta$ such that the Frisch elasticity is very small and labor is rather unresponsive to volatility shocks. Setting $\eta = 1000$, which implies a Frisch elasticity of 0.0023, of a similar order of magnitude as in Fernández-Villaverde et al. (2011b), it is possible to restore the right signs for the
impulse responses, as shown in figure 6. Notice, however, that under this type of preferences and assuming a non-responsive labor supply, the dynamics pay a major cost in terms of magnitudes. Specifically, this model tends to imply a much smaller response of consumption investment, output and markups variation following a volatility shock given that the Frisch elasticity imposes a very small response of labor supply to wealth and wage changes.

6 Spread volatility shocks

Shocks to the real interest rate and shocks to the volatility of real interest rates have been recently studied. Fernández-Villaverde et al. (2011b) show that these shocks have quantitatively important effects in emerging economies’ dynamics. In this section, I study the role
of endogenous markups in the transmission of volatility shocks to the real interest rate. The baseline model assumes homoskedastic technology shocks and a stochastic volatility model for the innovations to the real interest rate. Importantly, when discussing the role of interest rate shocks, their impact depends on whether interest rates have a direct effect on the production side of the economy. For this reason, this section considers two variants of the model: the first one without working capital constraints and the second one with working capital constraints as in Neumeyer and Perri (2005).

6.1 Baseline model with spread volatility shocks

This section extends the model to include spread shocks and stochastic volatility of spreads. The baseline specification follows the one presented in Section 3. To simplify the analysis here I assume homoskedastic productivity shocks, instead this section assumes that the process for spreads follows this specification,

$$R_t = R^* + \Psi(\hat{D}_t - D) + \epsilon_t - 1.$$

Here, $R^*$ denotes the risk free rate that is assumed constant. $\Psi(\hat{D}_t - D)$ denotes an endogenous component of the sovereign spread that also works as a inducing stability device. Additionally, in line with García-Cicco et al. (2010), this term can be interpreted to capture the role of financial frictions. $\epsilon_t$ denotes an spread shock given by

$$\epsilon_t = \rho_t \epsilon_{t-1} + \sigma_t \epsilon^{v_t} \epsilon_t,$$

where

---

9In Fernández-Villaverde et al. (2011b) the risk free rate is assumed to follow a stochastic volatility model and the real rate is completely exogenous. They find, however, that risk free rate shocks and the volatility shocks to the risk free rate have a limited importance to explain the dynamics of emerging economies. The term in $\Psi(\hat{D}_t - D)$ is meant to capture the fact that some variability of real interest rates in emerging economies is due to endogenous sources, see Uribe and Yue (2006).
\[ v_{e,t} = \rho_{v,e} v_{e,t-1} + \sigma_{v,e} \eta^t_e. \]

Most of the parameters of this model are fixed to the ones in the baseline model, in particular, those in Table 3 remain unchanged. Additionally, I calibrate the parameters governing the technology and spread shocks in order to match the moments in Table 6 that also presents the moments implied by the model.\(^{10}\)

Table 6: Moments to match

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Targets</th>
<th>Baseline Model</th>
<th>Model WCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma(y_t) )</td>
<td>3.7</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>( \sigma(c_t) )</td>
<td>4.5</td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>( \sigma(i_t) )</td>
<td>10.5</td>
<td>17</td>
<td>12.4</td>
</tr>
<tr>
<td>( \sigma(nxy_t) )</td>
<td>3.9</td>
<td>5.2</td>
<td>3.6</td>
</tr>
<tr>
<td>( \rho(y_t, nxy_t))</td>
<td>-5.1</td>
<td>-6.8</td>
<td>-2.9</td>
</tr>
<tr>
<td>( \rho(y_t, y_{t-1}))</td>
<td>50.4</td>
<td>83</td>
<td>48</td>
</tr>
<tr>
<td>( \rho(c_t, c_{t-1}))</td>
<td>69.4</td>
<td>68</td>
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</tr>
<tr>
<td>( \rho(i_t, i_{t-1}))</td>
<td>76.6</td>
<td>96</td>
<td>92.9</td>
</tr>
<tr>
<td>( \rho(nxy_t, nxy_{t-1}))</td>
<td>75.8</td>
<td>90</td>
<td>86</td>
</tr>
</tbody>
</table>

Note: Average targets for Argentina, Brazil, Ecuador and Venezuela. Data is HP filtered at quarterly frequency. Moments are in percentage terms. \( y_t, c_t, i_t \) and \( nxy_t \) denote (respectively): quarterly log HP filtered output, consumption, investment; and quarterly HP filtered net exports to output ratio. \( \sigma(\cdot) \) denotes standard deviations and \( \rho(\cdot, \cdot) \) denotes correlations.

As seen in Table 6, both models -with and without working capital constraint- slightly underestimate the volatility of output, but are able to capture the overall stylized facts in emerging economies. Table 7 presents the parameters implied by each exercise. For now, we

\(^{10}\)Note that the results and calibration in this section are not directly comparable to the ones in Fernández-Villaverde et al. (2011b) because of 2 reasons. First, Fernández-Villaverde et al. (2011b) calibrates a monthly model whereas in this paper I work with a quarterly model. Second, and more important, here I calibrate the model with endogenous markups to match the moments observed in the data while Fernández-Villaverde et al. (2011b) calibrate a model with fixed markups. For this reason, the appropriate comparison for impulse response functions is the one shown in Figure 7. The online appendix presents another possible exercise. In the online appendix I calibrate the model without endogenous markups in line with Fernández-Villaverde et al. (2011b), and then introduce firm dynamics to see which role do they play. As can be seen there, we can find the same amplifying role for endogenous markups.
focus on the third column of the table. The persistence of spreads and volatility are in line, although slightly larger, than those in Fernández-Villaverde et al. (2011b) once converted to quarterly frequency. The technology shocks are also more persistent in this calibration compared to the one in Fernández-Villaverde et al. (2011b), however the authors do not use this parameter for the matching moments strategy while I do. As it is well known, this parameter plays an important role in generating a higher volatility of consumption than output.

Table 7: Matching moments parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Model</th>
<th>Model WCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_\epsilon$</td>
<td>Steady state volatility of spread</td>
<td>0.001</td>
<td>0.04</td>
</tr>
<tr>
<td>$\rho_\epsilon$</td>
<td>Persistence of spread shock</td>
<td>0.96</td>
<td>0.65</td>
</tr>
<tr>
<td>$\rho_{v,\epsilon}$</td>
<td>Persistence of stochastic volatility shock</td>
<td>0.50</td>
<td>0.59</td>
</tr>
<tr>
<td>$\sigma_{v,\epsilon}$</td>
<td>Standard deviation of stochastic volatility shock</td>
<td>0.22</td>
<td>0.49</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>Persistence of technology shock</td>
<td>0.99</td>
<td>0.999</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>Standard deviation of technology shock</td>
<td>0.005</td>
<td>0.002</td>
</tr>
<tr>
<td>$\Theta$</td>
<td>Working capital constraint coefficient</td>
<td>-</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Note: These parameters are calibrated in order to match the moments on Table 6. The main text explains the details on this procedure.

Figure 7 shows the impulse response functions to a spread volatility shock for the model with endogenous markups in solid lines and the model with fixed markups in dashed lines. Following an increase in the volatility of spreads, future income becomes more uncertain and the precautionary motive induces a drop in consumption. Given that consumption falls on impact and output is relatively fixed in the short run, as employment and capital falls slowly, net exports increase and the trade balance improves. As before, this part of the story is the same for both models, the model without endogenous markups and the model with endogenous markups. However, as before in the case of endogenous markups, the fact that output starts falling, translates into lower demand of intermediary goods which in fact induce firms to exit the market, increases markups and induce a second round of negative
impact on output and the real wage, this fall in the real wage decrease labor supply and exacerbates the crisis.

Figure 7: Impulse response to a spread volatility shock

Note: This figure plots the response to a 1std shock to the volatility of real interest rate shocks in percentage deviations of each variables with respect to their ergodic means at quarterly frequency.

Both from the economics reasoning and the quantitative exercise shown in the figure, it can be seen that endogenous markups play a similar role after a spread volatility shock to the one played after a technology volatility shock. The precautionary savings motive is amplified by the impact on real wages. Note that with endogenous markups, output and hours fall is twice as large as in the model with fixed markups, the increase in net exports is larger and the persistence in the fall of consumption and investment is also larger than in the model with fixed markups.
6.2 Working capital constraints

The previous specification does not include a working capital constraint. However, several authors emphasize this channel as a source of amplification for emerging markets fluctuations. Suppose that firms have to pay a fraction, $\Theta$, of the wage bill in advance, that is before production takes place, while keeping the rest of the model unchanged. In order to do so, firms have to borrow funds at a market rate. This assumption only affects the market wage,

$$w_t = \frac{(1 - \alpha)}{(1 + \Theta(R_t - 1))} \frac{Y_t}{H_t}.$$  

The calibration for this section follows the same strategy as before. Targets and moments implied by the model are shown in Table 6. The model with the working capital constraints does slightly better in many aspects, in particular in terms of the volatility of investment and net exports to output ratio as it has an extra free parameter, the share of the wage bill that has to be advanced before production takes place, as explained below. The model implies that 1/4 of the wage bill has to be paid in advance. This estimate is actually much smaller than the calibration and the findings in the existing literature. The reason for this calibration relies on the fact that our model has in the firm dynamics an already strong amplifying device. The calibrated parameters are shown in the fourth column in Table 7. As can be seen, even though the working capital constraint coefficient is not large, it substantially affects the parameterization of the stochastic processes. In particular, the size of average volatility of spread shock increases, as well as the standard deviation of its volatility, while the volatility of technology shocks is smaller. The reason for this is that now interest rate shocks have a direct impact on the supply side of the economy. Figure 8 presents the impulse response functions for the model with endogenous markups using the solid lines and without endogenous markups using the dashed blue lines.

As seen in the figure, endogenous markups play a similar role to that in previous variants of the model. Here, the calibration implies that the impact of volatility shocks is larger
than without working capital constraints. This is reasonable as working capital constraints induce a direct effect of the stochastic process of spread in the labor demand. Additionally, allowing for endogenous markups amplifies the response of output and hours by a factor of 3. Similar effects are observed in the dynamics of investment and consumption.

6.3 Non-targeted moments

As can be seen from the previous exercises, moments related to the real interest rate are non-targeted. Instead, I want to consider those moments to assess the plausibility of the dynamics of the models with and without working capital constraints. Table 8 presents the dynamics of interest rates and macroeconomic aggregates for each of the economies considered in the sample. Notice that even though there is a substantial heterogeneity in terms of the degree of
Table 8: Co-movement with interest rates

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Argentina</th>
<th>Brazil</th>
<th>Ecuador</th>
<th>Venezuela</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma(r_t)$</td>
<td>2.2</td>
<td>0.6</td>
<td>1.6</td>
<td>0.54</td>
</tr>
<tr>
<td>$\rho(r_t, y_t)$</td>
<td>-49.7</td>
<td>-11.2</td>
<td>-4.4</td>
<td>-14.9</td>
</tr>
<tr>
<td>$\rho(r_t, c_t)$</td>
<td>-61.9</td>
<td>-21.2</td>
<td>-27.3</td>
<td>-11.3</td>
</tr>
<tr>
<td>$\rho(r_t, i_t)$</td>
<td>-61.3</td>
<td>8.3</td>
<td>-24.8</td>
<td>-13.5</td>
</tr>
<tr>
<td>$\rho(r_t, nx_t)$</td>
<td>69.3</td>
<td>5.4</td>
<td>25.6</td>
<td>-1.5</td>
</tr>
</tbody>
</table>

Note: Moments for Argentina, Brazil, Ecuador and Venezuela. Data is HP filtered at quarterly frequency. Moments are in percentage terms. $y_t$, $c_t$, $i_t$ and $nx_t$ denote (respectively): quarterly log HP filtered output, consumption, investment; and quarterly HP filtered net exports to output ratio. $r_t$ denotes the log HP filtered real interest rate computed by using 3 months T-bill rate plus EMBI+ net of expected inflation. $\sigma(\cdot)$ denotes standard deviations and $\rho(\cdot, \cdot)$ denotes correlations.

variability and correlation signs, it can be seen that interest rates are negatively correlated to output, consumption and investment in most of the cases, and tends to be positively correlated with the net exports to output ratio.

Table 9 presents the dynamics of real interest rate in the data and the ones implied by the two previous models.

Table 9: Non-targeted moments

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data (Averages)</th>
<th>Baseline Model</th>
<th>Model WCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma(r_t)$</td>
<td>1.23</td>
<td>0.14</td>
<td>5.7</td>
</tr>
<tr>
<td>$\rho(r_t, y_t)$</td>
<td>-20.1</td>
<td>26.2</td>
<td>-86.1</td>
</tr>
<tr>
<td>$\rho(r_t, c_t)$</td>
<td>-30.5</td>
<td>-24.1</td>
<td>-44.3</td>
</tr>
<tr>
<td>$\rho(r_t, i_t)$</td>
<td>-22.9</td>
<td>-24.5</td>
<td>-40.5</td>
</tr>
<tr>
<td>$\rho(r_t, nx_t)$</td>
<td>24.7</td>
<td>47.6</td>
<td>11.9</td>
</tr>
</tbody>
</table>

Note: Average moments for Argentina, Brazil, Ecuador and Venezuela. Data is HP filtered at quarterly frequency. Moments are in percentage terms. $y_t$, $c_t$, $i_t$ and $nx_t$ denote (respectively): quarterly log HP filtered output, consumption, investment; and quarterly HP filtered net exports to output ratio. $r_t$ denotes the log HP filtered real interest rate computed by using 3 months T-bill rate plus EMBI+ net of expected inflation. $\sigma(\cdot)$ denotes standard deviations and $\rho(\cdot, \cdot)$ denotes correlations.
Overall, it seems the model is able to generate plausible dynamics for the interest rate. As can be seen, both models are able to capture the negative correlation between interest rate and consumption and interest rate and investment as well as the positive correlation with net exports to output ratio. Moreover, even though the degree of variability in both models are in a similar order of magnitude to the ones observed for the average and in country specific cases.

In sum, even though interest rates moments are non-targeted, the moments implied by the models in line with stylized facts observed in the data, suggesting that the economies studied in this section are likely to generate plausible dynamics for the variables of interest.

7 The mechanism: empirical evidence

It was shown that the impact of volatility shocks is greatly amplified under time-varying markups. Moreover, the assumptions in the baseline model suggest that when volatility increases, output falls, the number of firms drops and markups increase, amplifying the drop in aggregate demand and output. In section 2, I studied the behavior of markups in small open economies over the business cycle and show that the countercyclicality of markups implied by the model is plausible for a variety of emerging economies. This section provides two sources of evidence related to the mechanism implied by this model: first, I present evidence that suggests that firm dynamics in emerging economies is procyclical, suggesting that the mechanism behind the model that suggests that markups and firm dynamics are related is also plausible; and, second I review evidence based on case studies documented in existing literature that supports the negative correlation between the number of firms and output.
7.1 Empirical evidence: firm dynamics

A key implication of the model is that firms exit is countercyclical, that is firms tend to exit during bad times. This section presents evidence on firm dynamics and GDP growth. Specifically, Table 10 computes the correlation between net entry and exit of firms and GDP growth using annual data from Bartelsman et al. (2009).11

Table 10: Firm dynamics and the growth rate of GDP

<table>
<thead>
<tr>
<th>Country</th>
<th>Correlation</th>
<th>St Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>87.6</td>
<td>35.7</td>
</tr>
<tr>
<td>Brazil</td>
<td>69</td>
<td>34.5</td>
</tr>
<tr>
<td>Chile</td>
<td>40.5</td>
<td>9.28</td>
</tr>
<tr>
<td>Colombia</td>
<td>22.7</td>
<td>5.87</td>
</tr>
<tr>
<td>Mexico</td>
<td>15.2</td>
<td>3.92</td>
</tr>
<tr>
<td>Portugal</td>
<td>31.1</td>
<td>8.04</td>
</tr>
<tr>
<td>Venezuela</td>
<td>-98.9</td>
<td>56.6</td>
</tr>
</tbody>
</table>

Note: Correlation between firms entry share net of firms exit share and GDP growth in percentage. Details on data sources and management are explained in the Data Appendix.

The table shows the percentage correlation between rate of net firms entry and GDP growth. As seen in the table, there is strong evidence suggesting that net entry of firms is procyclical. As can be seen, however, standard errors are large, which occurs because of short sample. Note that, the correlation for Venezuela is not significantly different from zero. The remaining correlations are positive to a 5% significance level.

In other words, Table 10 supports the prediction of the model that suggests that firms tend to entry during good times and tend to exit during bad times. Moreover, as shown in the previous subsection, the expansion seems to be characterized by a drop in markups while the contraction tends to occur with an increase in markups. The empirical analysis of this section relies on looking at correlations for different small open economies and, of course

11Data is available at http://econweb.umd.edu/~haltiwan/download.htm.
it does not impose any particular direction for the causality. However, it provides strong evidence that supports the plausibility of the mechanism behind the theoretical model.

7.2 Firm dynamics case studies: a short look at the literature

Jaimovich and Floetotto (2008) studies the correlation between firm failures by industries and real GDP and find that this correlation is negative and significant for most of the industries and sectors, up to 3 digits SIC, in US for the period 1958 and 1995, using data from Dun and Bradstreet.

Even though similar evidence for other economies is hard to find and possible strictly not suitable for international comparison, there has been some attempts to study the firm dynamics over the business cycle in small open economies. The first ambitious project in this direction is the one by Roberts and Tybout (1996), where the authors aim to characterize the patterns for firms entry and exit as well as markups variation in developing economies. In line with the assumptions in the model, the authors find that entry and exit varies substantially over the business cycle. Moreover, this volume presents several case studies. For the cases of Colombia (1977-1985), Chile (1980-1985), Mexico (1985-1989) and Morocco (1984-1989), they find that markups tend to increase with Herfindahl index using industry level regressions. Another example is Álvarez and Vergara (2010), who study plant exit and entry in Chile for the period 1979-2000 and, additionally, they study the way firms behavior is affected by macroeconomic reforms.\textsuperscript{12} Controlling for reforms and a set of variables, the authors find that the exit of plants with more than 20 workers is negatively related to the growth rate of GDP. However, the significance of this relationship seems to vanish when the real exchange rate is included.

Similar evidence is observed for the case of Argentina. Here using a database that includes service and retail and industrial firms, it can be seen that the number of firms substantially

\textsuperscript{12}The authors correctly acknowledge that a plant is not a firm, but in their survey most firms are single-plants.
decrease during the financial crisis, since 1998 to 2002. A similar pattern can be observed for the case of Canada, as shown by Ciobanu and Wang (2012), where the number of exit firms increased after 2006 and the number of entry firms substantially decreased after 2007.

Using data from Colombian manufacturing establishments for the period 1995-2004, Eslava et al. (2010) show that exit rates more than doubles during bad times regardless of the firm being financially constrained or unconstrained. This finding is robust to several model specifications.

In sum, the references discussed in this section provide different type of evidence supporting the fact that the number of firms tend to decrease during bad times, as the dynamics observed in the model suggest.

8 Conclusions

This paper studies the role of time-varying markups in the amplification of volatility shocks in real models. Specifically, it shows that the existence of endogenous time-varying markups amplifies the response of hours, consumption, investment and output compared to the model with fixed markups. This is indeed the main contribution of this paper given that time-varying markups have so far only been studied using sticky prices models, where it is not possible to isolate the effects of markups from those of sticky prices. On the contrary, this paper shows that pure markup effects can substantially affect the quantitative responses of endogenous variables to volatility shocks.

The paper starts by looking at the dynamics of markups in open economies. Using annual data from UNIDO Indstat2 on 28 industries for several economies, it is shown that markups volatility is substantial and it is, on average, negatively correlated with output. Although substantial country heterogeneity, this same fact is observed in several countries, and it holds on average. Moreover, this findings is robust to various detrending methods.

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The paper then proposed a model to study the role of time-varying markups in a pure real economy. The baseline model is a version of real business cycle small open economy model with endogenously time-varying markups and stochastic volatility shocks to the technology process. The baseline specification of the model assumes monopolistic competition as in Jaimovich (2007) which generates entry and exit of firms and gives rise to countercyclical markups as firm dynamics affects the degree of competition. This model, hence, allows us to study the role of endogenously time-varying markups without assuming neither price frictions nor nominal disturbances and, consequently, allows us to isolate the effects of markups from those of nominal frictions, something that is impossible in New-Keynesian sticky prices models.

Using this model, I show that endogenous time-varying markups amplifies the responses of endogenous variables to a volatility shock because it exacerbates the impact of volatility shocks on the real wage. Specifically, an increase in volatility triggers a consumption drop because of precautionary savings motives. Additionally, it negatively affects investment because it makes investment returns more risky. These two effects decrease the demand side of the economy. In the open economy, the trade balance improves, imports drop and the domestic economy increases savings in foreign debt. Given the assumptions of monopolistic competitive firms, the drop in demand forces the exit of firms which lowers the degree of competition and drives markups up. The increase in markups operates as inducing a drop in the technology and decreases the real wage inducing a drop in labor supply. The joint drop in labor and technology through the increase in markups induces an extra negative impact on output which subsequently reinforces the drop in demand. This channel is absent without time-varying markups. These findings are robust to different degrees of Frisch elasticity, adjustment costs, spreads elasticity and utility functions. Moreover, these findings are robust to alternative ways of modeling endogenously time-varying markups. For instance, the online appendix shows that if markups are time-varying because of the existence of deep habits as in Ravn et al. (2006), the same type of amplification is observed.
Additionally, I study the role of endogenous markups also in the transmission of shocks to the volatility of the real interest rate spread. I find that the amplification of dynamics following a volatility shock are of the order of 3 for a model without working capital constraints and for a model in which firms are subject to a working capital constraint. One of the main implications of this paper is that the use of a real model might underestimate the impact of volatility shocks as long as they do not consider the existence of time-varying markups.

References


