

Optimal Input Trade Policy Under Economic Uncertainties in A Small Open Economy

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Abstract

This paper theoretically analyzes optimal input trade policy under economic uncertainties in a small open economy. The benchmark model has two innovations. First, it is a dynamic stochastic general equilibrium model that explains both key business cycle moments and asset prices of the Argentina economy. Second, in the static version of the model, there is no gain by deviating from the free input trade policy. The main findings are: (1) with any type of those commonly discussed exogenous shocks, it is always optimal for the government to subsidize imported immediate inputs in the benchmark model and (2) the result is robust to key structural parameters.

Keywords: Business Cycle, Optimal Input Trade Policy, Trade Openness.

JEL Classification: E32; E61; F41.

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1 Introduction

Emerging economies are more volatile than developed economies [Aguiar and Gopinath (2007) among others]. This empirical regularity naturally raises one important question: should emerging economies increase its trade openness as an optimal response to volatile exogenous (external and internal) shocks? The existing empirical studies have not provided a definite answer yet. For example, Calvo et al. (2004), Calvo and Talvi (2005), and Cavallo and Frankel (2008) show that economies more open to trade will adjust their output less when they are hit by sudden stops; a finding that seems to recommend an open trade policy. However, some other empirical studies show that greater trade openness increases output growth volatility [Rodrik (1997) and Loayza and Raddatz (2007) for aggregate data, and Di Giovanni and Levchenko (2006) for disaggregate data], thus a lower growth rate [Ramey and Ramey (1995) and Easterly et al. (2001)]. These findings suggest the optimality of a protective trade policy. Given mixed empirical evidence, it is of interest to examine whether a small open economy should increase its trade openness to deal with economic uncertainties from a theoretical perspective.

This paper answers the question by discussing optimal input trade policy under economic uncertainties in a dynamic stochastic general equilibrium (DSGE) model of a small open economy. One major difference between our model and those in Neumeyer and Perri (2005) and Uribe and Yue (2006), and Garcia-Cicco et al. (2010) is that our model includes imported *intermediate inputs* (hereafter inputs). The feature is motivated by two concerns. First, with tariffs on imported inputs, our model is tractable in the sense that we can explicitly discuss the relationship between trade openness and the cost of exogenous shocks. The

second concern is its empirical relevance: more than 50% world trade consists of trade in intermediate inputs. In line with those closely related papers, our model considers financial frictions and three types of shocks, temporary productivity shocks, world interest rate shocks, and country spread shocks. Both country spread shocks and financial frictions have been argued as important contributing factors that drive business cycles in emerging economies [Neumeyer and Perri (2005) and Uribe and Yue (2006) for country spread shocks and Garcia-Cicco et al. (2010) and Jahan-Parvar et al. (2012) for financial frictions].

There are two innovations. First, we focus on optimal input trade policy under economic uncertainties. Numerous empirical studies have shown that declines in intermediate input tariffs are associated with sizable productivity gains [Head and Ries (1999), Kasahara and Rodrigue (2008), Amiti and Konings (2007), Goldberg et al. (2010), and many others]. Even though these facts have inspired discussions on their trade implications, especially their implications on trade volumes, there are very few studies analyzing the trade policy implications in models with input tariffs except Dixit and Grossman (1982), Spencer and Jones (1992),¹ Antràs and Staiger (2010), among a few others.² Surprisingly, all these theoretical studies analyze trade policy in a model without economic uncertainties. In this paper, we extend the discussion to economies with exogenous shocks. For this purpose, we choose a model in such a way that in the static version of the model, i.e., without exogenous shocks, there is no gain by deviating from the free input trade policy. Thus, any deviation from the free input trade policy in our stochastic economy is simply due to the existence of

¹Spencer and Jones (1992): Supply conditions for the input significantly affect whether imports of the input should be taxed or subsidized.

²Models by Ethier (1982), Markusen (1989), show that lower input tariffs can lead to increased productivity from access to more varieties of intermediate inputs, access to higher quality inputs, and through learning effects.

economic uncertainties.

Second, we analyze optimal input trade policy in a *realistic* DSGE model. Our model may be regarded as being realistic because it successfully replicates key business cycle facts and asset prices of a representative small open economy: the Argentina economy. The reason of choosing a realistic model is mainly because replicating different sets of moments implies different structural parameter values. For example, Jahan-Parvar et al. (2012) show that a model replicates both business cycle moments and equity returns has different values of some key structural parameters from a model solely generates the same set of business cycle moments. As it is well known, policy implications, in many cases, hinge on parameter values. In addition, since our model replicates key asset prices, our model satisfies the “Atkeson-Phelan principle” after Atkeson and Phelan (1994) in that it replicates the way small open economies price consumption uncertainty. According to Barro (2009), our model, which satisfies that principle, provides a suitable vehicle to carry out policy analysis.

Formally, we evaluate the relationship between the welfare costs of different types of exogenous shocks and trade openness.³ Our numerical results indicate that it is optimal to subsidize imported inputs. In our economy, a reduction in the tariff rate on imported inputs will generate productivity gains and increase households’ work effort in the model. Without economic uncertainties, the disutility due to the additional work effort will be completely offset by the corresponding increase in consumption given the preference and the exogenous interest rates. As a result, there is no gain by deviating from the free input trade policy.

With the introduction of productivity shocks, consumption will respond quite differently.

³Here costs are defined in the same way as in Lucas (1987). Trade openness is measured by the ratio of trade turnover to GDP.

In particular, consumption in the benchmark model, due to the precautionary saving incentive, will increase by a smaller amount for any given reduction in the tariff rate on imported inputs, compared to that in a static model.⁴ This quantitatively different response of consumption results in two effects. On the one hand, the utility in the current period in the benchmark model will be smaller than that in the corresponding static model because work efforts will change in the same amount across the two models. On the other hand, the subjective discount factor will be higher in the benchmark model: households will value the future consumption more. The two effects are balanced in the benchmark model when the tariff rate is set at a negative value. Similar mechanisms apply to the cases of world interest rate shocks and country spread shocks. The policy implication is quite robust: we obtain the same result with respect to key structural parameter.

The rest of the paper is organized as follows: Section 2 outlines the model. Section 3 presents optimal input trade policy without exogenous shocks. Section 4 discusses results about business cycle and asset prices, and optimal trade policy under economic uncertainties. And Section 5 concludes.

2 The benchmark economy

The model is a stylized DSGE model with imported inputs. There are three types of agents, domestic households, firms, and the government. There are four real frictions: capital adjustment costs, debt adjustment costs, incomplete asset market, and a working capital constraint. The economy is driven by a joint process of productivity shocks, world interest rate shocks,

⁴The precautionary saving motivation has been identified as an important determinant of households' wealth accumulation [Gourinchas and Parker (2001), Carroll and Samwick (1998), Cagetti (2003) and others].

and country spread shocks. Our model is very close to that in Jahan-Parvar et al. (2012) except two differences. (1) We assume an exogenous non-stochastic steady state of country spreads and an exogenous process of the deviation of country spreads from the steady state; while country spreads in Jahan-Parvar et al. (2012) are completely endogenous. (2) We introduce imported inputs while they do not.

2.1 The representative household

The representative household chooses hours and consumption to maximize its expected lifetime utility

$$\max_{\{c_t, h_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \theta_t \frac{(c_t - h_t^\omega / \omega)^{1-\gamma} - 1}{(1-\gamma)}, \quad (2.1)$$

where \mathbb{E}_0 denotes the mathematical expectation operator conditional on information available at time 0 and ω denotes the exponent of labor supply in utility. c_t , and h_t denote consumption and hours. The law of motion of the subjective discount factor from period t to period 0, θ_t , is given by $\theta_{t+1} = \beta(\tilde{c}_t, \tilde{h}_t)\theta_t, t \geq 0$. Here $\beta(c_t, h_t) = (1 + c_t - h_t^\omega / \omega)^{-\beta_1}$, where β_1 is the preference parameter. \tilde{c}_t and \tilde{h}_t denote the cross-sectional averages of consumption and hours, which are taken as given by individual households.

The representative household receives the profit, the capital rent, the labor income, and income from the intermediate input sale to firms.⁵ The household's period budget constraint

⁵Our results do not change if firms buy inputs directly from the rest of the world because they are 100% owned by domestic households.

is given by:

$$d_t + r_t k_t + w_t h_t + r_t^m m_t + \Gamma_t \geq R_t d_{t-1} + \Psi (d_t - d) + c_t + i_t + (1 + \tau) m_t + \Phi(k_{t+1} - k_t), \quad (2.2)$$

where d_t , m_t , k_t , r_t , w_t , r_t^m , and i_t denote foreign debt position, imported inputs, capital, the rate of return on capital, the wage rate, the firm-paid price of imported inputs, and investment. τ denotes the tariff rate levied on imported inputs. Γ_t denotes the government transfer. We do not include profit in the budget constraint because it is well known that the profit is zero with the assumed constant return to scale technology. The classical terms-of-trade externality theory argues that a country with market power on imported goods may gain by setting tariffs on its imports [Bagwell and Staiger (1999) and Broda et al. (2008)]. To shut down this terms-of-trade externality channel, we set the (before-tariff) relative price of inputs at unity.⁶

The interest rate faced by individual households, R_t , is the product of the world interest rate, R^{us} , and the exogenous country spread, CR . The law of motion of country interest rates is assumed to follow the estimated process in Neumeyer and Perri (2005):

$$\hat{R}_t^{us} = 0.81 \hat{R}_{t-1}^{us} + \varepsilon_{t,R^{us}}, \quad (2.3)$$

$$\hat{C}R_t = 0.78 \hat{C}R_{t-1} + \varepsilon_{t,CR1}. \quad (2.4)$$

Here the variables with hat denote the percentage deviations from their corresponding non-

⁶The macroeconomic effect of terms of trade shocks has been extensively studied [Ostry and Reinhart (1991), Mendoza (1995), Rodrik (1998), Hoffmaister et al. (1998), and many others].

stochastic steady state values. The variance and covariance of innovations are given by $\sigma_{\varepsilon_{Rus}} = 0.63\%$ and $\sigma_{\varepsilon_{CR1}} = 2.29\%$.

We assume that debt adjustment costs are given by $\Psi(d_t) = \psi/2 (d_t - d)^2$, where d denotes the non-stochastic steady state of net foreign debt. There are several reasons to consider such costs. First, the inclusion of debt adjustment costs is sufficient to assure the stationary behavior of debt [Schmitt-Grohé and Uribe (2003)]. Second, there is bountiful empirical evidence in support of costly borrowing and lending. According to Demirguc-Kunt et al. (2004), the mean of overhead costs (proxy of debt adjustment costs) is 3.02% of the value of loans. Third, financial frictions have played an important role in understanding business cycles and asset prices in emerging economies. For example, they are crucial to generate the observed dynamics of key variables such as trade-balance to GDP ratio [Garcia-Cicco et al. (2010)] and equity returns [Jahan-Parvar et al. (2012)]; the connection between the exchange rate regime and financial distress [Gertler et al. (2007)]; etc..⁷ Fourth, financial integration significantly weakens the negative relationship between macroeconomic volatility and economic growth [Bekaert et al. (2005), Kose et al. (2006), and Raddatz (2006)]. Nevertheless, the literature has been silent on the effect of financial frictions on optimal trade policy.

$\Phi(k_{t+1}, k_t) = \phi(k_{t+1} - k_t)^2/2$ denotes the capital adjustment cost, which helps the model match the cyclical behavior of investment. The law of motion of capital is given by

$$k_{t+1} = (1 - \delta)k_t + i_t. \tag{2.5}$$

⁷There is more about financial frictions in the closed economy environment [Bernanke et al. (1998), Faia and Monacelli (2007), Christiano et al. (2009), and many others].

where δ denotes the depreciation rate.

The representative household is subject to the non-Ponzi-game condition

$$\lim_{j \rightarrow \infty} \mathbb{E}_t \frac{d_{t+j+1}}{\prod_{s=0}^j R_{t+s}} \geq 0. \quad (2.6)$$

The condition rules out the possibility that the representative household borrows to finance its consumption without limit.

The household's utility maximization problem is to choose c_t , h_t , d_t , m_t , i_t , and k_{t+1} to maximize Eq. (B.1) subject to the non-Ponzi game condition (2.6), period budget constraints holding with equality (2.2), and the law of motion of capital (2.5). The Euler equation with respect to k_{t+1} is given by:

$$\mathbb{E}_t \left[\frac{\left(1 + c_t - \frac{h_t^\omega}{\omega}\right)^{-\beta_1} \left(c_{t+1} - \frac{h_{t+1}^\omega}{\omega}\right)^{-\gamma}}{\left(c_t - \frac{h_t^\omega}{\omega}\right)^{-\gamma}} \right] \left[\frac{1 - \delta + \phi(k_{t+2} - k_{t+1}) + r_{t+1}}{1 + \phi(k_{t+1} - k_t)} \right] = 1$$

Accordingly, the equity return, r_{t+1}^e , and the equity premium, r_t^p , respectively, are defined as:

$$1 + r_{t+1}^e = \frac{1 - \delta + \phi(k_{t+2} - k_{t+1}) + r_{t+1}}{1 + \phi(k_{t+1} - k_t)}, \quad (2.7)$$

$$r_t^p = \mathbb{E}_t r_{t+1}^e - r_t^f. \quad (2.8)$$

Here r_t^p denotes the equity premium conditional on the information available at time t .

2.2 The firms

There are many identical final-good production firms (100% owned by domestic households).

Firms use constant return to scale technology to produce

$$y_t = z_t k_t^{\alpha_k} h_t^{\alpha_h} m_t^{\alpha_m}, \quad (2.9)$$

where $0 < \alpha_k < 1$, $0 < \alpha_h < 1$, $0 < \alpha_m < 1$, and $\alpha_k + \alpha_h + \alpha_m = 1$. y_t and z_t denote the final good and the total productivity factor, respectively. In addition to their empirical relevancy [Gertler et al. (2007)] and the tractability of the model as mentioned in the introduction, imported inputs are considered for one more reason: models with three inputs have been used in the literature to explain different economic phenomena [McCallum and Nelson (2000), Leitemo and Soderstrom (2005), Huang and Liu (2007), Adolfson (2007), Mendoza and Yue (2008), Braggion et al. (2009)].⁸

Our production function may be regarded as an ad hoc representation of the idea that declines in intermediate input tariffs are associated with productivity gains. To see this, note that when the tariffs go down, the market price of imported inputs, r_t^m , will decrease because in the equilibrium we always have $r_t^m = 1 + \tau$. With the decrease of r_t^m , the demand of m_t will increase. As a result, the marginal products of capital and labor efforts will increase.

⁸There are several important differences between this paper and Mendoza and Yue (2008). First, we consider capital accumulation while they do not. Second, our model is calibrated in such a way to replicate both key business cycle moments and equity returns while they do not consider equity returns. Third, they consider defaults while our model is silent on the possibility of defaults.

In this economy, the total productivity factor is assumed to follow the process⁹

$$\ln(z_{t+1}) = \rho \ln(z_t) + \varepsilon_{t+1}^z, \varepsilon_{t+1}^z \sim \text{IIND}(0, \sigma_z^2), \quad (2.10)$$

where $0 < \rho < 1$ denotes the first order serial autocorrelation of $\log(z)$, ε_{t+1}^z denotes the technology shocks, IIND denotes identical and independent normal distribution, and σ_z^2 denotes the variance of technology shocks.

Firms are subject to a working capital constraint. For simplicity, we adapt the same constraint as that in Uribe and Yue (2006): $WK_t \geq \varphi w_t h_t$, where WK_t denotes the amount of working capital and $\varphi \geq 0$ denotes the number of quarter wage bills that the representative firm needs to pay. We include the working capital constraint mainly in order to improve the empirical fit of the model. First, output in our models with such a constraint will drop in the presence of a positive country spread shock [Chari et al. (2005)], which is in line with the data. Second, Neumeyer and Perri (2005) and Jahan-Parvar et al. (2012) show that a working capital constraint helps explain the observed countercyclical country spreads and countercyclical trade balances.

As shown in the appendix, the representative firm chooses k_t , h_t , and m_t to maximize the following objective function by taking z_t , r_t , w_t , and r_t^m as given

$$\max_{\{k_t, h_t, m_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \theta_t \frac{\mu_t}{\mu_0} \pi_t,$$

where μ_t denotes the marginal wealth utility of the representative household. The first-order

⁹The structural parameters, ρ and σ_z , are calibrated in the Section 3.3.

conditions with respect to k_t , h_t , and m_t for the firms are given by:

$$r_t = \alpha_k z_t h_t^{\alpha_h} k_t^{\alpha_k - 1}, \quad (2.11)$$

$$w_t \left[1 + \eta \left(\frac{R_t^* - 1}{R_t^*} \right) \right] = \alpha_h z_t k_t^{\alpha_k} h_t^{\alpha_h - 1} m_t^{\alpha_m}. \quad (2.12)$$

$$r_t^m = \alpha_m z_t h_t^{\alpha_h} k_t^{\alpha_k} m_t^{\alpha_m - 1}, \quad (2.13)$$

where $R_{t-1}^* = R_{t-1} / [1 - \psi(d_t - d)]$ is the effective interest rate. Profits are equal to zero since we have assumed constant returns to scale technology.

2.3 The government

The government's sequential budget constraint is then given by:

$$\tau m_t = \Gamma_t, \quad t \geq 0. \quad (2.14)$$

We do not consider the government expenditure shocks in order to simplify the discussion.

2.4 Competitive equilibrium

In equilibrium, the capital market, the labor market, and the intermediate input market all clear. The aggregates equal to the counterparts of the representative household's because households are assumed to be identical:

$$\tilde{c}_t = c_t; \quad (2.15)$$

$$\tilde{h}_t = h_t. \quad (2.16)$$

The competitive equilibrium is defined as a sequence of real allocations $\{c_t, h_t, d_t, m_t, i_t, k_{t+1}, \tilde{c}_t, \tilde{h}_t, y_t, \Gamma_t\}_{t=0}^{\infty}$, and prices $\{\mu_t, q_t, r_{t+1}^e, r_{t+1}^p, r_t, w_t, r_t^m\}_{t=0}^{\infty}$, given $\{r_{-1}^f, d_{-1}, k_0, z_0, R_0^{us}, CR_0\}$, the law of motion of the interest rates (2.3)-(2.4), and the law of motion of the total productivity factor (2.10), such that households maximize utility, firms maximize profit, the government balances its budget, and all markets are cleared. For details, please see the appendix.

2.5 Welfare Cost

We focus on the unconditional cost instead of a conditional cost because the ranking of the conditional cost will depend upon the assumed initial state of the economy [Schmitt-Grohé and Uribe (2006)]. The cost of any type of exogenous shocks is defined as a lump sum consumption, $\lambda(\tau, \sigma)$, which the representative household is willing to give up in order to be as well off as without economic uncertainties. σ denotes the standard deviation of the exogenous shocks we consider. Our notation implies that when we focus on one type of shocks, we shut down the other two types of shocks.¹⁰ Mathematically, the welfare cost is indirectly defined by

$$\mathbb{E}V(\tau, \sigma) = \frac{[c(\tau) - \lambda(\tau, \sigma) - h(\tau)\omega/\omega]^{1-\gamma} - 1}{(1-\gamma) \left\{ 1 - [1 + c(\tau) - \lambda(\tau, \sigma) - h(\tau)\omega/\omega]^{-\beta_1} \right\}}. \quad (2.17)$$

The non-stochastic steady consumption and hours are functions of τ and $\mathbb{E}V$ is a function of both τ and σ . As a result, the cost is a function of both τ and σ . We can write down the

¹⁰We also consider the welfare cost of all three types of exogenous shocks jointly together. In that case, σ becomes a vector of three elements, one element corresponding to the standard deviation of one type of exogenous shocks.

cost in Eq. (2.17) without changing hours because with GHH momentum utility function, there is no wealth effect on the labor supply. Once we solve the model, we obtain numerical values for $\mathbb{E}V(\tau, \sigma)$, $c(\tau)$, and $h(\tau)$. There is only one unknown in Eq. (2.17), $\lambda(\tau, \sigma)$. The equation is solved using the MATLAB command, ‘fsolve.m’.

3 Optimal Input Trade Policy without Economic Uncertainties

In the non-stochastic steady state, trade openness is negatively related to the value of the tariff rate on inputs. Mathematically, it is straightforward to show that in the non-stochastic steady state:

$$TO \equiv \frac{\text{Exports} + \text{Imports}}{y - m} = \frac{TB + 2m}{y - m} = s_{tb} + \frac{2}{(1 + \tau)/\alpha_m - 1}, \quad (3.1)$$

where TO denotes trade openness, TB denotes trade balance, y denotes output, m denotes the intermediate imported inputs, s_{tb} denotes the trade-balance to GDP ratio, and α_m is the parameter in the production process.¹¹ The value added (or GDP) to this small open economy is given by $y - m$. Equation (3.1) makes it clear that trade openness is decreasing in the tariff rate, holding s_{tb} and α_m constant. In our model, the government can adjust trade openness by changing the tariff rate.

Without exogenous shocks, there is no gain by deviating from the free input trade policy, i.e., it is optimal to have the free input trade policy ($\tau = 0$) in the non-stochastic steady state.

¹¹In our numerical exercise, both s_{tb} and α_m are kept constant.

To see this, note that the non-stochastic steady state of lifetime indirect utility function is given by:

$$V = \frac{[c(\tau) - h(\tau)\omega/\omega]^{1-\gamma} - 1}{(1-\gamma)[1 - \beta(c(\tau), h(\tau))]} = \frac{[\log(R)/\beta_1 - 1]^{1-\gamma} - 1}{(1-\gamma)(1 - 1/R)}. \quad (3.2)$$

$c(\tau)$, $h(\tau)$, and $\beta(c(\tau), h(\tau))$ denote the non-stochastic steady state consumption, hours and the one-period endogenous subjective discount factor. They are functions of τ . Here ω , γ , and β_1 are structural parameters and R is the non-stochastic steady state of country interest rate. The last equality comes from the following Euler equation in the non-stochastic steady state, $\beta(c(\tau), h(\tau))R = (1 + c - h\omega/\omega)^{-\beta_1} R = 1$. From Eq. (3.2), the non-stochastic steady state lifetime utility is independent of tariff rates (trade openness).

It is worth mentioning that there are always productivity gains in this economy, with or without economic uncertainties. Since there is no gain by deviating from the free input trade policy in the static model, productivity gains associated with the declines in tariffs on imported inputs do not necessarily imply that it is optimal to reduce the existing tariff rates.

4 Optimal Input Trade Policy with Economic Uncertainties

4.1 Data and Calibration

The data are about the Argentina economy. Our calibration is standard. To save space, we put the details of the calibration in Appendix C. Here we explain how we pin down

the values of five structural parameters: the serial correlation of productivity shocks, ρ , the standard deviation of the innovation to productivity shocks, σ_z , the capital adjustment cost parameter, ϕ , the debt adjustment cost parameter, φ , and the working capital constraint parameter, η . Define \hat{y} , \hat{i} , \hat{c} , and \hat{h} denote the percentage deviations of the business cycle components of output, investment, consumption, and labor efforts from the corresponding trends. We choose values for these five parameters, simulate the model, and repeat this process until the simulated standard deviations of \hat{y} , \hat{i} , \hat{c} , and the trade-balance to GDP ratio, as well as the first-order autocorrelation of \hat{y} and the mean equity return match the data as close as possible.

The calibration is shown in Table 1. Our estimate of η is the same as that in Jahan-Parvar et al. (2012) and our estimate of ρ is also close to that in Jahan-Parvar et al. (2012) in the Argentina economy case. Nevertheless, there is an important difference between the calibration in our model and that in those similar models in the literature. In particular, we set $\psi = 240$ and $\phi = 210$. These are substantially larger than those chosen in the literature. For example, Garcia-Cicco et al. (2010) set $\psi = 2.8$ and $\phi = 4.6$ while Jahan-Parvar et al. (2012) $\psi = 0.6$ and $\phi = 60$ in the Argentina economy case. Compared to Garcia-Cicco et al. (2010), the calibration in Jahan-Parvar et al. (2012) makes it harder to adjust capital. In our economy with imported inputs, the requirement of matching both key business cycle moments and equity returns makes it even harder to adjust both capital and debt. As a result of the larger ϕ , our estimate of σ_z is also substantial larger than that in Jahan-Parvar et al. (2012).

This important difference is mainly due to the different focuses among those papers. Given this difference, we also consider much lower values of ψ and ϕ . When we do so, our

key qualitative result, i.e., it is optimal to subsidize imported inputs, still holds even though the overall ability of the model fitting key empirical facts becomes weaker.

In general, there is no analytical solution to this DSGE model. We apply the second order perturbation method discussed in Schmitt-Grohé and Uribe (2004) to obtain the numerical solution.¹² First, perturbation methods have been widely used in the literature and it has been shown that such methods deliver quite accurate numerical solutions to DSGE models with differentiable policy functions. Second, we use the second order approximation algorithm because the first order approximation method could not differentiate welfare in two different economies with the same non-stochastic steady state but different volatilities.

4.2 Business Cycles, Asset Prices, and Welfare Cost

The model-generated key business cycle moments and asset prices (including equity returns and country spreads) are close to the data, see Table 2. For example, country spreads are countercyclical because an increase of output will decrease the net foreign debt position. Trade balances are countercyclical because an increase of the interest rate will reduce output due to the working capital constraint, causing savings to increase and investment to fall. Given that our model builds on those in Neumeyer and Perri (2005), Uribe and Yue (2006), and Jahan-Parvar et al. (2012), the success of our model replicating those key empirical facts is not surprise.

In addition, the model generates typical responses as we have observed in the data. For example, when there is a positive country spread shock, the representative household

¹²We have additional notes, which are available upon request, showing how to solve the dynamic stochastic general equilibrium. Similar notes could be found from the Internet as well.

borrowers less because the cost of borrowing rises. With the working capital constraint, the labor demand decreases even though the labor supply does not move because of the GHH preferences. As a result, the positive country spread shock decreases both hours and output in equilibrium. Thus a sudden stop of the type addressed in Chari et al. (2005) emerges. Consumption drops because of the negative welfare effect. Investment drops dramatically because the opportunity cost of investing is high. Trade balance and current account are thus improved.

Our model generates the observed equity premium in Argentina as well. The main reason is the inclusion of debt adjustment costs. Such costs make it harder to adjust the debt position to absorb the effect of shocks, i.e., the supply of debt becomes inelastic. As a result, consumption becomes more sensitive to exogenous shocks, such that the MRS across states becomes more volatile, a necessary condition for replicating equity returns in the presence of smooth world interest rates. For details, please see Jahan-Parvar et al. (2012).

Compared to the model in Jahan-Parvar et al. (2012), our model makes a big improvement in terms of its ability of replicating empirical facts. One limitation of the model in Jahan-Parvar et al. (2012) is that it implies a negative mean of country spreads. This may not be a surprising result. According to Weil (1989), a volatile MRS across time tends to force down the mean of the country's effective interest rate. In the Jahan-Parvar et al. (2012)'s model with an exogenous world interest rate and purely endogenous country spreads, the mean of the model-generated country spreads has to be pushed down below its steady state, which is 0, in response to this force. Even though such a result is expected in that model, the generated negative mean of country spreads is clearly counterfactual. Jahan-Parvar et al. (2012) propose that such an unrealistic implication may be rectified by further modifying

their benchmark model. One way is to introduce a process of exogenous country spreads as in Neumeyer and Perri (2005). This is exactly what we have imposed in our model here. As expected, our model generates a positive mean of country spreads.

The welfare costs associated with productivity shocks, world interest rates shocks, country spread shocks, and all shocks are, respectively, 0.24%, 0.09%, 1.16%, and 1.56% of the non-stochastic steady state consumption. Apparently, stabilizing country spread shocks will generate the largest welfare gain, comparing to stabilizing the other two types of shocks. Such an important role played by country spread shocks is in line with the literature, Uribe and Yue (2006) and Jahan-Parvar et al. (2012).

Our positive welfare cost result confirms the importance of the “Atkeson-Phelan principle” defined in Barro (2009), which essentially states that it is important to replicate the way small open economies price consumption uncertainty. To see this, note that on the one hand, we obtain the positive welfare cost result because the requirement to replicate equity returns assigns an important role to financial frictions. On the other hand, both Ericson and Liu (2012b) and Ericson and Liu (2012a) show that the welfare cost of productivity shocks and that of country spread shocks in a small open economy are usually negative, i.e., positive welfare effects, unless financial frictions are strong. The change from negative welfare costs in the literature to positive welfare costs in our paper clearly confirms the importance of such a principle because consumption uncertainty is rightfully priced in our model with strong financial frictions.

4.3 Optimal Input Trade Policy

Our model is able to replicate both key business cycle moments and key asset prices. Equally important is that in our model, risk aversion households dislike economic uncertainties, which is in line with the consensus that exogenous shocks should be welfare-deteriorating to risk aversion households. Given all of these and in particular that our model satisfies the “Atkeson-Phelan principle”, it is appropriate to use such a model to analyze policy implications.

In this section, we analyze optimal input trade policy on imported inputs when the tariff rate is constant over time. To obtain optimal tariff rates, we calculate the welfare cost associated with each value of τ over the range of $[-0.4, 0.2]$.¹³ When we calculate the welfare cost, we keep other structural parameters, except the trade openness, unchanged. This is because when we change the tariff rate, we have to change one parameter in order to close the model. Since we focus on the relationship between the cost and the trade openness, we choose to change the value of trade openness whenever we change the tariff rate. In the sensitivity analysis, we consider different scenarios by changing the values of γ , ω , ϕ and ψ and repeat the exercise of finding optimal τ for each scenario. Fig. 1 displays some results by changing γ and ω while keeping ϕ and ψ the same as in the benchmark model.

Here are the results. In the benchmark model, the optimal tariff rate is -24%. It is negative, i.e., it is optimal to subsidize imported inputs. Such an optimal input trade policy also holds when the economy is solely driven by productivity shocks, or world interest rate

¹³The boundary values are determined in such a way that the numerical solutions to all competitive equilibria under any combination of structural parameter values we consider in the paper have negligible approximation errors: less than 10^{-12} .

shocks, or country spread shocks. In the latter case, the optimal tariff rates are, respectively, -25%, -24%, and -23%. It is quite robust with respect to key structural parameters, see Fig. 1. Furthermore, additional results (not reported) show that it is still optimal to subsidize imported inputs when financial frictions are weaker, i.e., the value of ψ becomes smaller. In other words, financial frictions, even though they are important in terms of replicating equity returns, are not crucial in obtaining the negative optimal tariff rate result.

The underlying mechanism of the optimal input trade policy implication is as follows. A reduction of the tariff rate not only increases the trade openness, but also the marginal products of capital and labor. The increase of the marginal product of labor will inevitably increase the labor demand and thus the equilibrium labor effort. Without economic uncertainties, the disutility of the additional equilibrium labor effort will be completely offset by the increase of consumption, for the given preference and the exogenous interest rates. We have shown this point mathematically in Section 3.

With productivity shocks, the response of consumption to a change of the tariff rate will, because of the precautionary saving motive, usually be smaller than that in the corresponding economy without economic uncertainties. In turn, there are two effects. On the one hand, the disutility of the additional equilibrium labor effort will be only partially offset by an “insufficient” increase of consumption and thus the period utility will decrease. On the other hand, the subjective discount factor will increase, which means that households value their future consumption more. The two effects work against each other in terms of the households’ lifetime utility. Our numerical results indicate that the latter effect is stronger in the $\tau = 0$ case so that it is optimal to further reduce the tariff rate. In other words, it is optimal to subsidize imported inputs if we consider productivity shocks only. Similar

mechanisms apply to the cases of world interest rate shocks and country spread shocks and we have the same optimal input trade policy.

Given that the use of the tariff rate does not introduce distortion in the non-stochastic steady state and our model excludes terms of trade shocks, monopolistic competition, strategic behavior, and price stickiness, it is appropriate to ascribe the identified trade policy implication to the existence of exogenous (external and/or internal) shocks. This is a new result. It contributes to the literature by showing the optimal input trade policy in models with economic uncertainties. This is also an important result. It makes it optimal to further liberalize trade given the existing positive tariff rates.

4.4 Some Remarks

For completeness, we also have additional sensitivity exercises with additional preferences, such as Cobb-Douglas preferences and GHH preferences with a constant subjective discount factor. In general, the key result remains: the optimal input trade policy deviates from the free input trade policy.

Nevertheless, these additional numerical results do not strengthen our findings for several reasons. First, in models with either Cobb-Douglas preferences or GHH preference with a constant β , it is not optimal to set τ at 0 when there are no economic uncertainties. As a result, it is difficult to justify the use of those preferences to study optimal input trade policy under economic uncertainties in the first place. Second, models with those preferences are in general have a weaker ability in replicating the key business cycle moments. For example, models with Cobb-Douglas preferences tend to over-estimate the volatility of labor effort and trade openness and models with a constant β have difficulty in replicating equity returns.

5 Conclusions

We have shown with a realistic DSGE model that, in general, it is optimal to set a negative tariff rate on imported inputs. The deviation from the free input trade policy in our model is simply due to the existence of economic uncertainties. In this sense, we extend the main result in Hoff (1994) to a dynamic stochastic general equilibrium framework: the classical trade theory may break down in models with economic uncertainties.

These results are robust to the values of discussed key structural parameters and types of exogenous shocks. Additional numerical exercise indicates that the results are also robust to financial frictions. Because it is optimal to subsidize the import, it is optimal to further liberalize trade by reducing the existing positive input tariff rates when the economy is driven by those commonly discussed exogenous shocks. This theoretical result justifies the trade-liberalization movements in the past several decades.

There is, however, scope for improvement in our analysis. For example, this paper analyzes optimal tariff rates in a highly stylized DSGE model without considering many important empirical regularities such as monopolistic competition, price stickiness, terms of trade shocks, strategic behavior, etc., all of which have trade policy implications. To obtain a complete picture of optimal tariff rates in a more realistic model, it seems necessary to extend our model by including those factors. Nevertheless, such modifications will fundamentally change the model and is out of scope of this paper and we defer it to our future research projects.

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A Tables and figures

Table 1: Calibration of Structural Parameters

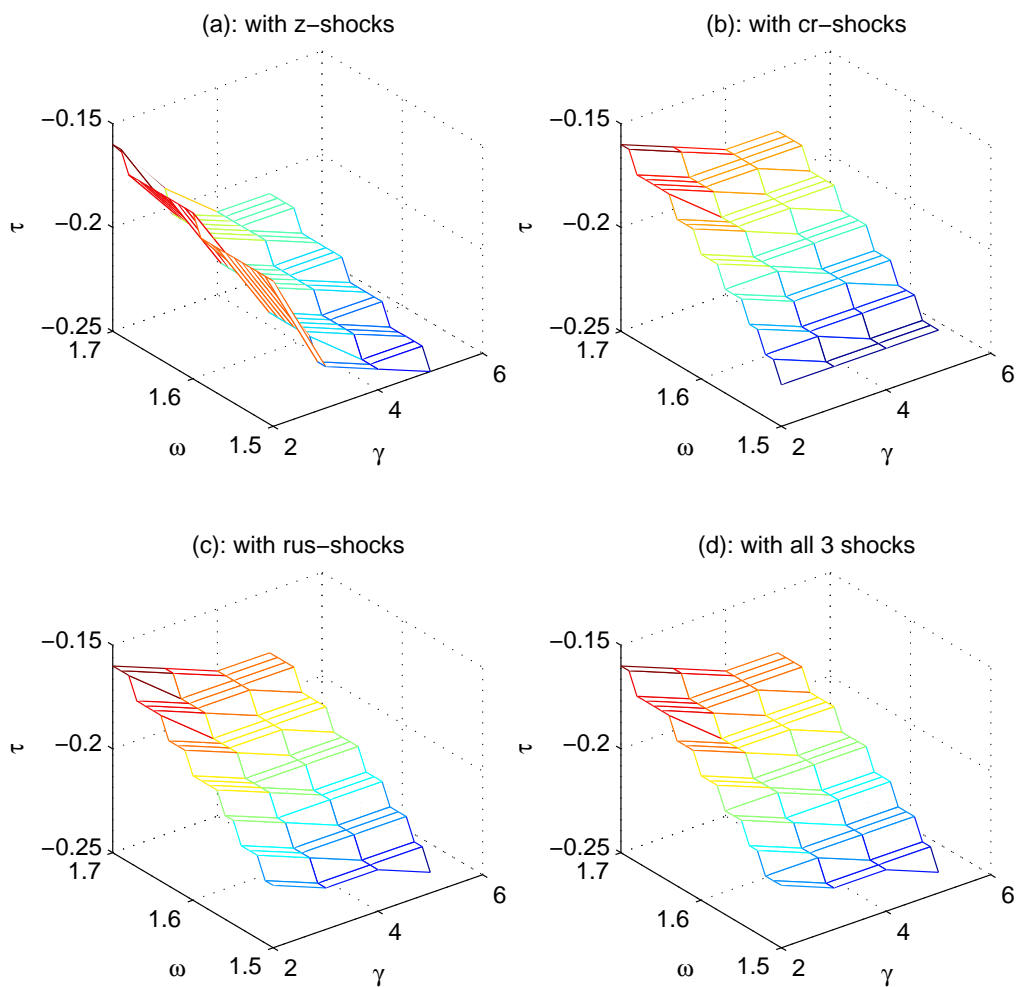
Symbol	Definition	Value
γ	Risk aversion coefficient	5
δ	Capital depreciation rate	0.025
ω	Exponent of labor supply in utility	1.5
α_m	Imported input elasticity	0.1422
α_h	Labor elasticity	0.5318
α_k	Capital elasticity	0.3260
β_1	Subjective discount factor parameter	0.1886
s_h	Share of labor income in value added	0.62
s_k	Share of capital income in value added	0.38
s_{tb}	Share of trade balance in value added	0.025
R^{US}	Steady state of world interest rate	1.01625
R	Steady state of interest rate	1.0275
TO	Steady state of trade openness	0.31
r	Marginal return to capital	0.0525
τ	Average tariff rate	0.14
ρ	Serial autocorrelation coefficient	0.84
σ_z	The standard deviation of productivity shocks	0.009
ϕ	The capital adjustment cost parameter	210
ψ	The debt adjustment cost parameter	240
η	The working-capital constraint parameter	0.03

Table 2: Equity Returns and Business Cycle Moments

Moments	Benchmark	Data
	Model	
Business Cycle		
$\sigma_{\hat{y}}^*$	4.51	4.30
$\sigma_{\hat{i}}^*$	5.28	5.56
$\frac{\sigma_{\hat{c}}}{\sigma_{\hat{y}}}$	1.35	1.06
σ_{tby}	3.27	1.37
$\sigma_{\hat{h}}$	3.08	–
$\rho(\hat{y}_t, \hat{y}_{t-1})^*$	0.88	0.81
$\rho(\hat{i}_t, \hat{i}_{t-1})$	0.91	0.85
$\rho(\hat{c}_t, \hat{c}_{t-1})$	0.85	0.81
$\rho(tby_t, tby_{t-1})$	0.79	0.96
$corr(\hat{i}, \hat{y})$	0.70	0.96
$corr(\hat{c}, \hat{y})$	0.83	0.98
$corr(tby, \hat{y})$	-0.11	-0.65
$corr(cr, \hat{y})$	-0.43	-0.74
Asset Pricing		
$\mathbb{E}r^P$	3.03	3.17
$\mathbb{E}cr$	1.086	1.125

Notes: σ denotes the standard deviation. ρ denotes the first-order autorrelation. $corr$ denotes the correlation coefficient. \hat{y} , \hat{i} , \hat{c} , and \hat{h} denote the percentage deviations of the business cycle components of output, investment, consumption, and labor efforts from the corresponding trends. tby denotes the trade-balance to GDP ratio. cr denotes country spreads. $\mathbb{E}(r^e)$, $\mathbb{E}r^P$, $\mathbb{E}cr$ denote the unconditional mean of equity returns, equity premium and country spreads, and they are in percentages. All the standard deviations are in percentages. * means the moment is the targeted moment in the calibration process. The columns labeled “Data” report the unconditional sample moments. We do not report the estimated value of $\sigma_{\hat{h}}$ from the data we used because, in general, the quality of the data on this indicator for emerging economies is rather poor; see, for example, Aguiar and Gopinath (2007).

Figure 1: Sensitivity Analysis: Optimal Tariff Rate



Notes: The x-axis represents ω , the y-axis represents γ , and the z-axis represents the optimal tariff rate, τ . Panel (a) presents the results associated with z-shocks, panel (b) presents the results associated with country spreads (cr) shocks, panel (c) presents the results associated with world interest rate (rus) shocks, and panel (d) presents the results associated with all three types of shocks. The values of other structural parameters are the same as those in Table 1.

B The Model

B.1 The representative household

The representative household chooses hours and consumption to maximize expected its lifetime utility

$$\max_{\{c_t, h_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \theta_t \frac{(c_t - h_t^\omega / \omega)^{1-\gamma} - 1}{(1-\gamma)}, \quad (\text{B.1})$$

where \mathbb{E}_0 denotes the mathematical expectation operator conditional on information available at time 0 and ω denotes the exponent of labor supply in utility. c_t , and h_t denote consumption and hours. The law of motion of the subjective discount factor from period t to period 0, θ_t , is given by $\theta_{t+1} = \beta(\tilde{c}_t, \tilde{h}_t)\theta_t, t \geq 0$. Here $\beta(c_t, h_t) = (1 + c_t - h_t^\omega / \omega)^{-\beta_1}$, where β_1 is the preference parameter. \tilde{c}_t and \tilde{h}_t denote the cross-sectional averages of consumption and hours, which are taken as given by individual households. The preference is called the stationary cardinal utility, which consists of the GHH period utility [Greenwood et al. (1988)] and the endogenous subjective discount factor. As long as $\beta_1 < \gamma$, this preference guarantees a unique limiting distribution of state variables and that the consumption good in every period is a normal good; and it is suitable for dynamic programming [Mendoza (1991)].

The representative household receives the profit, the capital rent, the labor income, and income from the intermediate input sale to firms. The household's period budget constraint is given by:

$$d_t + r_t k_t + w_t h_t + r_t^m m_t + \Gamma_t \geq R_t d_{t-1} + \Psi(d_t - d) + c_t + i_t + (1 + \tau)m_t + \Phi(k_{t+1} - k_t), \quad (\text{B.2})$$

where d_t , m_t , k_t , r_t , w_t , r_t^m , and i_t denote foreign debt position, imported inputs, capital, the rate of return on capital, the wage rate, the firm-paid price of imported inputs, and investment. τ denotes the tariff rate levied on the imported inputs. Γ_t denotes the government transfer. We do not include profit in the budget constraint because it is well known that the profit is zero with the assumed constant return to scale technology.

The interest rate faced by individual households, R_t , is the product of the world interest rate, R^{us} , and the exogenous country spread, CR . The law of motion of country interest rates is assumed to follow the estimated process in Neumeyer and Perri (2005):

$$\hat{R}_t^{us} = 0.81\hat{R}_{t-1}^{us} + \varepsilon_{t,R^{us}}, \quad (\text{B.3})$$

$$\hat{C}R_t = 0.78\hat{C}R_{t-1} + \varepsilon_{t,CR1}. \quad (\text{B.4})$$

Here the variables with hat denote the percentage deviations from their corresponding non-stochastic steady state values. The variance and covariance of innovations are given by $\sigma_{\varepsilon_{R^{us}}} = 0.63\%$ and $\sigma_{\varepsilon_{CR1}} = 2.29\%$. The law of motion of capital is given by

$$k_{t+1} = (1 - \delta)k_t + i_t. \quad (\text{B.5})$$

where δ denotes the depreciation rate. The representative household is subject to the non-Ponzi-game condition

$$\lim_{j \rightarrow \infty} \mathbb{E}_t \frac{d_{t+j+1}}{\prod_{s=0}^j R_{t+s}} \geq 0. \quad (\text{B.6})$$

The condition rules out the possibility that the representative household borrows to finance its consumption without limit.

The household's utility maximization problem is to choose c_t , h_t , d_t , m_t , i_t , and k_{t+1} to maximize Eq. (B.1) subject to the non-Ponzi game condition (B.6), period budget constraints holding with equality (B.2), and the law of motion of capital (B.5). Let λ_t and $\lambda_t \varphi_t$ be the Lagrange multipliers associated with (B.2) and (B.5), respectively. The first order conditions are:

$$0 = \lambda_t - \left(c_t - \frac{h_t^\omega}{\omega} \right)^{-\gamma}, \quad (\text{B.7})$$

$$0 = w_t - h_t^{\omega-1}, \quad (\text{B.8})$$

$$0 = r_t^m - (1 + \tau), \quad (\text{B.9})$$

$$0 = \lambda_t [1 - \psi(d_t - d)] - \left(1 + c_t - \frac{h_t^\omega}{\omega} \right)^{-\beta_1} R_t \mathbb{E}_t \lambda_{t+1}, \quad (\text{B.10})$$

$$0 = 1 - \varphi_t, \quad (\text{B.11})$$

$$0 = \lambda_t [1 + \phi(k_{t+1} - k_t)] - \left(1 + c_t - \frac{h_t^\omega}{\omega} \right)^{-\beta_1} \mathbb{E}_t \lambda_{t+1} [1 - \delta + \phi(k_{t+2} - k_{t+1}) + r_{t+1}], \quad (\text{B.12})$$

From the Euler equation with respect to k_{t+1} , Eq. (B.12), the equity return, r_{t+1}^e , and the equity premium, r_t^p , respectively, are defined as:

$$1 + r_{t+1}^e = \frac{1 - \delta + \phi(k_{t+2} - k_{t+1}) + r_{t+1}}{1 + \phi(k_{t+1} - k_t)}, \quad (\text{B.13})$$

$$r_t^p = \mathbb{E}_t r_{t+1}^e - r_t^f, \quad (\text{B.14})$$

where r_t^p denotes the equity premium conditional on the information available at time t .

B.2 The firms

There are many identical final-good production firms (100% owned by domestic households). Firms use constant return to scale technology to produce

$$y_t = z_t k_t^{\alpha_k} h_t^{\alpha_h} m_t^{\alpha_m}, \quad (\text{B.15})$$

where $0 < \alpha_k < 1$, $0 < \alpha_h < 1$, $0 < \alpha_m < 1$, and $\alpha_k + \alpha_h + \alpha_m = 1$. y_t and z_t denote the output of the final good and the total productivity factor, respectively.

In this economy, the total productivity factor is assumed to follow the process¹⁴

$$\ln(z_{t+1}) = \rho \ln(z_t) + \varepsilon_{t+1}^z, \varepsilon_{t+1}^z \sim \text{IIND}(0, \sigma_z^2), \quad (\text{B.16})$$

where $0 < \rho < 1$ denotes the first order serial autocorrelation of $\log(z)$, ε_{t+1}^z denotes the technology shocks, IIND denotes identical and independent normal distribution, and σ_z^2 denotes the variance of technology shocks.

Firms are subject to a working capital constraint. For simplicity, we adapt the same constraint as that in Uribe and Yue (2006): $WK_t \geq \varphi w_t h_t$, where WK_t denotes the amount of working capital and $\varphi \geq 0$ denotes the number of quarter wage bills that the representative firm needs to pay.

The representative firm's debt position evolves as

$$d_t^f = R_{t-1}^* d_{t-1}^f - y_t + w_t h_t + r_t k_t + r_t^m m_t + \pi_t - WK_{t-1} + WK_t,$$

where d_t^f denotes the debt position of the firms, $R_{t-1}^* = R_t / [1 - \phi(d_t - d)]$, and π_t denotes the profit. Defining the net liability of the representative firm as $a_t = R_t^* d_t^f - WK_t$, we can rewrite the budget constraint of the representative firm as

$$\frac{a_t}{R_t^*} = a_{t-1} - y_t + w_t h_t + r_t k_t + r_t^m m_t + \pi_t + \left(\frac{R_t^* - 1}{R_t^*} \right) WK_t. \quad (\text{B.17})$$

The representative firm is also subject to the following non Ponzi-game constraint

$$\lim_{j \rightarrow \infty} \mathbb{E}_t \frac{a_{t+j}}{\pi_{s=0}^j R_{t+s}^*} \leq 0. \quad (\text{B.18})$$

Since the representative firm is solely owned by the representative household, it chooses k_t , h_t , and m_t to maximize the following objective function by taking z_t , r_t , w_t , and r_t^m as given

$$\max_{\{k_t, h_t, m_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \theta_t \frac{\mu_t}{\mu_0} \pi_t,$$

where μ_t denotes the marginal wealth utility of the representative household. Any process a_t that satisfies Eqs. (B.17) and (B.18) will be optimal for the representative firm. Under the assumption that the firm starts without liabilities, the optimal plan is $a_t = 0$. For this reason, we set a_t at 0 [Uribe and Yue (2006)].

The first-order conditions with respect to k_t , h_t , and m_t for the firms are given by:

$$r_t = \alpha_k z_t h_t^{\alpha_h} k_t^{\alpha_k - 1}, \quad (\text{B.19})$$

$$w_t \left[1 + \eta \left(\frac{R_t^* - 1}{R_t^*} \right) \right] = \alpha_h z_t k_t^{\alpha_k} h_t^{\alpha_h - 1} m_t^{\alpha_m}. \quad (\text{B.20})$$

$$r_t^m = \alpha_m z_t h_t^{\alpha_h} k_t^{\alpha_k} m_t^{\alpha_m - 1}, \quad (\text{B.21})$$

¹⁴The structural parameters, ρ and σ_z , are calibrated in the Section 3.3.

where $R_{t-1}^* = R_{t-1}/[1 - \psi(d_t - d)]$ is the effective interest rate. Profits are equal to zero since we have assumed constant returns to scale technology.

B.3 The government

The government's sequential budget constraint is then given by

$$\tau m_t = \Gamma_t, \quad t \geq 0, . \quad (\text{B.22})$$

We do not consider the government expenditure shocks in order to simplify the discussion.

B.4 Competitive equilibrium

In equilibrium, the capital market, the labor market, and the intermediate input market all clear. The aggregates equal to the counterparts of the representative household's because households are assumed to be identical:

$$\tilde{c}_t = c_t; \quad (\text{B.23})$$

$$\tilde{h}_t = h_t. \quad (\text{B.24})$$

The competitive equilibrium is defined as a sequence of real allocations $\{c_t, h_t, d_t, m_t, i_t, k_{t+1}, \tilde{c}_t, \tilde{h}_t, y_t, \Gamma_t\}_{t=0}^{\infty}$, and prices $\{\mu_t, q_t, r_{t+1}^e, r_{t+1}^p, r_t, w_t, r_t^m\}_{t=0}^{\infty}$, given $\{r_{-1}^f, d_{-1}, k_0, z_0, R_0^{us}, CR_0\}$, the law of motion of the interest rates (B.3)-(B.4), and the law of motion of the total productivity factor (B.16), satisfying equation (B.2) with equality, equations (B.5)-(B.15) and (B.19)-(B.24), such that households maximize utility, firms maximize profit, the government balances its budget, and all markets are cleared.

C Data and Calibration

For the benchmark economy, we select the Argentina economy as a representative because it is well known that Argentina has suffered a lot from sudden stops. We use the International Financial Statistics of International Monetary Fund to obtain data about GDP, investment (fixed capital formation), total consumption, exports of goods and services, and imports of goods and services.¹⁵ All data are deseasonalized using the X-12 ARIMA procedure provided by the Bureau of Census and deflated by the GDP deflator. We apply the HP filter to obtain the cyclical components of each time series and consequently obtain the standard deviations of output, investment, trade openness and consumption, and the first order serial autocorrelation of output. They are listed in Table 1. With the same data source, we set the non-stochastic steady state trade openness, TO , at 0.31, which is the average of trade openness of Argentina from the first quarter of 1993 to the first quarter of 2009. The non-stochastic steady state trade balance to GDP ratio, s_{tb} , is set at 0.01. We obtain the data on tariff rates that governments actually charge on imports and the value of imports for

¹⁵Here total consumption is defined in the same way as in Neumeyer and Perri (2005): the sum of private consumption, government spending, change in the inventories, and statistical errors and discrepancy.

products from the World Trade Organization. The average of value-weighted ad valorem tariff rates of Argentina for years 1999–2001 is 0.14. Thus, we set the non-stochastic steady state tariff rate at 0.14.

We also rely on the literature to determine the values of some parameters. For example, the non-stochastic steady state interest rate, R , is set at 1.0275 [Uribe and Yue (2006)]. It is consistent with the average 11% annual real interest rate faced by a small open economy in the international capital market. The non-stochastic steady state world interest rate R^{us} is set at 1.01625 [Mendoza and Uribe (2000)]. The non-stochastic steady state of net foreign debt is given by $d = TB/(R - 1)$, where TB denotes the non-stochastic steady state trade balance.

The risk aversion coefficient, γ , and the capital depreciation rate, δ , are set at 5 and 0.025.¹⁶ Both values are commonly used in the literature. The exponent of labor supply in utility, ω , is set at 1.5, a value close to that in Mendoza (1991).¹⁷ The share of labor income in the value added, s_h , and the share of capital income in the value added, s_k , are set at 0.62 and 0.38, respectively, [Neumeyer and Perri (2005)].

The parameter α_m is chosen to make sure that in the non-stochastic steady state, trade openness is 31%. The parameters, α_k and α_h , are determined by two conditions: first, in the value added, capital income share is $s_k = 0.38$ and labor income share is $s_h = 0.62$; second, the production is homogeneous of degree one, so $\alpha_k + \alpha_h = 1 - \alpha_m$. The non-stochastic steady state rate of return on capital, r , is calculated from the non-stochastic steady state optimal condition $r = R - 1 + \delta$. The share of investment in value added, s_i , is calculated by the following equation $s_i = \frac{i}{y-m} = \frac{\delta r k}{r(y-m)} = \frac{\delta s_k}{r}$. The share of consumption is derived by using the accounting identity in the non-stochastic steady state, $s_c = 1 - s_i - s_{tb}$. From the calibration so far, the determination of the non-stochastic steady state of c and h is independent of β_1 . Thus, the parameter β_1 can be calibrated by the following non-stochastic steady state optimal condition

$$1 = (1 + c - h^\omega/\omega)^{-\beta_1} R.$$

The implied value for β_1 is 0.1886, which is less than $\gamma = 2$. This guarantees that the GHH utility function is suitable for dynamic programming.

Given the above parameters, we search for the values of five structural parameters, ρ , σ_z , ϕ , ψ , and η , in the benchmark model. We do so by trying to match, through a grid search procedure, the standard deviations of the business cycle components of output, investment, consumption, and the trade-balance to GDP ratio, as well as the first-order autocorrelation of the business cycle components of output and the mean equity return. Following the same calibration method used in Jermann (1998), we search over hundreds of thousands of grid points, each defined by the quintuple formed by the particular values of these five parameters. Table 1 reports the values of these five structural.

Once the above structural parameters are calibrated, their values will be kept constant,

¹⁶Here is how we choose the value of γ . For each country, we start with $\gamma = 2$ and solve the model to see whether we can explain business cycle moments and asset prices. If not, we increase its value to 5; if yes, we stop; etc.

¹⁷As argued in Neumeyer and Perri (2005), there is no independent estimate of ω . They set it at 1.6.

except that the non-stochastic steady state TO will be changed to accommodate the change of those key structural parameters in the sensitivity analysis.