Twin Ds and Credit to the Private Sector*

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Abstract

Empirical evidence suggests that sovereign defaults and devaluation crises occur simultaneously (Twin Ds) and are often associated with a sharp decline of private sector access to foreign currency debt. This paper studies the joint dynamics of private and sovereign default risk in different exchange rate regimes and their macroeconomic implications in a small open economy model. The framework features endogenous sovereign and private default risk as well as downward rigid nominal wages. The wage rigidity causes unemployment in equilibrium and generates a role for an active exchange rate policy. The model replicates important features of historical Twin D crises in emerging market economies, such as rising sovereign and private spreads, deep recessions with below trend output and imports, as well as nominal and real devaluations. Although private default risk makes nominal devaluations costly the flexible exchange rate regime is optimal in this framework.

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1 Introduction

Sovereign defaults are often accompanied by strong devaluations of the nominal exchange rate. Reinhart (2002) calls these events Twin Ds. Joint debt and devaluation crises are typically associated with deep recessions, manifesting especially in the nontradable good sector and high unemployment rates. Tornell and Westermann (2002) show that this asymmetric pattern across sectors is a typical feature of financial crises in emerging market economies. Arteta and Hale (2009) report a strong fall in foreign credit to the private sector after Twin Ds.

What is the explanation for the observed relationship between currency crises, sovereign default events and private sector access to foreign credit? How does the interaction between exchange rate policies, private default risk and sovereign default risk influence macroeconomic outcomes? What are the welfare implications of fixed and flexible exchange rate regimes when the interactions between default risks and exchange rate policies are taken into account? The existing theoretical literature has addressed joint default and devaluation decisions (e.g. Na et al. 2018; Moussa 2013), the link between private and sovereign default risk (e.g. Kaas et al. 2016; Andreasen 2015; Sandleris 2014) and the link between private sector foreign debt, currency crises and economic activity (e.g. Fornaro 2015; Schneider and Tornell 2004; Céspedes et al. 2004) separately, but never jointly. This paper aims to close this gap and investigates the dynamic relationship between private and sovereign default risk in different exchange rate regimes and its welfare implications.

The paper develops a two sector, stochastic general equilibrium model of a small open economy with nominal downward rigid wages and incomplete debt markets for sovereign and private credit. With nominal downward rigid wages, the labor market does not clear in general, generating a role for nominal exchange rate policy. Private firms hold foreign currency debt which is subject to default risk. The government has the option to default on its debt obligations and follows an exogenously given rule for the nominal exchange rate.

The modeling approach follows the quantitative literature on sovereign debt with endogenous default risk (e.g. Aguiar and Gopinath 2006; Arellano 2008) where the government borrows from international investors but cannot commit to repay its debt obligations (Eaton and Gersovitz 1981). As in Na et al. (2018) the economy consists of a tradable and a non-tradable good sector. Production takes place only in the non-tradable good sector and tradable output is exogenous. The economy inhabits domestic households, domestic firms producing intermediate inputs and a non-tradable consumption good, a benevolent domestic government and risk neutral international investors. Households value consumption of a tradable and a non-tradable consumption good and inelastically supply one unit of labor to the domestic intermediate good firms. With the supplied labor, intermediate good firms produce the domestic intermediate input good and sell it to the firms in the non-tradable good sector. Nominal wages are downward rigid (Schmitt-Grohé and Uribe 2016). Although the labor market is perfectly competitive, it may fail to clear because wage changes are bounded below. The market for private debt is specified as in Kaas et al. (2016)[1]. A continuum of firms in the non-tradable good sector uses imperfectly substitutable domestic and imported inputs in production. A share of the intermediate imports needs to be financed by foreign currency working capital loans. Firms face idiosyncratic productivity shocks and repay the working capital loan only if they generate enough revenues.

In a quantitative exercise I calibrate the model such that it mimics the Argentine economy in several dimensions. The model matches the relative size of the tradable good sector in GDP, the relative importance of intermediate imports in the production of the non-tradable good, as well as the average spread on sovereign debt. Furthermore, the model generates countercyclical private and sovereign spreads. Simulated default events are in line with the Argentine default in 2002:Q1. In particular, a typical default event in the model with fixed exchange rates is accompanied by a sharp decline in output, intermediate imports and credit to the private sector, a strong increase in unemployment (with fixed exchange rate regime), as well as a steep nominal devaluation (with flexible exchange rate) and a real exchange rate depreciation.

As in Céspedes et al. (2004) the real exchange rate plays a central role in explaining the dynamic pattern of the private spread. In this framework the real exchange rate is the inverse of the real price of the non-tradable consumption good. The equilibrium real price of the non-tradable consumption good depends on the realization of the endowment shock and government transfers. With countercyclical sovereign default risk, a low realization of the endowment shock leads to a fall in the sovereign bond price and reduces government transfers to the households. Both, the fall of government transfers and low tradable good endowment decreases the equilibrium price of the non-tradable consumption good, a real devaluation. The real devaluation reduces the profitability of non-tradable good firms and more firms default. This generates countercyclical private spreads.

The countercyclicality of sovereign default risk has also direct implications for unemployment and the nominal exchange rate. A joint fall of endowment and government transfers generates downward pressure on the real wage to clear the labor market. Due to the downward nominal wage rigidity, the real wage cannot fall when the nominal exchange rate remains fixed and involuntary unemployment emerges. With flexible exchange rates the full employment allocation can be restored by deflating the real wage such that the labor market

[1]Arellano et al. (2017) and de Ferra (2016) use a similar framework to study the interaction between sovereign and private default risks.

clears again. But this devaluation comes at a cost. A nominal devaluation induces a further real devaluation and generates higher private default risk.

For low debt levels, the private interest rate is lower in the flexible exchange rate regime than in the fixed exchange rate regime but increases faster when debt rises. There are two effects influencing the different dynamics of interest rates in the two exchange rate regimes. First, due to weaker sovereign default incentives in the flexible exchange rate regime, the government can borrow more and provides higher transfers to the households. This increases the demand for the non-tradable consumption good, as well as its price. A high price of the non-tradable consumption good reduces private default risk and therefore lowers the private risk premium. The second effect works in the opposite direction and relates to the nominal exchange rate. Since a nominal devaluation decreases the price of the non-tradable consumption good, it increases the private risk premium. At high debt levels, the devaluation effect dominates and the private risk premium is higher in the flexible than in the fixed exchange rate regime.

Although nominal devaluations are costly as they increase private default risk, my welfare analysis shows that the flexible exchange rate regime is optimal. The benefit to clear the labor market dominates the cost of higher private default risk such that households are willing to give up 2.24% of life-time consumption to move from a fixed to a flexible exchange rate regime.

This paper build on two strands of the quantitative sovereign default literature. First, it is related to the literature exploring the interaction of sovereign default risk and private sector access to foreign credit. The modeling of private default risk draws heavily on the work of Kaas et al. (2016), who analyze how sovereign and private default risk interact. In their framework a continuum of final good firms produces final output using domestic and intermediate imports. A share of intermediate imports is financed by foreign credit. Firms face aggregate and idiosyncratic productivity shocks and repay only if they can generate enough revenues. In contrast to my model, they assume that the government levies a linear sales tax to finance a public good. With countercyclical default risk this generates procyclical tax rates. Since taxes influence the profitability of final good firms, private default risk becomes countercyclical as well. In my model the link between sovereign and private default risk is generated by the real exchange rate, which is influenced by government transfers.

Other papers relate to the banking channel to generate spill over effects from sovereign default risk to private credit markets. Sosa-Padilla (2018), Engler and Große-Steffen (2016) and Niemann and Pichler (2016) develop quantitative stochastic general equilibrium models to study how endogenous sovereign default risk affects private sector credit when banks hold sovereign debt on their balance sheet. Sandleris (2014) and Andreasen (2015) argue that the government's repayment decision transfers information on the underlying state of the economy to international investors and thereby influences private sector credit conditions. Arellano and Kocherlakota (2014) go the other way around and argue that due to weak bankruptcy institutions a private debt crisis can weaken government's tax revenues such that sovereign default risk increases.

Second, this paper builds on the sovereign default literature on optimal default and devaluation. Moussa (2013) and Na et al. (2018) integrate endogenous sovereign default risk á la Eaton and Gersovitz (1981) into a model of a small open economy with a tradable and a non-tradable good sector, where, as in Schmitt-Grohé and Uribe (2016), nominal wages are downward rigid. Na et al. (2018) show that a flexible exchange rate regime is optimal in this framework, because it eliminates unemployment. Moussa (2013) studies how debt denomination influences the optimality of flexible exchange rates depending on the state of the economy. She finds that it is optimal to remain in the fixed exchange rate regime, even when the country is close to default. None of the two papers considers foreign currency working capital loans.[2]

This paper also relates to the theoretical currency crisis literature that explores the role of private foreign currency debt. Important contributions are the papers by Schneider and Tornell (2004) and Céspedes et al. (2004). Schneider and Tornell (2004) show that bailout guarantees and enforceability problems in the non-tradable good sector can endogenously generate a currency mismatch on the balance sheet of non-tradable good firms. The currency mismatch induces borrowing constraints on non-tradable good firms and allows the model to replicate credit driven boom-bust cycles. Céspedes et al. (2004) explore the role of foreign currency debt on the optimal choice of the exchange rate regime. They find that even with foreign currency debt the flexible exchange rate is optimal. More recent contributions to this literature are Fornaro (2015) and Ottonello (2004). They explore the optimality of different exchange rate regimes under financial frictions. None of the papers considers the role of sovereign default.

The remainder of the paper is structured as follows. The next section reviews the stylized facts on financial crises in emerging market economies and provides an empirical example of a recent Twin D event. The case of Argentina in 2002. Section 3 describes the theoretical environment. Section 4 discusses the main mechanism. In section 5 I calibrate the model to Argentina in order to explore

[2]Further contributions to the quantitative sovereign default literature highlight other important dimensions of sovereign default risk. For instance, the role of fiscal policy (e.g., Cuadra et al. (2010)), political uncertainty (e.g., Scholl (2017) and Cuadra and Sapriza (2008)), the maturity structure of sovereign debt (e.g., Hatchondo and Martinez (2009), Arellano and Ramanarayanan (2012) and Chatterjee and Eyigungor (2012)), the role of domestic debt (e.g., Fink (2014), Du and Schreger (2016) and Röttger (2016)), debt renegotiations (e.g., Yue (2010)), endogenous default cost (e.g., Mendoza and Yue (2012)), bailouts (e.g., Roch and Uhlig (2016), Pancrazi et al. (2015) and Fink and Scholl (2016)) and the role of trade (e.g., Asonuma (2016), Popov and Wiczer (2014) and Gu (2015)).

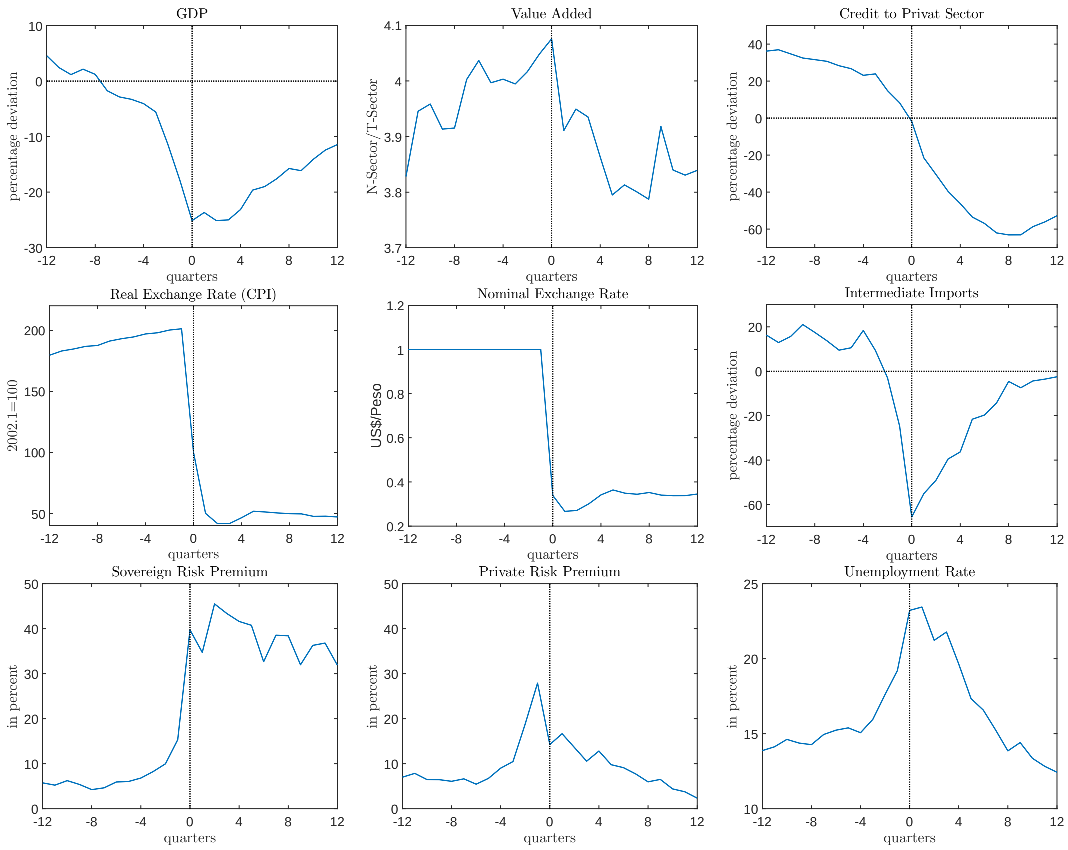

Figure 1: Argentine Default 2002.1.

Notes: The figure shows the evolution of GDP, the relative size of tradable to non-tradable value added, credit to the private sector, the real exchange rate against the United States based on the CPI, the nominal exchange rate against the US$, intermediate imports, the annualized sovereign and private spread and unemployment, 12 quarters before and after the Argentine default in 2002:Q1. GDP, intermediate imports and credit to the private sector are log-linear detrended. The unemployment rate and the risk premia are in percentage terms and the real exchange rate is an index normalized to 100 in 2002:Q1. The sovereign spread is the EMBI Global spread and the private spread is compute as the difference between interest rates on short term, foreign currency loans in Argentina and a 3 month US T-bill. Credit to the private sector is measured by claims on the private sector by deposit money banks. Section A presents the data source for the individual time series.

the quantitative properties of the mechanism and study the welfare implication of fixed and flexible exchange rate regimes. Section 6 concludes.

2 Twin D - The Case of Argentina

Reinhart (2002) shows that there is a close link between large devaluations and sovereign default events. She estimates that the probability of experiencing a large nominal devaluation increases from 17% to 84% when conditioning on sovereign default events.[3] Tornell and Westermann (2002) show that recent currency crises in emerging market economies follow a specific boom-bust pattern. Typically, crises are preceded by a real exchange rate appreciation, a

[3] Asonuma (2016) describes a close relationship between real exchange rate depreciation and sovereing default in a sample of 18 emerging market economies in 1998-2013. Bauer et al. (2003) show the empirical importance of joint sovereign debt and currency crises.

lending boom, and higher growth rates in the non-tradable good sector compared to the tradable good sector. When the crisis hits, the real exchange rate depreciates, credit to the private sector falls sharply and the tradable good sector experiences a milder and shorter recession than the non-tradable good sector.[4] Furthermore, Tornell and Westermann (2002) find that the premium on private sector credit increases over the crisis episode. Arteta and Hale (2009) show that a significant share of the drop in private foreign currency borrowing after a currency crisis comes from a reduction in credit supply. They also report that the drop in credit supply is partially attributed to sovereign default events.

The 2001/2002 financial crisis in Argentina fits the stylized facts from Reinhart (2002) and Tornell and Westermann (2002), although it is not included in their sample. In December 2001 the Argentine government announced that it is going to default on its external debt. The default was one of the largest in history, involving more than $100 billion of privately held debt. In early 2002 Argentina also abandoned the fixed exchange rate leading to a nominal depreciation of over 300%.[5] The crisis was accompanied by a sharp drop in external credit to the private sector (Arteta and Hale 2009) and a rise in the cost of borrowing for private sector firms (Kaas et al. 2016).

Figure 1 provides evidence that the Argentine crisis fits the stylized facts. I consider real GDP, the relative size of tradable to non-tradable value added, credit to the private sector, the real exchange rate against the United States (based on the CPI), the nominal exchange rate against the US-$, intermediate imports, the sovereign spread, the private spread and the unemployment rate. Figure 1 plots the evolution of these variables 12 quarters before and after the default. The default quarter is in $t = 0$. GDP, intermediate imports and credit to the private sector are log-linear detrended. The unemployment rate and the risk premia are in percentage terms and the real exchange rate is an index normalized to 100 in 2002:Q1.

In line with the evidence of Tornell and Westermann (2002) Argentina experienced a deep recession, that was accompanied by a strong real devaluation and a severe fall in credit to the private sector. Prior to the default event, the real exchange rate appreciated and the non-tradable good sector (N-sector) was growing faster than the tradable good sector (T-sector). This is reflected in an increase of the relative size of the non-tradable good sector. The boom in the non-tradable good sector is also accompanied by above trend credit to the private sector. This pattern is reversed after the default. The ratio of non-

[4]Other papers identifying individual features of boom-bust cycles for specific countries or particular episodes are, among others, Rebelo and Vegh (1995), Sachs et al. (1996), Mendoza and Uribe (2000), Gourinchas et al. (2001), Hutchison and Noy (2006), Kehoe and Ruhl (2009) and Pratap and Urrutia (2012).

[5]See Sturzenegger and Zettelmeyer (2006) for an excellent summary of the events surrounding the Argentine default in 2002.

tradable to tradable value added falls, the real exchange rate depreciates and credit to the private sector falls below its trend, fitting important dimensions of the boom-bust cycles identified by Tornell and Westermann (2002).

Besides defaulting on its foreign debt, Argentina also abandoned the fixed exchange rate regime against the US$, leading to a strong devaluation of the Argentine Peso. This confirms the close link between default events and exchange rate devaluations identified by Reinhart (2002). The recession was also accompanied by a sharp fall in intermediate imports.[6] This is in line with Gopinath and Neiman (2014), who show that Argentine firms substituted intermediate imports by domestic inputs over the course of the default crisis.

During the default quarter private and sovereign credit cost increase significantly, whereas the increase of private credit cost is less persistent and more modest. Ağca and Celasun (2012) show that an increase in private borrowing cost is a common feature of sovereign default events. Furthermore, unemployment grows over the default crisis. The unemployment rate peaks around the default quarter approximately 10% points above its pre crisis average.[7]

3 Environment

In this section I describe a two sector dynamic stochastic general equilibrium model of a small open economy that features imperfect enforcement of external debt as in Eaton and Gersovitz (1981), downward nominal wage rigidity as in Schmitt-Grohé and Uribe (2016) and private sector default risk as in Kaas et al. (2016).

The economy inhabits a large number of identical households, domestic intermediate good firms, a continuum of final good firms, producing a non-tradable consumption good, a benevolent government and international investors lending to the government and private firms. There are 4 different goods: a tradable and a non-tradable consumption good, a domestic intermediate input good and an imported intermediate input good.

I focus on the interaction between private sector default risk, originating in foreign currency debt on firms' balance sheets, sovereign default risk and exchange rate policies and take production in the tradable good sector as exogenously given. I follow Schneider and Tornell (2004) who argue that firms in the tradable good sector are not credit constraint because they generate foreign currency revenues that can be used as collateral. Therefore tradable good firms are only of secondary importance for private sector default risk in my framework.[8]

[6] Data on intermediate imports are taken from MECON and relate to products that are typically used in further production steps.

[7] The average unemployment rate in Argentina between 1993:Q1 and 2000:Q4 is approximately 13%.

[8] Arteta and Hale (2008) show that during sovereign defaults the fall of private credit to

In every period domestic households receive a random endowment of the tradable consumption good, as well as lump-sum transfers of the tradable consumption good from the government. They consume both, the tradable and the non-tradable good. They own all domestic firms and inelastically supply one unit of labor to the intermediate good firms. The intermediate good firms use only labor in production and sell their output to final good firms that produce the domestic non-tradable consumption good. Final good firms use the domestic intermediate good and intermediate imports to produce their output. Domestic and imported intermediate inputs are imperfect substitutes. A fraction of the imported inputs is financed by foreign currency debt. After making the import and borrowing decision final goods firms are hit by idiosyncratic productivity shocks. Firms with low realizations can default on their debt if their continuation value becomes negative.

The government borrows in terms of the tradable consumption good from international financial markets and provides lump-sum transfers to the households when net-borrowing is positive. Otherwise, the government collects lump-sum taxes from the households. The government cannot commit to repay its debt obligations. As in Arellano (2008) and Aguiar and Gopinath (2006) a defaulting government is excluded from international financial markets for a stochastic number of periods. Furthermore, a country suffers an exogenous output loss in terms of the tradable good as long as it is in financial autarky.

The timing in the model is as follows. A period starts with the realization of the endowment shock. The government decides if it repays outstanding debt obligations or defaults. The nominal exchange rate is determined, following an exogenous exchange rate rule. In case of repayment the government borrows and provides transfers to/collects taxes from the households. Non-tradable good firms buy intermediate imports and borrow abroad. Domestic intermediate good producer hire labor and produce. Then the idiosyncratic productivity shock is realized. Final good firms with positive continuation values repay, buy the domestic intermediate input good and produce the domestic non-tradable consumption good. Defaulting firms exit the market and are replaced by new entrants in the next period.

3.1 Households

The economy is populated by a large number of identical households with preferences

$$\mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t\right), \tag{1}$$

the private sector concentrates on non-exporting firms. This reinsures me that treating the tradable good sector exogenous is an acceptable assumption.

where c_t denotes consumption and $\beta \in (0,1)$ is the subjective discount factor. The per period utility function $U(\cdot)$ is assumed to be increasing and concave in c_t. Final consumption is a composite of tradable consumption, c_t^T, and non-tradable consumption, c_t^N. The aggregator function

$$c_t = A\left(c_t^T, c_t^N\right) \tag{2}$$

is an increasing, concave and linearly homogeneous function. In this environment households are hand-to-mouth and consume all their income in every period. Their sequential budget constraint is given by

$$P_t^T c_t^T + P_t^N c_t^N = W_t h_t + \Pi_t^M + \Pi_t^N + P_t^T T_t + P_t^T y_t^T \,, \tag{3}$$

where P_t^T is the domestic currency price of the tradable consumption good, P_t^N denotes the local currency price of the non-tradable consumption good, W_t is the nominal wage, Π_t^M and Π_t^N are nominal profits from owning the intermediate and non-tradable good firms, respectively, T_t are lump-sum government transfers, y_t^T is an exogenous endowment of the tradable consumption good and h_t are hours worked. I define tradable income, I_t, as the sum of tradable endowment, y_t^T and government transfers, T_t.

As in Schmitt-Grohé and Uribe (2016) households inelastically supply $\bar{h}$ hours to the intermediate good firms. Because nominal wages are downward sticky, households may be unable to sell all of $\bar{h}$. Households take the amount of labor they can sell, $h_t \leq \bar{h}$ as given.

In line with Schmitt-Grohé and Uribe (2016), I assume that the law of one price holds for tradable goods, implying

$$P_t^T = \mathcal{E}_t P_t^{T\star} \,,$$

where P_t^T is the local currency price of the tradable consumption good, $P_t^{T\star}$ denotes the foreign currency price of the tradable consumption good and $\mathcal{E}_t$ is the nominal exchange rate. Furthermore, the foreign currency price of the tradable consumption good is normalized to unity $P_t^{T\star} = 1$. Consequently, the nominal price of the tradable consumption good equals the nominal exchange rate, $P_t^T = \mathcal{E}_t$, making the tradable consumption good the numeraire good in this framework.

Since households are not allowed to save they only choose to allocate their total income[9] across tradable and non-tradable consumption. They choose $\left\{c_t^T, c_t^N\right\}$ to maximize equation (2) subject to (3), taking as given P_t^T, P_t^N W_t,

[9]Total income relates to the income generated in the non-tradable good sector and the tradable income, which is exogenously supplied to the private sector.

h_t, Π_t^M, Π_t^N and I_t. With

$$p_t \equiv \frac{P_t^N}{\mathcal{E}_t}$$

the corresponding optimality condition is given by

$$\frac{A_2\left(c_t^T, c_t^N\right)}{A_1\left(c_t^T, c_t^N\right)} = p_t, \tag{4}$$

where A_1 (A_2) is the derivative of the consumption aggregator with respect to its first (second) argument. The price p_t is the relative price of the non-tradable consumption good in terms of the tradable consumption good. In this framework, p_t is also the inverse of the real exchange rate.[10] Equation (4) defines the demand for non-tradable consumption as a function of the relative price of the non-tradable consumption good, p_t, and the level of tradable absorbtion, c_t^T. Conditional on c_t^T, the demand for non-tradable consumption goods is strictly decreasing in p_t. Furthermore, an increase in c_t^T leads to higher non-tradable good consumption c_t^N.[11]

3.2 Wage Rigidity

As in Schmitt-Grohé and Uribe (2016), the present framework features downward rigid nominal wages. In particular, I assume

$$W_t \geq \psi W_{t-1},$$

where $\psi > 0$ captures the intensity of the downward nominal wage rigidity. With downward rigid nominal wages the labor market does not clear in general,

$$h_t \leq \bar{h}. \tag{5}$$

Therefore, the economy features involuntary unemployment $ue_t = \bar{h} - h_t$. The wage stickiness condition can be rewritten in real terms

$$w_t \geq \frac{\psi w_{t-1}}{\epsilon_t}, \tag{6}$$

where $\epsilon_t = \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}$ denotes the gross depreciation rate of the nominal exchange rate and $w_t \equiv \frac{W_t}{\mathcal{E}_t}$ is the real wage in terms of the tradable consumption good.

[10] The real exchange rate is defined as $RER_t = \mathcal{E}_t \frac{P_t^\star}{P_t}$, where $\mathcal{E}_t$ is the nominal exchange rate, $P_t^\star$ denotes the foreign country CPI and P_t denotes the domestic CPI. With the law of on price holding for tradable goods and assuming that the foreign CPI is time invariant and normalized to one it follows $RER_t = \frac{\mathcal{E}_t}{P_t^N}$, which is the inverse of the relative price of the non-tradable consumption good.

[11] These properties are direct consequences of the assumed properties of the aggregator function A.

3.3 Intermediate Good Firms

Similar to Mendoza and Yue (2012) intermediate goods, m_t, are produced by perfectly competitive firms with technology $m_t = f^M(h_t)$. The production function f^M is assumed to be strictly increasing and concave in hours worked. Intermediate good firms maximize profits taking the real wage, w_t, and the real price of the domestic intermediate input good, $p_t^M \equiv \frac{P_t^M}{P_t^T}$, as given. Their profit maximization problem is given by

$$\max_{h_t} \pi_t^M = p_t^M A^M f^M(h_t) - w_t h_t\,.$$

The labor demand of intermediate good firms satisfies

$$p_t^M A^M \frac{\partial f^M}{\partial h_t}(h_t) = w_t. \tag{7}$$

3.4 Non-tradable Good Firms

Following Kaas et al. (2016), the non-tradable consumption good, y_t^N, is produced by a continuum of firms employing domestic and imported intermediate inputs, m_t and $m_t^\star$. A share of the cost to buy intermediate imports needs to be financed by foreign credit. Firms take up their working capital loan at the beginning of the period and repay at the end of the period.[12] Each firm operates a production function $x_{i,t} f^N(m_t, m_t^\star)$, where $x_{i,t}$ denotes idiosyncratic productivity. The production function f^N exhibits constant returns to scale and is concave in both arguments. Firms borrow and buy intermediate imports before the idiosyncratic productivity shock is realized. The idiosyncratic shock is drawn i.i.d. from a cumulative distribution function $X(\cdot)$.

Imported intermediate imports are bought at the local currency world market price P_t^{FM}. As in Kaas et al. (2016) and Mendoza and Yue (2012) I assume that the share ξ of the cost for intermediate imports needs to be financed by foreign currency working capital credit. The remaining part of the bill is paid from domestic funds.[13] The credit market for working capital loans is incomplete, such that its interest rate R_t reflects the firms' default risk. A firm that imports $m_t^\star$ has real external debt $\xi R_t p_t^{M\star} m_t^\star$ on its balance sheet, where $p_t^{M\star} \equiv \frac{P_t^{FM}}{P_t^T}$ is the relative price of foreign intermediate inputs. I also assume that the law of one price holds for the foreign intermediate input good, such that $p_t^{M\star} = \frac{\mathcal{E}_t P_t^{M\star}}{\mathcal{E}_t P_t^{T\star}}$ is the relative price of the foreign intermediate input good relative to the tradable consumption good. It is determined on the world

[12]The assumption that working capital loans are intra-period ensures that the private sector equilibrium is static. This simplifies the solution of the private sector equilibrium considerably, since firms do not need to forecast government policies to solve their optimization problem.

[13]Following Kaas et al. (2016) I abstract from the distinction of domestic equity or debt financing to keep the model simple.

market.

After the realization of the idiosyncratic productivity shock $x_{i,t}$ a non-tradable good firm has two options, it can either repay and continue or default and go out of business. A firm decides to default whenever its continuation value is negative: $p_t x_{i,t} f^N(m_{i,t}, m_t^\star) - p_t^M m_t - \xi R_t p_t^{M\star} m_t^\star < 0$. A continuing firm buys domestic inputs according to

$$m_{i,t} = m_t^\star \Phi\left(x_{i,t} p_t, p_t^M\right), \tag{8}$$

where Φ is increasing in its first and decreasing in its second argument. Due to constant returns to scale in the production function, real profits before interest $\tilde{\pi}^N\left(x_{i,t} p_t, p_t^M\right) m_t^\star$ are linear in intermediate imports, too. The function $\tilde{\pi}^N$ is increasing in the first and decreasing in the second argument. Firms default whenever idiosyncratic productivity is below the default threshold, $x_{i,t} < \bar{x}_t$. The default threshold is defined by

$$\tilde{\pi}^N\left(\bar{x}_t p_t, p_t^M\right) = \xi R_t p_t^{M\star}. \tag{9}$$

The default threshold is decreasing in p_t and increasing in p_t^M, R_t and $p_t^{M\star}$.

Before firms know the realization of their idiosyncratic productivity shock they choose intermediate imports, $m_t^\star$ to maximize expected profits

$$\int_{\bar{x}_t}^{\infty} \left[\tilde{\pi}^N\left(x_{i,t} p_t, p_t^M\right) - \xi R_t p_t^{M\star}\right] m_t^\star dX(x) - p_t^{M\star}(1-\xi) m_t^\star.$$

Since profits before interest $\tilde{\pi}^N$ and domestic intermediate inputs per intermediate imports Φ are linear in $m_t^\star$, the first order condition implies zero-expected profits

$$(1-\xi) p_t^{M\star} = \int_{\bar{x}_t}^{\infty} \left[\pi^N\left(x_{i,t} p_t, p_t^M\right) - \xi R_t p_t^{M\star}\right] dX(x) \tag{10}$$

3.5 International Investors

International investors are risk neutral, have complete information and have access to an internationally traded risk free bond with constant gross interest rate $\bar{R}$. They lend to the domestic government and to domestic non-tradable good firms as long as they make zero profits in expectations. I follow Kaas et al. (2016) and assume that in case of a private default, international investors recover the share η of their investment, whereas in case of a sovereign default the whole investment is lost. The parameter η captures institutional features of the country, such as the legal system. The international investors' arbitrage condition for the intra-period working capital loans is given by

$$\bar{R} = R_t\left[1 - X\left(\bar{x}_t\right)\right] + \eta X\left(\bar{x}_t\right), \tag{11}$$

where $X(\bar{x}_t)$ is the default probability of non-tradable good firms.

3.6 Private Sector Equilibrium

I define the private sector equilibrium as the partial equilibrium factor allocation and prices that solve the household and firm problems, taking as given, past wages, the exchange rate policy, tradable income[14] and world market prices for intermediate imports, $\left(w_{t-1}, I_t, \epsilon_t, p_t^{M\star}\right)$.

I define aggregate output of the non-tradable consumption good as

$$y_t^N = \int_{\bar{x}_t}^{\infty} x_{i,t} f^N(m_{i,t}, m_t^\star)\, dX(x). \tag{12}$$

In equilibrium, the markets for domestic intermediate goods, as well as tradable and non-tradable consumption goods clear. For domestic intermediate goods this implies

$$f^M(h_t) = \int_{\bar{x}_t}^{\infty} \Phi\left(x_{i,t} p_t, p_t^M\right) dX(x)\, m_t^\star. \tag{13}$$

Furthermore, all production of non-tradable consumption goods is consumed by the households

$$c_t^N = y_t^N. \tag{14}$$

The market clearing-condition for traded goods follows from equations (13) and (14), profits from the intermediate good sector,

$$\pi_t^M = p_t^M f^M(h_t) - w_t h_t,$$

aggregate profits in the non-tradable consumption goods sector,

$$\pi_t^N = p_t y_t^N - p_t^M \int_{\bar{x}_t}^{\infty} m_{i,t}\, dX(x) - (1 - \xi + \xi(1 - X(\bar{x}_t))R_t)\, p_t^{M\star} m_t^\star$$

and the household budget constraint (3). It is given by

$$c_t^T = I_t - (1 - \xi + \xi(1 - X(\bar{x}_t))R_t)\, p_t^{M\star} m_t^\star. \tag{15}$$

Households consume the tradable good income, minus the amount that is spent by the non-tradable good firms to purchase intermediate imports.

With downward rigid nominal wages, involuntary unemployment is a regular phenomenon in equilibrium. Suppose, without loss of generality, that the nominal depreciation rate is fixed at $\epsilon_t = 1$, the economy is at full employment and tradable income falls. A fall in tradable income calls for a reduction of the real wage. From equation (5) it is apparent that the real wage can only

[14] Tradable income consists of the stochastic endowment and government transfers. Therefore, households and firms do not internalize how their decisions influence the governments optimization problem.

fall up to ψw_{t-1}. Since households inelastically supply $\bar{h}$ hours, but domestic intermediate goods firms demand less hours at real wage ψw_{t-1}, involuntary unemployment emerges. The following slackness condition summarizes this mechanism and must hold at all times:

$$\left(w_t - \frac{\psi w_t - 1}{\epsilon_t}\right)\left(\bar{h} - h_t\right) = 0. \tag{16}$$

The private sector equilibrium $\left[c_t, c_t^N, c_t^T, y_t^N, m_{i,t}, m_t^\star, h_t, \bar{x}_t, R_t, w_t, p_t^M, p_t\right]$ solves equations (2) and (4) to (16), taking $\mathcal{S} = \left\{w_{t-1}, \epsilon_t, I_t, p_t^{M\star}\right\}$ as given. I assume that the private sector equilibrium exists for the admissible values of $\mathcal{S}$. $\mathcal{C}\left(w_{t-1}, \epsilon_t, I_t, p_t^{M\star}\right)$ denotes private sector equilibrium consumption.

Real GDP at equilibrium prices is the sum of tradable endowment and domestic production of the non-tradable good, minus the cost for intermediate inputs. Therefore, real GDP is

$$y_t = y_t^T + p_t y_t^N - (1 - \xi + \xi(1 - X(\bar{x}_t))R_t)\, p_t^{M\star} m_t^\star.$$

3.7 The Government

The government borrows from international financial markets to smooth household consumption. The government cannot commit to repay its debt obligations. If the government is in good credit standing at the beginning of the period it decides about repayment and default. If the government repays, it issues new one period discount bonds b_{t+1} at price $q\left(z_t, b_{t+1}, w_t\right)$. The bond price reflects the government's default risk in the next period. The net revenue from borrowing is transferred to the households, $T_t = b_t - q\left(z_t, b_{t+1}, w_t\right) b_{t+1}$.

As in Arellano (2008) and Aguiar and Gopinath (2006) the government is temporarily excluded from international financial markets and faces an exogenous output cost on tradable endowment when it decides to default. The exogenous endowment of the tradable consumption good is driven by a Markov process z_t. The endowment is determined by $y_t^T = f^T\left(z_t, s_t\right)$, with $s_t \in \{R, D\}$. The indicator variable s_t denotes if the economy is in financial autarky ($s_t = D$), or not ($s_t = R$). If the government is in financial autarky, the exogenous output cost is realized. The government regains access to international financial markets in the future with exogenous probability ϕ. If the government reenters international financial markets, it does so without debt and does not face any other consequences of past defaults. Since the government is not allowed to borrow in financial autarky, transfers to the household are restricted to $T_t = 0$.

I assume that the government follows an exogenously given exchange rate policy, that determines the nominal depreciation rate as a function of relevant variables, $\epsilon_t = \mathcal{E}\left(\cdot\right)$. As in Na et al. (2018) and Moussa (2013) I study two different exchange rate rules. A fixed exchange rate regime, where $\epsilon_t = 1, \forall t$ and a flexible exchange rate regime, where the exchange rate is set such that there is no unemployment in equilibrium. In the flexible regime, the depreciation rate is set according to $\epsilon_t = \max\left\{1, \frac{\psi w_{t-1}}{w_t^f}\right\}$. The real wage w_t^f denotes the wage rate where intermediate good firms demand all labor, $\bar{h}$.

The government takes the exchange rate regime and the private sector response to its policies as given. The relevant state variables at the beginning of the period are (z_t, b_t, w_{t-1}, s_t). The value function of a government with market access is

$$V\left(z_t, b_t, w_{t-1}, R\right) = \max\left\{V^R\left(z_t, b_t, w_{t-1}\right), V^D\left(z_t, w_{t-1}\right)\right\}, \tag{17}$$

where V^R $\left(V^D\right)$ denote indirect utility of repayment (default). The value of repayment is determined by

$$V^R\left(z_t, b_t, w_{t-1}\right) = \max_{b_{t+1}} u\left(c_t\right) + \beta \mathbf{E}_z V\left(z_{t+1}, b_{t+1}, w_t, R\right) \tag{18}$$

subject to

$$\begin{aligned} T_t &= b_t - q\left(z_t, b_{t+1}, w_t\right) b_{t+1} \\ I_t &= T_t + f^T\left(z_t, R\right) \\ \epsilon_t &= \mathcal{E}\left(w_{t-1}, I_t\right) \\ c_t &= \mathcal{C}\left(w_{t-1}, \epsilon_t, I_t, p_t^{M\star}\right) \end{aligned}$$

The first constraint is the government budget constraint, the second constraint determines tradable good income, the third constraint is the exchange rate rule and the last constraint refers to the private sector equilibrium.

If the government is in financial autarky there is no policy instrument for the government. The autarky value function is given by

$$V^D\left(z_t, w_{t-1}\right) = u\left(c_t\right) + \beta \mathbf{E}_z\left[\psi V\left(z_t, 0, w_{t-1}, R\right) + (1-\psi) V^D\left(z_t, w_{t-1}\right)\right] \tag{19}$$

with

$$\begin{aligned} I_t &= f^T\left(z_t, D\right) \\ \epsilon_t &= \mathcal{E}\left(w_{t-1}, I_t\right) \\ c_t &= \mathcal{C}\left(w_{t-1}, \epsilon_t, I_t, p_t^{M\star}\right) \end{aligned}$$

In the case where the government is in financial autarky, the government cannot borrow and therefore is not able to provide transfers to the household. The value of autarky takes into account that the government might be able to reenter financial markets without debt and with a clean record in the next period.

The government decides to default, whenever the value of repayment, V^R, is smaller than the value of default, V^D. The default set is formally defined as

$$\Sigma^D = \left\{ (z_t, b_t, w_{t-1}) \, | V^D (z_t, w_{t-1}) > V^R (z_t, b_t, w_{t-1}) \right\}. \tag{20}$$

From the viewpoint of period t, the probability of default in period $t+1$ can be determined from the definition of the default set and the transition probability of the shock governing the tradable good endowment. It is defined as

$$\mathbb{P} (z_t, b_{t+1}, w_t) \equiv \text{Prob} \left((z_{t+1}, b_{t+1}, w_t) \in \Sigma^D \middle| z_t \right). \tag{21}$$

As in the case for working capital loans, risk neutral international investors provide credit to the domestic government at an interest rate that ensures zero profits in expectation. The bond price satisfies

$$q (z_t, b_{t+1}, w_t) = \frac{1 - \mathbb{P} (z_t, b_{t+1}, w_t)}{\bar{R}}. \tag{22}$$

As the interest rate on working capital loans the bond price reflects the endogenous sovereign default risk.

3.8 Recursive Equilibrium

Definition: *The recursive equilibrium of this economy is given by*

(i) *value functions* $V (z_t, b_t, w_{t-1}, s_t)$, $V^D (z_t, w_{t-1})$, $V^N (z_t, b_t, w_{t-1})$ *and government policy function* $b_{t+1} = \mathcal{B}(z_t, b_t, w_{t-1}, s_t)$, *solving problems* (17)–(19), *and a default set* Σ^D *satisfying* (20).

(ii) *a bond pricing function* $q(z_t, b_{t+1}, w_t)$ *satisfying the arbitrage condition of foreign lenders* (22).

(iii) *a tradable income process* $I_t = f^T(z_t, s_t) + b_t - q(z_t, b_{t+1}, w_t)b_{t+1}$, *for* $s_t = R, D$.

(iv) *an exchange rate rule defining the nominal depreciation rate* $\epsilon_t = \mathcal{E} (I_t, w_{t-1})$.

(v) *a private sector equilibrium, defining consumption* $c_t = \mathcal{C}(w_{t-1}, \epsilon_t, I_t, p_t^{M\star})$, *unemployment* $ue_t = \mathcal{U}(w_{t-1}, \epsilon_t, I_t, , p_t^{M\star})$, *the private sector gross interest rate* $R_t = \mathcal{R}(w_{t-1}, \epsilon_t, I_t, , p_t^{M\star})$, *real wage* $w_t = \mathcal{W}(w_{t-1}, \epsilon_t, I_t, p_t^{M\star})$ *and the relative price of the non-tradable consumption good* $p_t = \mathcal{P}(w_{t-1}, \epsilon_t, I_t, p_t^{M\star})$, *satisfying* (2) *and* (4) – (16).

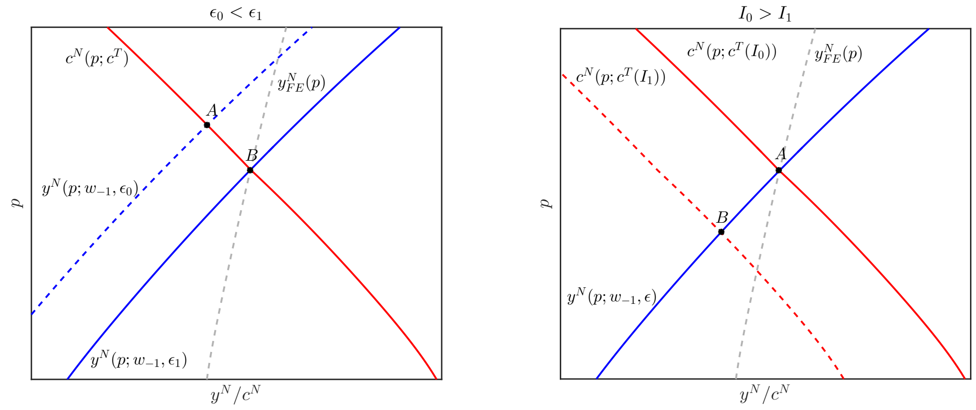

Figure 2: Non-tradable Good Market.

Notes: The figure shows the equilibrium in the non-tradable good market, taking into account the credit market equilibrium for working capital loans, the equilibrium on the labor market, as well as market clearing for the domestic intermediate and the tradable consumption good. The left panel shows the effect of a nominal devaluation on the equilibrium in the non-tradable good market. The right panel depicts the effect of a decrease in tradable income on the equilibrium in the market for non-tradable goods.

4 Default Risks and Nominal Devaluation

In this section I discuss the mechanism that links private sector default risk to the government borrowing condition and the exchange rate regime. I first describe the properties of the equilibrium on the market for working capital loans, then I illustrate the link between private sector default risk and exchange rate policies and finally I turn to the relationship between private and sovereign default risk.

The equilibrium on the market for working capital credit is determined by the interest rate jointly solving equations (9) and (10). It is given by

$$R_t \left[1 - X\left(\bar{x}^N\left(p_t, p_t^M, R_t\right)\right)\right] + \eta X\left(\bar{x}^N\left(p_t, p_t^M, R_t\right)\right) - \bar{R} = 0, \tag{23}$$

where $\bar{x}^N\left(p_t, p_t^M, R_t\right)$ is the default threshold implied by equation (9). The credit market equilibrium has a stable and an unstable solution. At the stable solution an increase in the interest rate leads to an increase in default risk which is overcompensated by the increase in the interest rate itself, such that profits of international investors increase. The equilibrium interest rate at the stable solution $R\left(p_t, p_t^M\right)$ is decreasing (increasing) in p_t (p_t^M).[15] The corresponding default threshold, $\bar{x}\left(p_t, p_t^M\right)$, has the same properties as the equilibrium gross interest rate, $R\left(p_t, p_t^M\right)$.[16]

[15]The properties of $R\left(p_t, p_t^M\right)$ follow directly from the properties of $\tilde{\pi}^N\left(p_t x_{i,t}, p_t^M\right)$. This result can be shown by applying the implicit function theorem.

[16]There are two corner solutions in the credit market equilibrium. If prices (p_t, p_t^M) are such that all firms repay at the risk free interest rate, the equilibrium interest rate is equal to the risk free interest rate and equation (9) holds with inequality. The other corner solution emerges when prices (p_t, p_t^M) are such that the profit maximum of international investors is negative. In this case international investors are not willing to provide working capital

Now consider a situation where the inherited real wage w_{t-1} is high enough such that the wage rigidity (equation (6))

$$w_t = \frac{\psi w_{t-1}}{\epsilon_t} > w_t^f$$

is binding, where w_t^f is the real wage that clears the labor market (equation (7)). In such a situation, a nominal depreciation, $\epsilon_t > 1$, reduces the real wage w_t, such that, conditional on price p_t^M, intermediate good firms demand more labor and increase their output.

Ceteris paribus, non-tradable good firms pair the additional domestic inputs with new intermediate imports and increase the supply of the non-tradable good. In equilibrium, this increased supply, leads to a falling price. The left panel of Figure 2 shows this situation. A nominal depreciation shifts the supply schedule of the non-tradable consumption good down (dashed blue line to the solid blue line). In order to sell the additional output and with fixed tradable good absorbtion, the relative price for the non-tradable good falls along the demand schedule (solid red line) from equilibrium A to B. In the new equilibrium non-tradable good firms sell more output at a lower real price[17].

The falling relative price of the non-tradable consumption good (real depreciation) reduces real revenues of non-tradable good firms, making it more difficult to repay the working capital loan. This leads to higher private default rates and the private spread increase.

Sovereign default risk influences private default risk through its impact on the demand of the non-tradable consumption good. If sovereign default risk rises, the bond price falls. With a lower bond price, it becomes more difficult to role over existing debt, not to mention keeping the current level of transfers to households. With lower transfers, tradable income falls.

The right panel of Figure (2) displays the equilibrium before (point A) and after a fall in tradable income (point B). Falling tradable income transfers into lower tradable consumption and the demand schedule for the non-tradable good shifts downwards (solid red line to dashed red line). In the new equilibrium B, households consume less of the non-tradable consumption good at a lower price. Since equilibrium B is to the left of full employment output and features a lower price p_t, there is unemployment and higher private sector default risk. Therefore private and sovereign risk premia are positively correlated.

Tradable income also falls after a low realization of the tradable endow-

credit to domestic firms. Consequently, they are not able to buy intermediate imports and produce using only domestic inputs.

[17]The dashed grey line shows output at full employment. An equilibrium can never be located to the right of full employment output $y_{FE}^N(p)$. If the equilibrium allocation is to the left of full employment output, the economy features unemployment (point A).

ment shock. Consequently, private default risk is countercyclical in the current framework.

5 Quantitative Analysis

In this section I solve the model numerically to study its quantitative properties and explore the welfare consequences of different exchange rate rules. For the sake of comparability to the literature and data availability I calibrate the model to Argentina at quarterly frequency. The parameters are set to match several features of the Argentine economy.

5.1 Calibration

My calibration strategy relies on two different data sets. First, I use the 1997 Input-Output table to recover the parameters related to the relative importance of intermediate imports in the non-tradable good sector. Second I use time series data on sovereign and private interest rates and economic activity from INDEC and international data sources to recover parameters related to credit markets and the sectoral composition of the Argentine economy.[18] Whenever suitable, I use parameter values from the literature.

5.1.1 Functional Forms

The instantaneous utility function is of the CRRA type

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

where $\sigma > 0$, denotes the parameter of relative risk aversion.

The consumption aggregator is a CES function as in Na et al. (2018)

$$A\left(c^T, c^N\right) = \left[\gamma\left(c^T\right)^{\frac{\rho^C-1}{\rho^C}} + (1-\gamma)\left(c^N\right)^{\frac{\rho^C-1}{\rho^C}}\right]^{\frac{\rho^C}{\rho^C-1}},$$

where $\rho^C < 1$ determines the elasticity of substitution between tradable and non-tradable consumption goods and $\gamma \in (0,1)$ captures the weight of tradable consumption in total consumption.

As in Mendoza and Yue (2012) I assume that the domestic intermediate input is produced with

$$f^M(h) = A^M (h)^{\alpha_M},$$

where $\alpha^M \in (0,1)$ is the labor share in the intermediate goods sector. The parameter $A^M > 0$ represents both fixed production factors and time-invariant

[18]Section A provides the exact data sources and details on the data.

total factor productivity in the intermediate good sector.

I choose a CES production function in the non-tradable good sector

$$f^N(m, m^\star) = A^N \left[\alpha^N (m)^\rho + \left(1-\alpha^N\right)(m^\star)^\rho\right]^{\frac{1}{\rho}},$$

with $A^N > 0$, $\alpha^N \in (0,1)$ and $\rho < 1$. As for the intermediate production function, the parameter A^N captures time-invariant production factors and total factor productivity in the non-tradable good sector. The elasticity of substitution between domestic and imported intermediate inputs is captured by ρ and α^N denotes the weight of domestic inputs in production. Domestic inputs per unit of imported inputs are defined as

$$\Phi\left(x\,p, p^M\right) = \left[\frac{1-\alpha^N}{\alpha^N}\right]^{\frac{1}{\rho}} \left[\left(\alpha^N\right)^{\frac{1}{\rho-1}} \left(\frac{x\,pA^N}{p^M}\right)^{\frac{\rho}{\rho-1}} - 1\right]^{-\frac{1}{\rho}}$$

and profits before interest are defined as

$$\tilde{\pi}^N\left(x\,p, p^M\right) = p^M \left[\frac{1-\alpha^N}{\alpha^N}\right]^{\frac{1}{\rho}} \left[\left(\alpha^N\right)^{\frac{1}{\rho-1}} \left(\frac{x\,pA^N}{p^M}\right)^{\frac{\rho}{\rho-1}} - 1\right]^{\frac{\rho-1}{\rho}}.$$

Both functions are defined for $\left(\alpha^N\right)^{\frac{1}{\rho}} \frac{x\,pA^N}{p^M} < 1$ if $\rho > 0$ and for $\left(\alpha^N\right)^{\frac{1}{\rho}} \frac{x\,pA^N}{p^M} > 1$ if $\rho < 0$.

The idiosyncratic productivity shock x is uniformly distributed on the interval $[1-\zeta, 1+\zeta]$ with cumulative distribution function $X(x) = \frac{x-1+\zeta}{2\zeta}$.

Similiar to Arellano (2008), the stochastic endowment is determined by

$$f^T(z,s) = \begin{cases} A^T\theta & \text{if } s = D \;\&\; z > \log(\theta)\,\mathbf{E}(z), \\ A^T \exp(z) & \text{otherwise.} \end{cases}$$

The parameter $\theta \in (0,1)$ represents the exogenous output cost of default. In default, the shock z_t is truncated from above at $\log(\theta)\mathbf{E}(z)$. $A^T > 0$ is a normalization needed to match the relative size of the tradable good sector in the data. The stochastic process z_t is assumed to follow an AR(1) process

$$z_t = \rho_z z_{t-1} + \varepsilon_t,$$

with persistence parameter $\rho_z \in (0,1)$. The innovation ε_t is i.i.d. $N(0, \sigma_\varepsilon^2)$.

5.1.2 Parameters

The model is calibrated to match the Argentine economy prior to the 2002 sovereign default. The sample period considered in the calibration is 1993:Q1-2000:Q4. Since Argentina was in a fixed exchange rate until the default crisis, I set the nominal gross devaluation rate to $\epsilon_t = 1 \forall t$. Table 1 lists the parameter choices together with their targets and sources.

The parameters of the consumption aggregator function γ and ρ^C are taken from Na et al. (2018) and the coefficient of risk aversion is set to $\sigma = 2$, which is a standard value in the related literature.[19]

Schmitt-Grohé and Uribe (2016) provide evidence that the nominal wage is rather rigid in emerging market economies with stable inflation rates. I follow them and assume $\phi = 0.99$. Hence, nominal wages can fall up to 4% per year.

I set $A^T = 0.26$ such that the share of tradable value added in the model matches the average share of tradable value added in GDP. I follow Na et al. (2018) and define tradable value added as the sum of value added in agriculture, fishing, mining and manufacturing in Argentina. I take their estimates for the parameters of the endowment process, $\rho_z = 0.9317$ and $\sigma_\varepsilon = 0.037$.[20]

The elasticity of substitution between domestic intermediate inputs and intermediate imports is taken from Mendoza and Yue (2012).[21] Since the model features only production in the non-tradable good sector I cannot apply their estimates directly. I assume that the elasticity of substitution between domestic intermediate inputs and intermediate imports is the same across the tradable and non-tradable sector and set its value to $\rho = 0.65$. I set the weight on domestic intermediate inputs such that the model replicates the ratio of intermediate imports to domestic intermediate inputs of $\frac{m_t^\star}{m_t} = 4.7\%$ from the 1997 Argentine Input-Output table. The value of A^N is set such that average GDP is equal to one.

As in Mendoza and Yue (2012) I set the labor share in the intermediate good production function to $\alpha_M = 0.7$. The parameter A^M, reflects time invariant inputs and TFP in the domestic intermediate good sector. Its value is set such that the model matches the increase of unemployment in the Argentine default in 2002:Q1. In Argentina unemployment was 10% above its pre-crisis average.

Ronconi and Kawamura (2015) use the World Bank Enterprise Survey to compute the share of production cost that is financed with internal cash-flows. I use their estimate for Argentina and set the share of credit financed intermediate imports to $\xi = 0.38$.

The volatility parameter of the idiosyncratic productivity shock, ζ is chosen to match an average risk premium on working capital loans of 8.45%. The recovery rate η is critical for the responsiveness of the private sector interest rate to exogenous shocks. Therefore, I calibrate its value to match the standard deviation of private spreads ($\sigma(PP) = 4.81$).

The discount factor, β, determines the desire to consume today, rather than

[19] See for example Arellano (2008), Mendoza and Yue (2012) or Kaas et al. (2016).

[20] Na et al. (2018) estimate the parameters on a slightly longer sample ranging from 1983:Q1 to 2001:Q4.

[21] They estimate the parameters of a CES production function using aggregate Mexican data and assume that they are similar in Argentina.

Parameter		Target/Source	Value
Risk aversion	σ	standard value	2
Curvature consumption aggregator	ρ^C	Na et al. (2018)	0.50
Weight on tradable consumption	γ	Na et al. (2018)	0.26
Nominal wage rigidity	ϕ	Schmitt-Grohé and Uribe (2016)	0.99
Normalization tradable good sector	A^T	tradable to non-tradable value added	0.26
Normalization non-tradable good sector	A^N	GDP = 1	0.36
Curvature production function	ρ	Mendoza and Yue (2012)	0.65
Weight on domestic inputs	α^N	domestic to intermediate inputs in non-tradable production	0.57
Normalization domestic intermediate good sector	A^M	unemployment in default	1
Labor share domestic intermediate good sector	α^M	Mendoza and Yue (2012)	0.7
Share of credit financed imports	ξ	Ronconi and Kawamura (2015)	0.38
Dispersion of idiosyncratic shocks	ζ	volatility of private spread	0.30
Recovery rate	η	average private spread	0.80
Price intermediate imports	$p^{M\star}$	volatility debt-service to GDP	1
Discount factor	β	debt-service to GDP	0.90
Reentry probability	φ	Moussa (2013)	0.0385
Output cost	θ	average sovereign spread	0.97
Persistence of z	ρ_z	Na et al. (2018)	0.9317
Volatility of z shocks	σ_ε	Na et al. (2018)	0.037

Table 1: Parameter Choices.

consuming tomorrow and the price of intermediate imports, $p^{M\star}$, influences how demand for intermediate imports adjusts to exogenous shocks. Following Arellano (2008), I calibrate β to match the government debt service to GDP ratio of 3%. I set $p^{M\star}$ to match the volatility of net-exports of $\sigma\left(\frac{nx}{y}\right) = 1.02$. I follow Na et al. (2018) and Chatterjee and Eyigungor (2012) and set the reentry probability to $\varphi = 0.0385$ and target the value of the output cost to match the average sovereign risk premium of $\mathbb{E}(SP) = 5.97$.[22]

5.2 Results

In this section I study the quantitative properties of the simulated model economy. First, I describe the main economic mechanism driving the interaction between sovereign and private default risk and the exchange rate policy in the model using the policy functions. Second, I perform an event study to evaluate if the model can replicate the historical evidence presented in Section 2 and discuss the importance of private sector default risk and the exchange rate regime for the results. Third, I describe the effects of private sector default risk and the exchange rate regime on the long run moments of the model economy. Finally I do a welfare analysis and calculate the welfare loss of the fixed exchange rate regime

5.2.1 Policy Functions

First, I discuss how the endowment shock influences the default incentives and borrowing decision of the government, and how this affects the private sector equilibrium in the fixed exchange rate regime. In Figure 3 I consider endowment shocks of one standard deviation, keeping the inherited real wage at $w_{t-1} = \hat{w}$. The wage $\hat{w}$ is the equilibrium wage from the private sector equilibrium with $\mathcal{S} = \{\hat{w}, f^T(\mathbb{E}(z), R) + T, \epsilon = 1, p_t^{M\star}\}$, where government transfers are set to $T = 0$.

The upper left panel of Figure 3 shows the sovereign bond price $q(z_t, b_{t+1}, w_t)$. The bond price is decreasing in debt, reflecting that the default incentives of the government increase with the debt stock. At low levels, the government always repays and the bond price is the inverse of the risk free gross interest rate. When default risk rises, international investors demand a risk premium and the bond price falls. The bond price also falls when the economy is hit by a low endowment shock. A low endowment shock makes it more difficult for the government to repay and increases its default incentives.

The upper right panel of Figure 3 shows the optimal borrowing decision of the government. The government borrows more at low debt levels and for better endowment shocks. When default risk rises and the bond price falls, the government becomes eventually borrowing constrained. The middle left panel

[22]The reentry probability of $\varphi = 0.0385$ implies an average exclusion period of 6.5 years.

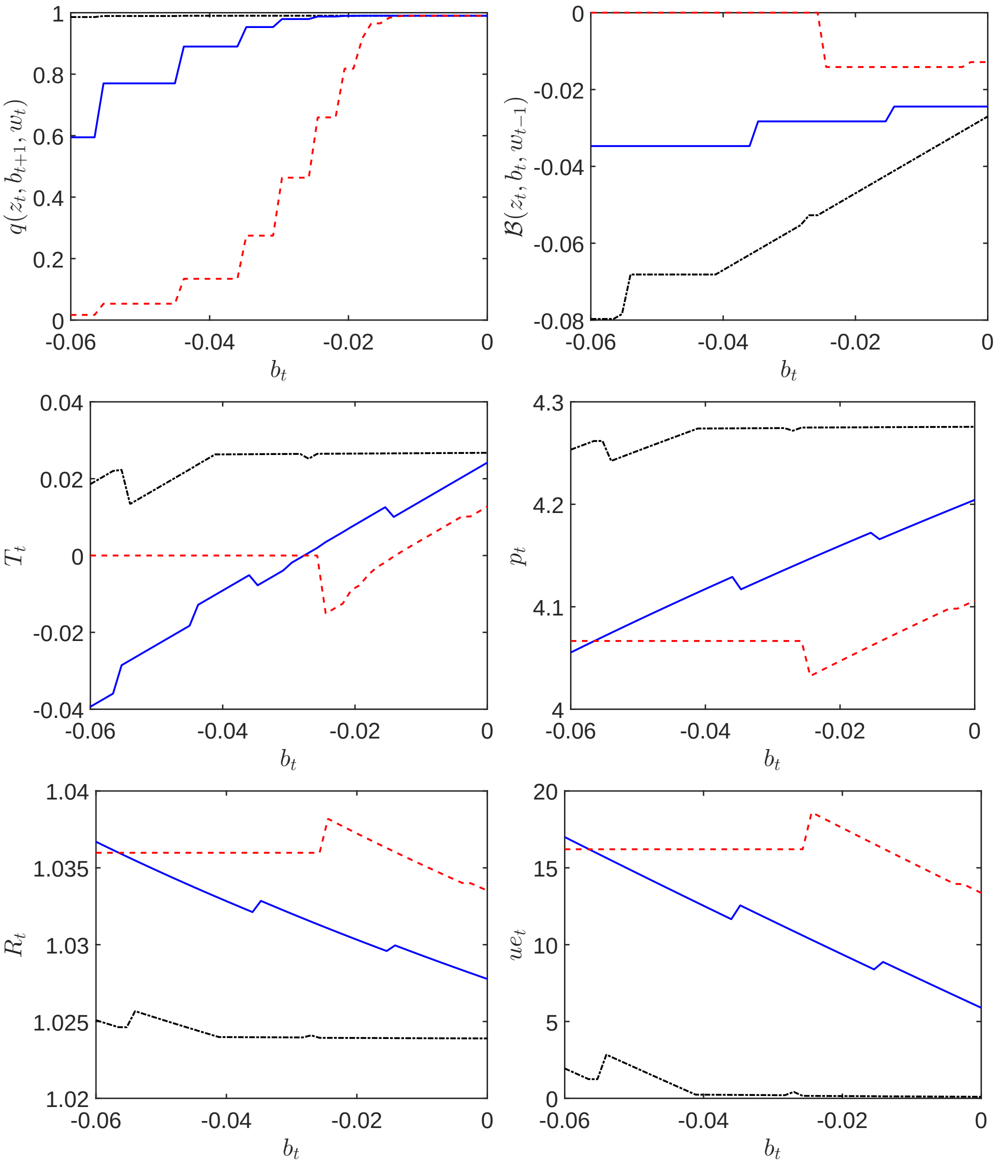

Figure 3: Policy Functions.

Notes: This figure shows the sovereign bond price function $q(z_t, b_{t+1}, w_t)$, debt policy $\mathcal{B}(z_t, b_t, w_{t-1}, s_t)$, government transfers, the real price of non-tradable goods, the quarterly private sector gross interest rate and the unemployment rate for realizations of the endowment shock of $\mathbb{E}(z) + \sigma_\varepsilon$ (dashed-dotted black line), $\mathbb{E}(z)$ (solid blue line) and $\mathbb{E}(z) + \sigma_\varepsilon$ (dashed red line) at past wage $w_{t-1} = \hat{w}$. The wage $\hat{w}$ is the equilibrium wage from the private sector equilibrium with $\mathcal{S} = \{\hat{w}, f^T(\mathbb{E}(z), R) + T, \epsilon_t = 1, p^{M\star}\}$, where government transfers are set to $T = 0$. All policy functions are plotted assuming fixed exchange rates $\epsilon_t = 1$, $\forall t$.

shows the corresponding government transfers to the household. Transfers are positive for low debt levels and high endowment shocks and decrease when the debt level rises and for lower shock realizations, turning eventually negative. When the government defaults transfers are restricted to zero.

The remaining three panels show responses of the private sector equilibrium to the government policies. The middle right panel of Figure 3 shows that the real price of the non-tradable consumption good is lower for higher debt levels and lower endowment shocks. As discussed in Section 4 a fall in government transfers generates a fall in the relative price of the non-tradable good. The falling relative price of non-tradable goods translates into higher private sector interest rates and higher unemployment. The behavior of the private sector gross interest rate and the unemployment rate are depicted in the lower left and the lower right panel, respectively. The private sector interest rate and unemployment are highest just before the government defaults. In order to avoid default the government collects lump sum taxes, reducing transfers and increasing unemployment and private interest rates. In default, however, government transfers are zero such that unemployment and private interest rates fall.

Second, I discuss how changes in the inherited real wage influence default incentives and optimal borrowing. The upper left panel of Figure 4 shows the sovereign bond price for changing inherited wages, w_{t-1}, keeping the endowment shock at its unconditional mean and the debt stock at $b = -0.015$ fixed. The sovereign bond price is first decreasing and then increasing in w_{t-1}.

In order to understand the decreasing part of the bond price schedule it is helpful to think about how the government can reduce unemployment in the model with fixed exchange rates. Suppose that the current allocation implies positive unemployment. The government can alleviate unemployment by increasing government transfers, shifting demand for the non-tradable consumption good upwards. The increased demand for the non-tradable consumption good, increases demand for the domestic intermediate input good and therefore leads to a higher labor demand. The government can increase transfers either by borrowing more, or in case of a high debt stock and low bond prices by defaulting.

As long as w_{t-1} is low, there is no unemployment and the government has no incentives to use foreign debt to reduce unemployment. Therefore, sovereign default risk is unaffected by the current value of w_{t-1}. This is reflected in the left flat part of the sovereign bond price schedule depicted in the upper left panel of Figure 4.

When w_{t-1} rises, such that constraint (6) binds, the government increases borrowing to avoid unemployment. Higher borrowing then increases sovereign default risk. This can be seen from the upper right panel and the two panels in the second row of Figure 4. The right panel in the second row depicts the

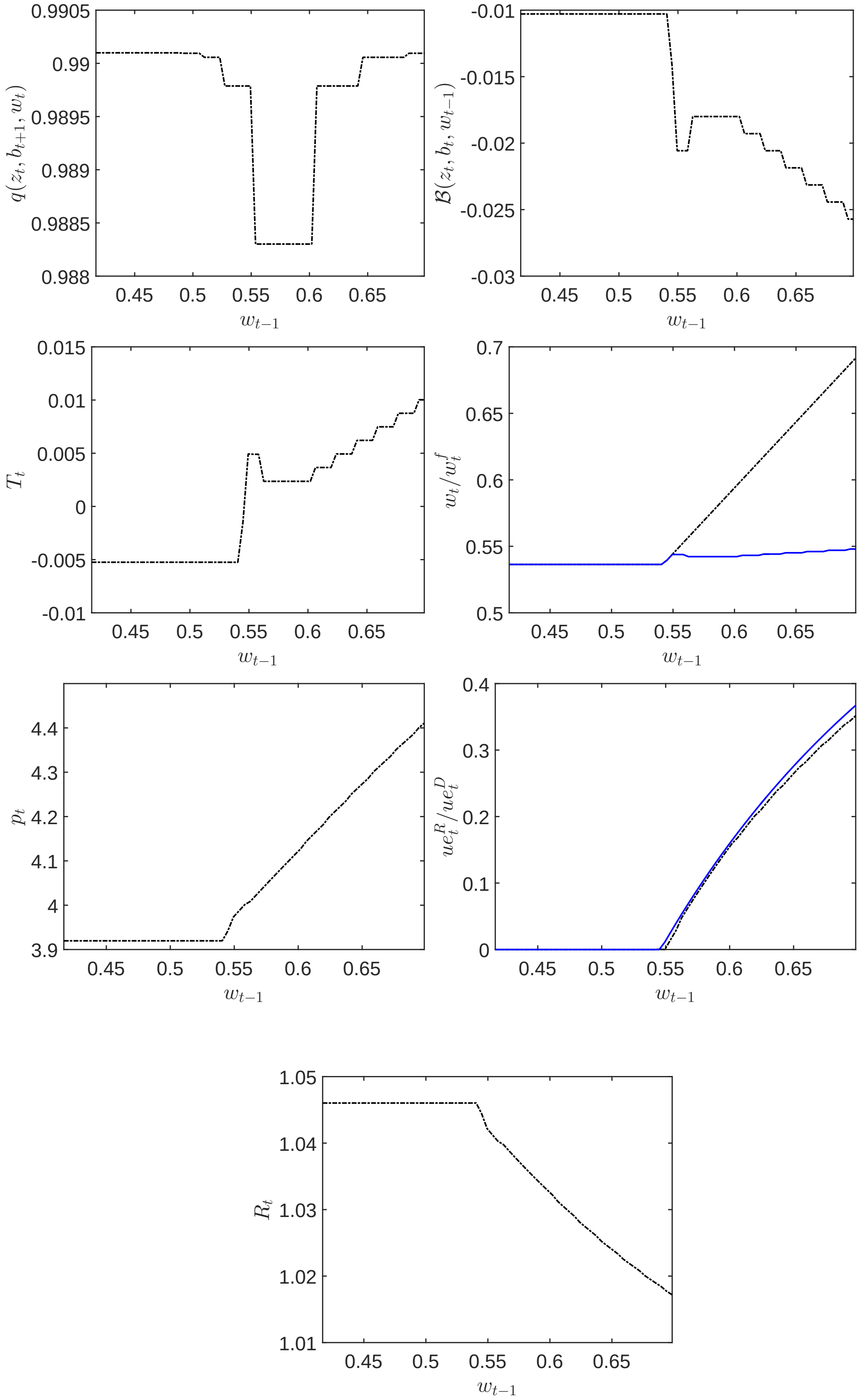

Figure 4: Policy Functions.

Notes: This figure shows the sovereign bond price function $q(z_t, b_{t+1}, w_t)$, debt policy $\mathcal{B}(z_t, b_t, w_{t-1}, s_t)$, government transfers, the real price of non-tradable goods, the quarterly private sector gross interest rate, the equilibrium (dash-dotted black line) and market clearing wage (solid blue line) and the unemployment rate in the repayment (dash-dotted black line) and default state (solid blue line) at the unconditional mean of the endowment shock and debt $b_t = -0.015$. All policy functions are plotted assuming fixed exchange rates $\epsilon_t = 1$, $\forall t$.

labor market clearing wage (solid blue line) together with the realized real wage (dash-dotted black line), $w_t = \max\left\{w_t^f, \psi w_{t-1}\right\}$. Both wages increase at the same level of w_{t-1} where the bond price starts to decrease. As can be seen from the upper right and the left panel in the second row this is also the point where the government increases borrowing and therefore transfers to the household. It turns out that transfers become positive, while they have been negative before.

The right panel in the third row depicts unemployment in the repayment state (dash-dotted black line) and in financial autarky (solid blue line). It shows that there is no unemployment if the government has market access at $w_{t-1} = 0.55$, although the wage constraint became binding. This is exactly because the government provides just enough transfers to the household to ensure $w_t^f = \psi w_{t-1}$ and prevent unemployment.

A further increase in w_{t-1}, requires more government transfers to fight unemployment. With higher borrowing cost, the government eventually reduces transfers to the household to a level that implies positive unemployment. However, this level of unemployment is still below what would emerge if the government defaults. The effect of transfers on unemployment increases the value of market access for the government. Therefore, a further increase in $w_m t - 1$ decreases the default incentives of the government and therefore default risk falls.

The left panel in the third row shows, that the relative price of the non-tradable good increases when government transfers rise. As Section 4 discusses, an increase in transfers shifts demand for the non-tradable consumption good up and therefore p_t rises. This increase raises real revenues and allows more firms to repay their working capital loans and private default risk falls. The bottom panel depicts the corresponding fall in the private sector gross interest rate.

Third, I compare the policy functions of the fixed and the flexible exchange rate regime. In Figure 5 I plot the policy functions at endowment shock $z = \mathbb{E}(z)$ and inherited real wage $w_{-1} = \hat{w}$. The upper left panel depicts the sovereign bond price in the fixed (dash-dotted black line) and the flexible exchange rate regime (solid blue line). The bond price in the flexible exchange rate regime lies always above the bond price in the fixed exchange rate regime, implying higher default incentives in the fixed regime. The default incentives in the fixed exchange rate regime are higher because there the government wants to avoid negative transfers that would generate additional unemployment.

The upper right panel shows optimal borrowing in the two exchange rate regimes. Since the default incentives of the government are lower in the full employment exchange rate regime, the government is less borrowing constrained. As shown in the middle left panel of Figure 5, the higher bond price and higher borrowing translates into higher government transfers in the full employment

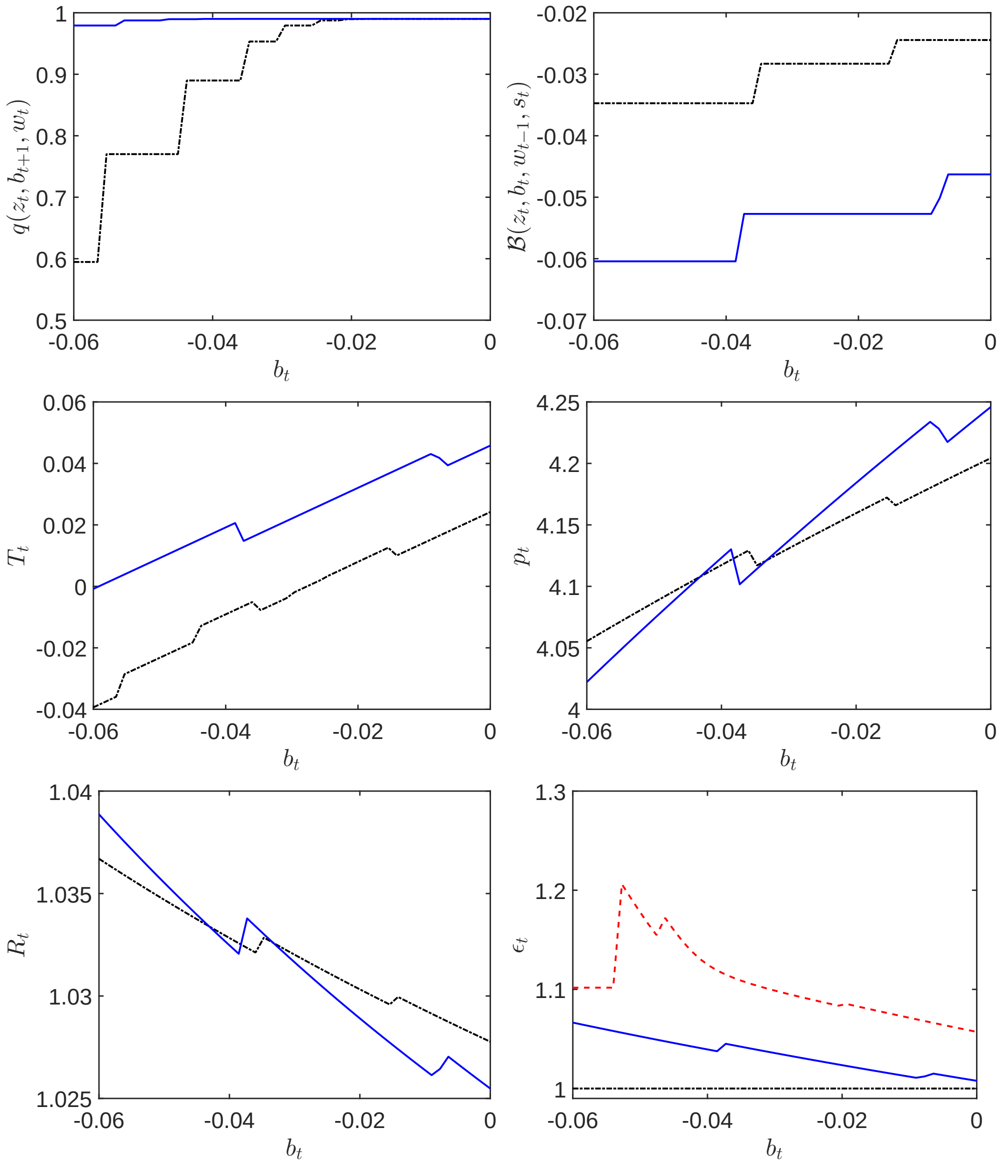

Figure 5: Policy Functions: Fixed vs Flexible Exchange Rate Regime.

Notes: This figure shows the sovereign bond price function $q(z_t, b_{t+1}, w_t)$, debt policy $\mathcal{B}(z_t, b_t, w_{t-1}, s_t)$, government transfers, the real price of non-tradable goods and the quarterly private sector gross interest rate at the unconditional mean of the endowment shock and at past wage $w_{t-1} = \hat{w}$. The wage $\hat{w}_t$ is the equilibrium wage from the private sector equilibrium with $\mathcal{S} = \{\hat{w}, f^T(\mathbb{E}(z), R) + T, \epsilon = 1, p^{M\star}\}$, where government transfers are set to $T = 0$. The policy functions are shown with fixed (dash-dotted black line) and flexible exchange rates (solid blue line). Furthermore, the lower left panel of this figure depicts the gross devaluation rate, ϵ_t, for realizations of the endowment shock of $\mathbb{E}(z) + \sigma_\varepsilon$ (dashed-dotted black line), $\mathbb{E}(z)$ (solid blue line) and $\mathbb{E}(z) + \sigma_\varepsilon$ (dashed red line) at past wage $w_{t-1} = \hat{w}$.

exchange rate regime, as long as the government repays in both regimes.

The relative price of the non-tradable consumption good is determined by the interaction of demand and supply. In Section 4, I discuss that an increase in government transfers shifts the demand schedule up and a nominal devaluation shifts the supply schedule down. The middle left panel shows that transfers are higher in the flexible exchange rate regime than in the fixed exchange rate regime. This implies that the demand schedule in the flexible exchange rate regime is above its counterpart in the fixed exchange rate regime. At the same time, the devaluation in the flexible exchange rate regime entails a higher supply of the non-tradable good.

The middle right panel shows the relative price of the non-tradable good in the fixed (dash-dotted black line) and the flexible exchange rate regime (solid blue line). For low debt levels, the demand side effect of higher transfers in the flexible exchange rate regime dominates. With low debt and high transfers, the labor market clearing wage is close to the inherited wage and there is no need for large devaluations. Consequently, the relative price of the non-tradable good is higher in the flexible exchange rate regime. However, when the government becomes more indebted, transfers fall, the gap between the labor market clearing wage and the inherited wage widens and a larger devaluation is needed to clear the labor market. For high debt levels, the devaluation effect becomes stronger and eventually the relative price of the non-tradable consumption good in the flexible exchange rate regime falls below its counterpart in the fixed exchange rate regime.

The lower left panel depicts the pattern of the private interest rate in the fixed and the flexible exchange rate regime. The private interest rate for working capital loans depends on the ability of non-tradable good firms to generate enough revenues to repay their foreign currency working capital loans. When the relative price of the non-tradable good is high, many firms are able to repay their credit and therefore the private interest rate is low. The dynamics of the private interest rate in the two exchange rate regimes mimic the ones of the relative price of the non-tradable consumption good. With low debt and high transfers, in the flexible exchange rate regime the relative price of the non-tradable good is larger and the private interest rate lower than in the fixed exchange rate regime. When debt rises the devaluation rate increases and the non-tradable good price in the flexible exchange rate regime falls below its fixed exchange rate regime counterpart. Consequently, the interest rate in the flexible exchange rate regime becomes larger than the interest rate in the fixed exchange rate regime.

The lower right panel depicts the evolution of the gross devaluation rate for for endowment shocks $E(z) + \sigma_\varepsilon$ (dashed-dotted black line), $E(z)$ (solid blue line) and $E(z) - \sigma_\varepsilon$ (dashed red line), keeping the inherited wage at $w_{t-1} = \hat{w}$. As discussed before, with higher debt levels transfers fall and the

Exchange Rate Regime	Argentina	FIX	FLEX
$\mathbb{E}\left(\frac{y^T}{y}\right)$	26.36	25.06	25.19
$\mathbb{E}\left(\frac{m^\star}{m}\right)$	4.70	2.94	2.82
$\mathbb{E}\left(\frac{b}{y}\right)$	-3.03	-1.10	-5.73
$\mathbb{E}\left(sp\right)$	5.97	6.10	18.50
$\mathbb{E}\left(pp\right)$	8.45	12.45	15.49
$\sigma\left(\frac{nx}{y}\right)$	1.02	0.46	1.21
$\sigma\left(sp\right)$	2.75	36.42	55.47
$\sigma\left(pp\right)$	4.81	4.86	11.74
$\rho\left(y, sp\right)$	-0.85	-0.25	-0.57
$\rho\left(y, pp\right)$	-0.81	-0.97	-0.92
Welfare gain in % , Δ		2.24	

Table 2: Business Cycle Moments and Welfare.

Notes: The table summarizes business cycle moments of the Argentine economy and simulated business cycle moments from the simulated model. The variables are the share of tradable value added in GPD $\frac{y^T}{y}$, imported to domestic intermediate inputs used in the non-tradable sector $\frac{m^\star}{m}$, the debt service to GDP ratio $\frac{b}{y}$, the annualized sovereign risk premium sp, the annualized private risk premium pp, the net export to GDP ratio $\frac{nx}{y}$ and gross domestic product y. For the computation of standard deviations and correlations, all variables are linearly detrended. Only aggregate GDP is logged before detrending. Statistics of the theoretical framework refer to the simulated model. The model is simulated for $100,000$ periods, where the first $10,000$ periods are discarded. The periods where the government is in financial autarky are excluded from the computation. the first column refers to Argentine data, the second column presents the results of the model with fixed exchange rates (FIX) and the third column presents the model with flexible exchange rates (FLEX).

gap between the labor market clearing wage and the inherited wage widens. A larger devaluation is needed to clear the labor market. Similarly, with a fall in the tradable good endowment, the disequilibrium in the labor market becomes worse and a larger devaluation is needed to clear the labor market.

5.2.2 Cyclical Properties

Table 2 reports business cycle moments of the Argentine economy and business cycle moments from the simulated model. The business cycle moments of the theoretical framework are obtained from simulated time series, excluding periods of financial autarky. For the computation of standard deviations and correlations all variables are linearly detrended.

The model is calibrated to the model with fixed exchange rates. The second column shows that the model replicates the relative size of the tradable good sector in GDP as well as the average sovereign risk premium. The relative importance of imported intermediate inputs in the non-tradable good sector is also broadly in line with the data and the model generates counter-cyclical private and sovereign risk premia in both exchange rate regimes. In the current calibration, the model generates too high private and too volatile sovereign spreads. Furthermore, the debt-service to GDP ratio and the volatility of net exports are too low.

In the fixed exchange rate regime, the debt-service to GDP ratio as well as the sovereign and private spread are lower than in the fixed exchange rate regime. In both exchange rate regimes, a default frees resources from government debt service. However, when exchange rates are fixed default has the additional benefit of reducing unemployment. After defaulting, the government no longer collects lump-sum taxes from households, tradable income rises and households demand more of the non-tradable consumption good. This raises the equilibrium prices of the non-tradable consumption good and the domestic input good. The labor market clearing wage increase and the gap to the inherited wage decreases, such that unemployment falls. Since in the fixed exchange rate regime the government has a higher incentive to default, it faces a higher risk premium and is more borrowing constrained.

Because the government in the flexible exchange rate regime has less incentives to default for a given state (z_t, b_t, w_{t-1}), its bond price is above the bond price of the government in the fixed exchange rate regime. Therefore, the government in the flexible exchange rate regime accumulates more debt. With the higher debt burden, the government in the flexible exchange rate regime also hits the endogenous borrowing constraint more often and defaults. Therefore, on average it has to pay a higher sovereign risk premium.

In the flexible exchange rate regime, the private risk premium is higher than in the fixed exchange rate regime. The higher private risk premium is driven by two effects. First, the government devalues the nominal exchange rate to eliminate unemployment and a nominal devaluation decreases the relative price of the non-tradable consumption good. This reduces real revenues and more non-tradable good firms default. Second, due to the higher average debt burden, a country with flexible exchange rates provides less transfers to the household, reducing tradable income and therefore, p_t falls again. Consequently, the debt channel increases private default risk even more.

The higher frequency of sovereign defaults in the flexible exchange rate regime also leads to more volatile sovereign and private spreads in the flexible exchange rate regime.

5.2.3 Default Dynamics

To understand the interaction of private and sovereign default risk with the exchange rate regime and their impact on the economy, I perform an event study. Figure 6 plots the dynamics of GDP, the ratio of non-tradable to tradable output, working capital credit, the relative price of the non-tradable consumption good, the gross devaluation rate, intermediate imports, the private spread, the sovereign spread and the unemployment rate 12 quarters before and after the default. The economy is in good credit standing until period $t = 0$, where it

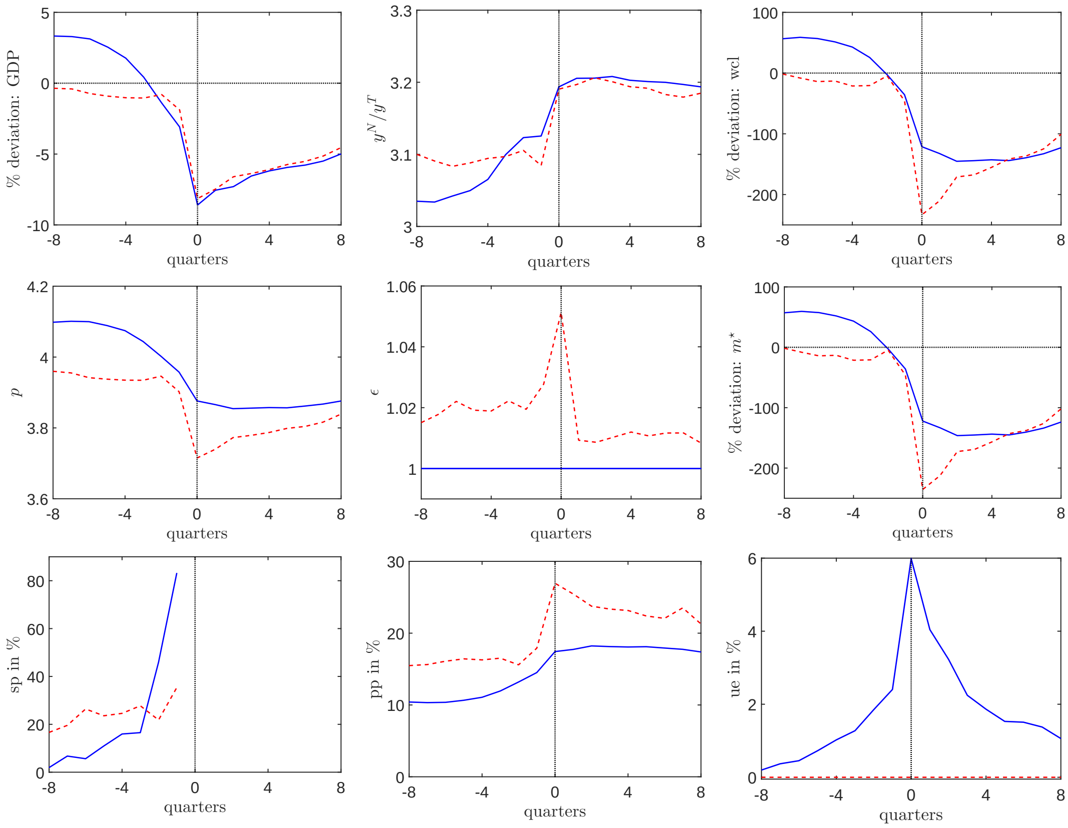

Figure 6: Policy Functions: Default Event.

Notes: This figure shows the dynamics of GDP, the non-tradable to tradable output ratio, working capital loans (wcl), the relative price of non-tradable goods (p), the gross devaluation rate (ϵ), intermediate imports ($m^\star$), the annualized sovereign risk premium (sp), the annualized private risk premium (pp) and the unemployment rate (ue). The series are shown 12 quarters before and after the default. The government defaults at $t = 0$. GDP, tradable endowment, working capital loans and intermediate imports are log-linearly detrended. The risk premia and the unemployment rate are plotted in percentage points and the dynamics of the nominal exchange rate are presented by the gross devaluation rate. The default dynamics are plotted for the model with fixed exchange rates (solid blue line) and the model with flexible exchange rates (dashed red line). The underlying time series are generated in simulations of the theoretical models over 100,000 quarters, where the first 10,000 quarters are discarded.

defaults. Figure 6 shows the dynamics for the model with fixed exchange rates (solid blue line) and the model with flexible exchange rates (dashed red line).

With fixed exchange rates, the economy is in a boom 8 quarters prior to default. The real exchange rate is appreciating, credit to the private sector grows and unemployment is low. A series of low endowment shocks drives down tradable good endowment (1st row, left panel). Households demand less of the non-tradable consumption good, putting downward pressure on the relative price of non-tradable consumption good. Non-tradable good firms pass on the downward pressure on prices to the domestic intermediate good firms. With downward rigid nominal wages and fixed exchange rates, the falling price for the domestic input good induces intermediate input producer to reduce labor demand. Since households inelastically supply one unit of labor, involuntary unemployment emerges (3rd row, right panel).

The fall in the relative price of the non-tradable consumption good (2nd row, left panel) makes it also more difficult for non-tradable good firms to repay their foreign currency working capital loans. Default rates increase and international investors demand a higher risk premium on working capital loans (3rd row, middle panel). Non-tradable good firms adjust to the higher interest rate by demanding less intermediate imports (2nd row, right panel) and less working capital loans (1st row, right panel).

A government facing an emerging recession with declining GDP, rising unemployment and rising risk premia is less willing to tax its citizens in order to repay foreign debt. International investors respond to the reduced willingness to repay by charging a higher risk premium. The increase in the risk premium makes it more difficult for the government to role over existing debt and support households through transfers. Therefore the government also cuts back on transfers to households. A fall in transfers has the same effect on the private sector as a low realization of the endowment shock and economic activity declines even more.

When the government defaults on its debt obligations, it is excluded from international financial markets and the exogenous output cost emerges. The output cost further decreases the supply of tradable goods generating higher unemployment, a higher private risk premium and lower demand for intermediate imports. After the default the economy starts to recover, as indicated by increasing GDP and falling unemployment. However, as indicated by the upper right panel the recovery is not accompanied by an increase in foreign credit to the private sector. Therefore the model captures the credit-less recovery phenomenon documented by Calvo et al. (2006).

When exchange rates are flexible (dashed red line), the government devalues the nominal exchange rate to eliminate unemployment. Driven by low endowment shocks, GDP is below trend and falling 12 quarters prior to default (1st row, left panel). The low tradable good endowment puts downward pressure on the the relative price of the non-tradable consumption good and therefore also on the price for the domestic input good. Due to the nominal downward rigid wage, domestic intermediate good firms demand less labor. To avoid unemployment the government devalues (2nd row, middle panel) such that the real wage falls and the labor market clears.

The devaluation increases the supply of the non-tradable consumption good, further reducing its equilibrium price (2nd row, left panel). The repayment capacity of non-tradable good firms rests on their ability to generate enough real revenues. With a falling relative price of the non-tradable consumption good, this becomes more difficult and default rates increase. Consequently, international investors charge a higher risk premium on private debt (3rd row, middle panel) and demand for intermediate inputs fall (2nd row, right panel).

Compared to the fixed exchange rate regime, the relative price of the non-tradable consumption good is lower and falls steeper in the default quarter when exchange rates are flexible. This is due to the devaluation of the nominal exchange rate and translates into a private spread that is higher in the flexible exchange rate regime. The strong nominal devaluation in the default quarter also translates into a stronger fall in intermediate imports in the flexible exchange rate regime.

The sovereign risk premium in the fixed exchange rate regime is below its flexible exchange rate regime counterpart 12 quarters before the default but rises much stronger and in the quarter prior to default it is approximately 50 %-points above the sovereign risk premium in the flexible exchange rate regime. The initially lower sovereign spread is in line with the results from Section 5.2.2 and is due to lower average debt in the fixed exchange rate regime (cf. Table 2). When the economy moves towards default in the fixed exchange rate regime the government uses government transfers to stabilize demand for the non-tradable consumption good such that unemployment is alleviated. It does so by borrowing from international financial markets and therefore its interest rate increases strongly. With flexible exchange rates, there is no need to borrow to reduce unemployment. Therefore the sovereign premium rises more slowly and by less.

The extremely high risk premium in the fixed exchange rate regime also indicates the high value of market access for the government. Even with such high interest rates, the government is willing to repay in order to keep its ability to influence unemployment through transfers.

A comparison of the dynamics prior to the default observed in Argentina in 2002:Q1 and the baseline model with fixed exchange rates (solid blue line) reveals that the model is able to replicate that the recession starts prior to the default, an overvalued real exchange rate (high p_t), increasing unemployment peaking in the default quarter and strongly increasing sovereign and private risk premia. The behavior of the non-tradable to tradable ratio in output is not fully consistent with the empirical evidence from Argentina.[23] While the non-tradable to tradable output ratio in the data decreases after the default it remains constant in the model. Argentina floated the exchange rate after the default and experienced a short and deep depreciation. The model with flexible exchange rates (dashed red line) replicates this feature of the data. The model also generates a strong decline in intermediate imports. However, the fall in intermediate imports is too strong in the model, compared to the data.[24]

5.2.4 Welfare Analysis

Finally, I compute the welfare benefit of flexible exchange rates. The welfare gain of flexible exchange rates is measured as the equivalent variation in consumption, given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left((1+\Delta)c_t^*\right) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t^\diamond\right).$$

The symbol $*$ refers to the model with fixed exchange rates and $\diamond$ is the model with the flexible exchange rates. Given the assumption on the utility functions Δ is recovered from

$$\Delta = \left(\frac{V_0^\diamond}{V_0^*}\right)^{\frac{1}{1-\sigma}} - 1.$$

The last row of table 2 reports the welfare gain of flexible exchange rates. Although nominal devaluations are costly as they increase private borrowing costs, households are willing to give up 2.24% of life-time consumption to move from a fixed to a flexible exchange rate regime when they enter the world with zero debt and initial wage $\hat{w}$. This finding is in line with Na et al. (2018) who, however, abstract from private default risk. Moussa (2013) shows that flexible exchange rates are optimal even when the government's debt burden increases with the nominal devaluation rate.

6 Conclusion

In this paper I analyze how exchange rate policies influence the interaction between private and sovereign default risk and explore how the presence of private sector default risk influences welfare in a fixed and a flexible exchange

[23]Due to data availabilty, I measure the relative performance of the tradable and the non-tradable sector in the data using sectoral value added, whereas in the model I measure relative performance of the two sectors using output.

[24]In the model, imports are only intermediate imports from the non-tradable good sector, whereas in the data total imports are considered. Therefore the results are not fully comparable.

rate regime. I develop a dynamic stochastic two sector general equilibrium model of a small open economy featuring private and sovereign default risk. Households inelastically supply labor which is demanded by domestic intermediate input producers. Nominal wages are downward rigid, generating unemployment when exchange rates are fixed. Firms in the non-tradable good sector use domestic and imported intermediate inputs in production. A share of intermediate imports needs to be financed by foreign currency working capital loans. In the flexible exchange rate regime nominal depreciation ensure full employment at the cost of higher private sector default risk. The model is able to account for several characteristics of financial crises in emerging markets. In particular, it is able to generate a high real exchange rate, a growing share of non-tradable production in total output and increasing private sector foreign currency borrowing prior to sovereign default events. After the default the real exchange rate depreciates and the country experiences a deep recession with GDP, imports and credit below trend.

The model also generates countercyclical sovereign and private risk premia. The default incentives of the government increases when the tradable endowment shock falls as it becomes more costly to repay. With higher sovereign default risk, the sovereign bond price falls and the government reduces its transfers to households. The low endowment shock and falling government transfers decrease the equilibrium price of the non-tradable consumption good and reduce the profitability of of non-tradable good firms such that more firms default. This generates countercyclical private spreads.

The countercyclicality of sovereign default risk has also direct implications for unemployment and the nominal exchange rate. A joint fall of endowment and government transfers requires that the real wage falls to clear the labor market. Due to the nominal downward wage rigidity, the real wage cannot fall when the nominal exchange rate remains fixed and involuntary unemployment emerges. With flexible exchange rates, the full employment allocation can be restored by deflating the real wage such that the labor market clears again. But this devaluation comes at a cost. A nominal devaluation induces a further real depreciation and generates higher private default risk.

For low debt levels the private interest rate is lower in the flexible exchange rate regime compared to the fixed exchange rate regime, but increases faster when debt levels rise. There are two effects influencing the different dynamics of the private interest rate in the two exchange rate regimes. First, due to lower sovereign default risk in the flexible exchange rate regime, the government can borrow more and provide higher transfers to households. This increases demand for the domestic non-tradable consumption good and therefore increases its price as well. With higher relative prices for the non-tradable consumption good, private default risk is lower and therefore the private interest rate is lower as well. The second effect works through the nominal devaluation in the flexible exchange rate regime. Since a nominal devaluation generates a decrease of the relative price of the non-tradable consumption good, it also increases private interest rates. When debt levels rise, the devaluation effect becomes stronger as the government uses the exchange rate to clear the labor market in the flexible exchange rate regime. Therefore, at high debt levels, private default risk becomes higher in the flexible exchange rate regime.

Although nominal devaluations are costly in terms of private sector defaults, the flexible exchange rate regime welfare dominates the fixed exchange rate regime. Households are willing to give up 2.24% of life-time income to move from the fixed to the flexible exchange rate regime.

This study takes the exchange rate regime as given, while in the real world the exchange rate is endogenously chosen by the government. An interesting extension of the current study would be to explore the interaction of endogenous default decisions and an endogenous choice of the exchange rate regime.

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A Data Sources

The following summary describes the computation and data source of all variables used in the event study of Section 2 and the calibration exercise. All time series are seasonal adjusted using the X-12 Algorithm implemented in Eviews.

- *GDP:* The time series on real GDP is taken from MECON (Ministry of Economy and Public Finances). It is obtained from Table 1.3 of the publication on Economic Activity. GDP is measured as the sum of value added across all sectors measured at producer prices. The base year is 1993.

- *Sectoral Value Added:* The ratio of non-tradable to tradable value added is computed using data from MECON. The time series are obtained from Table 1.3 of the publication on Economic Activity. Value Added of the tradable good sector is the sum of agriculture, fishing, mining and manufacturing. Sectoral value added is measured at producer prices and the base year is 1993. The average share of tradable value added in GDP used in the calibration is the time series average from 1993:Q1-2000:Q4.

- *Intermediate Imports:* Intermediate imports are obtained from INDEC (National Institute of Statistics and Census of Argentina) and downloaded from Datastream. The original data is in current US$ and is deflated using the corresponding price index.

- *Credit to the private sector:* Credit to the private sector is defined as in Tornell and Westermann (2002). It is measured as claims of deposit taking institutions to the private sector. The data is from the IFS (International Financial Statistics) and is downloaded from Datastream. The raw data is in current Argentine Peso and is deflated using the implicit price deflator of GDP.

- *Unemployment:* The unemployment rate is obtained from Oxford Economics and is downloaded from Datastream.

- *Nominal Exchange Rate:* The nominal exchange rate is the US$/Peso market based exchange rate obtained from the IFS. The data is downloaded from Datastream.

- *Real Exchange Rate:* The real exchange rate is computed using the nominal exchange rate and the CPIs of the United States and Argentina. The Argentinian CPI is taken from OECD.Stat and the U.S. CPI is taken from IFS.

- *Sovereign Spread:* The sovereign risk premium is the blended spread taken from J.P. Morgans EMBI Global index of Argentina. The data is downloaded from Datastream.

- *Private Spread:* The the private premium is calculated as the difference between short-term bank credit interest rate in US$ (IFS) and the 3-month US T-Bill (Source). The data is downloaded from Datastream.

- *Intermediate Inputs:* Domestic and imported intermediate inputs used in the non-tradable good sector are obtained from the 1997-IO Table of Argentina. The Input Output table is downloaded from OECD.Stat.

B Numerical Algorithm

The following algorithm is used to solve the model:

1. Start by discretizing the endogenous and exogenous states:

   (a) Discretize the endowment shock of the tradable consumption good using the method proposed by Tauchen (1986). The grid $z \in [-5\sigma_z, +5\sigma_z]$ consists of 55 equally spaced point.

   (b) Discretize the state space for debt, $b \in [-0.09, 0]$ with 71 equally spaced points.

   (c) Construct a grid for the inherited wage w_{t-1}. The lower bound of the grid is the labor market clearing wage, w_t^f, that solve the private sector equilibrium with maximum debt, no borrowing and the lowest possible realization of the endowment shock. The upper bound is the labor market clearing wage, w_t^f, that solve the private sector equilibrium without debt, maximum borrowing at the risk free rate and the highest possible realization of the endowment shock. The size of this grid is 150.

2. Start with a guess for borrowing $\mathcal{B}^0(z, b, w_{-1}, s) = 0$, bondprice $q^{0,0}(z, b, w) = \frac{1}{R}$ and value functions $V^{R(0,0)}(z, b, w_{-1}) = 0$ and $V^{D(0,0)}(z, w_{-1}) = 0$ for all states.

3. Compute the private sector equilibrium:

   (a) Find the wage $\tilde{w}$ such that

   $$I = b - q^{i,j}(z, \mathcal{B}^j(z, b, w_{-1}, s), \tilde{w})\mathcal{B}^j(z, b, w_{-1}, s) + f^T(z, s)$$

   and

   $$\tilde{w} = \mathcal{W}(\epsilon, I, w_{-1}, p^{M\star})$$

   hold. If this wage is off the wage grid use linear interpolation.

   (b) Store the corresponding equilibrium allocation, compute consumption and instantaneous utility.

4. Compute expectations. Obtain $V^{R(i,j)}(z_k, \mathcal{B}^j(z, b, w_{-1}, s), \tilde{w})$ and $V^{D(i,j)}(z_k, \tilde{w})$, for all attainable z-values on the grid. If $\tilde{w}$ is off the grid linear interpolate. Use the transition probability matrix to compute the expectations.

5. Given expectations and instantaneous utility, compute the new value functions $V^{R(i+1,j)}(z, b, w_{-1})$ and $V^{D(i+1,j)}(z, w_{-1})$ and the corresponding bond price function $q^{i+1,j}(z, b, w)$ taking into account the default decision.

6. Iterate on the value function until it converges for a given $\mathcal{B}^j(z, b, w_{-1}, s)$.

7. Solve for the optimal borrowing decision $\mathcal{B}^{j+1}(z, b, w_{-1}, s)$, given bond price function $q^{i,j}(z, b, w)$ and value functions $V^{R(i,j)}(z, b, w_{-1})$ and $V^{D(i,j)}(z, w_{-1})$. If $\max\{|\mathcal{B}^j(z, b, w_{-1}, s) - \mathcal{B}^{j+1}(z, b, w_{-1}, s)|\} < \varepsilon$ stop. Otherwise, go to step 3.