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On the pass-through of large devaluations*

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Abstract

In 2002 Uruguay faced a sudden stop of international capital flows, inducing a deep financial crisis and a large devaluation of the peso. The real exchange rate depreciated and exports expanded. Paradoxically, export shares and real exchange rates negatively correlate among Uruguayan exporters around 2002. To unravel this paradox, we develop a small open economy model of heterogeneous firms. Domestic firms are price takers in the international market, operate under monopolistic competition in the domestic market, and face financial constraints when exporting. Confronted to a large nominal devaluation, financial constraints deepen. Financially constrained exporters cannot optimally expand in the export market and react by passing-through the devaluation to the domestic price only partially, expanding domestic sales. As a consequence, the more financially constrained exporters are, the less their export shares expand and the more their firm specific real exchange rates depreciate. As a result, export shares and real exchange rates of exporters are negatively correlated as in the data.

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1 Introduction

In 2002 Uruguay faced a sudden stop of international capital flows, inducing a deep financial crisis and a large devaluation of the peso vis-à-vis the dollar. The reaction of the aggregates was in line with other episodes of large nominal exchange rate devaluations in emerging markets, which are generally followed by an important depreciation of the real exchange rate (RER) and an expansion of exports. In their seminal paper, Burstein et al. (2005) document a large depreciation of the real exchange rate for a set of large devaluation episodes. In a more recent paper, Alessandria et al. (2020) report evidence of a positive even if sluggish reaction of exports to large devaluations.[1]

The main contribution of this paper is to document and provide an explanation to the paradoxical fact that in the large devaluation episode suffered by Uruguay in 2002, and despite the simultaneous observation of a depreciation of the real exchange rate and an expansion of aggregate exports, the correlation between firm specific export shares of manufacturing exporters and their real exchange rates was negative. The firm specific export share is measured as the ratio of exports to total sales, and the firm specific real exchange rate as the ratio of export prices to domestic prices, both denominated in pesos. Exporters reporting large expansions in their firm specific export share are those facing small depreciations of their real exchange rate.

A standard trade model with heterogeneous firms cannot replicate this fact, since a depreciation of the real exchange rate is expected to raise export shares. The larger the depreciation faced by a firm, the higher the raise in its export share. In the Melitz (2003) framework, for example, an exogenous depreciation of the real exchange rate could be easily modelled as an asymmetric shock affecting variable trade costs: from the point of view of the country facing the RER depreciation, the iceberg trade cost faced by exporters reduces and the iceberg trade cost of imports increases.[2] A reduction in variable export costs expands exports in both margins. In the extensive margin, since profits from exporting raise, the marginal non-exporter becomes exporter.[3] In the intensive margin, a

[1]Their finding is in accordance with the conclusions by Reinhart (1995) that in developing countries even if relative prices are a significant determinant of the demand for exports, price elasticities tend to be low, suggesting that large relative price swings are required to have an appreciable impact on trade patterns.

[2]Alternatively, as in Atkeson and Burstein (2008), a real exchange rate movement in a multi-country trade model may result from an exogenous change in relative TFPs across countries.

[3]Alessandria et al. (2020) document the working of the extensive margin in large devaluation episodes,

reduction in the price of exports relative to the domestic market raises the export share of exporters. Moreover, if the reduction in variable trade costs were heterogeneous across exporters, the larger the exporter specific real exchange rate depreciation, the higher the raise in the export share.

To replicate the observed negative correlation between firm specific export shares and firm specific real exchange rates, we develop a heterogenous firm small open economy model with financial frictions. The main mechanism relies on a firm specific incomplete *pass-through* from the nominal exchange rate to domestic prices. Two critical sets of assumptions are in play. Under these assumptions, exporters fully pass-through a nominal devaluation to the export price. However, they partially pass it through to the domestic price depending on their capacity to expand on the export market, which critically depends on their liquidity. The more constrained an exporter is on expanding abroad, the less it passes the devaluation through to its domestic price, expanding in the domestic market. Consequently, changes in firm specific real exchange rates are endogenous and negatively correlated with changes in firm specific export shares. Let us be more precise on these two sets of assumptions.

First, in the home country firms operate a Lucas (1978) span of control technology, jointly producing for both the domestic and foreign markets. They are price takers in the international market, the export price being set in the foreign currency, but monopolistically compete in the domestic market. The price taker assumption in the export market is suitable for small open economies like Uruguay exporting a set of relatively undifferentiated manufacturing goods, based on agricultural comparative advantages. Prominent examples of natural resource-based, commodity-type Uruguayan exports are slaughtering, preparing and preserving meat, spinning, weaving and finishing textiles, grain mill products, manufacture of dairy products, tanneries and leather finishing, and canning, preserving and processing of fish, among many others –see Appendix A for a detailed analysis of the issue. Under this assumption, price taker exporters fully pass-through a nominal devaluation to the export price. In the context of Uruguay, in which most trade is denominated in US dollars, this assumption is equivalent to the dominant-currency paradigm suggested by Gopinath et al. (2020). Moreover, given the small dimension of the local market, home firms are assumed to domestically differentiate their products, operating under monopolistic competition. Under these assumptions, in a frictionless world, exporters set the domestic price by charging a constant markup on the export

including the large devaluation of the Uruguayan peso in 2002.

price. Since the same unit could be exported or traded domestically, when selling in the domestic market, the export price operates as an opportunity cost. Consequently, in a frictionless world, exporters fully pass-through a nominal devaluation of the local currency to both the export price and the domestic price when both prices are measured in local currency.

Second, inspired by the seminal work of Manova (2013) and Chaney (2016), we assume that domestic firms are required to finance in advance fixed and variable export costs, affecting both the extensive and intensive export margins. The need of financing fixed export costs affects the decision of participating in the export market, while the need of financing variable export costs limits the capability of exporters to freely expand abroad. To be more precise, firstly, firms are assumed to be endowed with a firm specific liquidity, which under these assumptions affects the decision of participating in the export market and, conditional on exporting, it triggers a firm specific export quantity constraint. Second, firm's liquidity is supposed to depend on aggregate liquidity, assumed to be negatively affected by a devaluation of the domestic currency. This assumption has the direct implication that devaluations will be associated to a decline in liquidity, which couples a large devaluation with a financial crisis, like we have observed in Uruguay at the year 2002. Third, at the firm level, available liquidity is assumed to be increasing in firms productivity, reflecting the fact that larger, more productive firms have better access to the financial system. How do under these assumptions financial constraints affect the pass-through? As explained in the previous paragraph, exporters fully pass-through a nominal devaluation to the export price. However, when financially constrained, they only pass it partially through to domestic prices. Financially constrained exporters cannot expand in the export market as much as they would like. As a consequence, they optimally decide instead to expand in the domestic market by passing-through the devaluation to the domestic price only partially. The less financially constrained an exporter is, the more it passes through the devaluation to the domestic price, and the less it depreciates its real exchange rate while expanding in the export market. Following a devaluation of the domestic currency, changes in the export share of exporters are then negatively associated with a depreciation of their real exchange rate.

Section 2 discusses the related literature. Section 3 describes the 2002 crisis and empirically motivates our analysis by stating the above mention paradox. Section 4 describes and then studies the equilibrium of the model economy. Section 5 calibrates de model and shed some light on the Uruguayan paradox. Section 6 concludes.

2 Literature review

This section reviews the relevant literature.

Small open economy: In the framework of a heterogenous firms trade model à la Melitz (2003), Demidova and Rodríguez-Clare (2009, 2013) study the welfare gains from trade in small economies. We use a similar but more stringent version of the small economy concept in Demidova and Rodríguez-Clare (2009, 2013), and differently from them we study the pass-through of nominal devaluations. In our *small open economy*, not only the price of imports and the demand schedule faced by exporters are taken as given, but the demand elasticity of exports is also assumed to be infinitely large, i.e., exporters are price takers in international markets.[4]

Financial constraints: Manova (2013) and Chaney (2016) study trade models of heterogeneous firms with credit and liquidity constraints, respectively. In Chaney (2016), firms are endowed with a firm specific liquidity, positively correlated with firm's productivity, which is needed to cover fixed export costs. Liquidity constrains negatively affect then the export extensive margin. Since firms' liquidity is nominated in the local currency, an appreciation of the exchange rate has the effect of increasing liquidity allowing the marginal non-exporter to enter the export market. In Manova (2013), exporters face credit constraints to finance not only fixed but variable trade costs, affecting both the export extensive and intensive margins. She finds significant effects of credit constraints on trade, of the order of 20% to 25%, with one third due to the extensive margin and two thirds due to the intensive margin, concluding that financial development plays an important role in the adjustment to exchange rate movements, among other shocks.

Both ways of modelling are highly relevant for the study of large devaluation, which generality ocurre simultaneously with a financial crisis, generating an important reduction of liquidity and a large increase in credit constraints. Like in Chaney (2016), we assume that firms face liquidity constraints when operating in the export market, with firm specific

[4]The behavior of small open economies with perfectly competitive product markets is studied in Finn (1990), Cardia (1991), Mendoza (1991), Correia et al. (1995) and Schmitt-Grohé and Uribe (2003), among others. In this literature, the economy is small in the sense that it does not affect international prices. Exporters, indeed, are assumed to be price takers since product markets are perfectly competitive. When these assumptions are combined with financial frictions, as discussed below, the pass-through of nominal devaluations to firm specific export and domestic prices endogenously determine the firm specific real exchange rate.

liquidity being denominated in the local currency and positively related to productivity. Nominal devaluations are then associated to financial crisis, since they reduce the value in the foreign currency of firms liquidity, negatively affecting exporters, with low productivity exporters being more affected. Following Manova (2013), we assume that not only fixed export costs but also variable trade costs need to be financed in advance. This introduces the possibility that firms are constrained in the intensive margin, i.e. exporting less than optimal and partially passing-through nominal devaluations to the domestic price. This assumption turns out to be critical for the main contribution of this paper, introducing a new channel leading to incomplete pass-through and exchange rate disconnect. When the economy faces a large devaluation, firms' liquidity contracts in the foreign currency generating a financial crisis. Since firms face additional constraints for expanding in the export market, firm specific real exchange rates endogenously depreciate disconnecting the change in domestic prices from the change in export prices.

Local-currency pricing, producer-currency pricing and the dominant-currency paradigm. Engel (2002) uses the distinction between local-currency pricing and producer-currency pricing to study the desirability of flexible vs fixed exchange rate policies under *price stickiness*. Under *producer-currency pricing* nominal prices are set in the currency of producers. When producers' prices are sticky in the foreign currency, a devaluation is fully passed-through to consumer prices, raising the domestic price of imported goods and switching consumption from imported to domestic goods. This is the well-known *expenditure switching effect* supporting the desirability of flexible exchange rate regimes –see Obstfeld and Rogoff (1995, 1998, 2000), as well as Lane (2001) for a survey. However, under *local-currency pricing*, nominal prices are sticky in the domestic currency. A devaluation is only passed-through partially to consumer prices, which critically reduces its expenditure switching effect, questioning the desirability of flexible exchange rates –see Betts and Devereux (2000), Chari et al. (2002), and Devereux and Engel (2002), among others. On the empirical side, Gopinath et al. (2010) find for the US strong evidence that the path-through of nominal devaluations is almost complete (95%) when American imports are invoiced in a foreign currency, but highly incomplete (25%) when they are invoiced in dollars.

More recently and based on the observation that most international trade is invoiced in a few dominant currencies, Gopinath et al. (2020) test the alternative assumption that "firms set export prices in a dominant currency (most often the dollar) and change them infrequently." This is the *dominant-currency paradigm* hypothesis. Consistently with the dominant-currency paradigm, they find that, for a globally representative dataset on bilateral trade, the pass-through to export and import prices is quantitatively dominated by the dollar exchange rate.

In a highly dollarized small open economy, as it is the case of Uruguay, most import and export prices are set in dollars. For this reason and in line with the dominant-currency paradigm, we model the Uruguayan economy as a small open economy taking as given export and import prices, both invoiced in dollars. In this framework, dominant-currency pricing is equivalent to assume that imports are set under producer-currency pricing but exports are set under local-currency pricing. Since both prices in dollars are taken as given by domestic agents, price taking behavior in a small open economy is an extreme case of price stickiness in foreign markets. More important, in this framework, the mechanics explaining the Uruguayan paradox operates through a particular *expenditure switching channel*. Depending on the degree of financial constraints faced by exporters, nominal devaluation pass-through to firm specific domestic and export prices differently: Domestic consumption switches then from less constrained to more constrained exporters. This mechanism rationalise the observed negative correlation between firm specific real exchange rates and expenditure shares reported in this paper.

Pricing-to-market. In an imperfectly competitive framework with variable markups, the *pricing-to-market* literature studies the heterogeneous reaction of exporters to changes in real exchange rates –see Bergin and Feenstra (2001) and Atkeson and Burstein (2008), among others. The main prediction is that the more productive a firm is, the more it absorbs exchange rates movements in its markup. Using French firm level data, Berman et al. (2012) test the main predictions of the pricing-to-market approach, i.e, the elasticity of export prices (quantities) to a real exchange rate change is increasing (decreasing) with firm's performance –see also Berman et al. (2015). Atkeson and Burstein (2008) model *pricing-to-market* under Cournot competition as "the decision of a single producer to change the relative price at which he sells his output abroad and at home in response to changes in international relative costs." In their framework, pricing-to-market helps quantitatively replicating observed deviations from relative purchasing power parity.

In this paper, like in Atkeson and Burstein (2008), pricing-to-market operates through changes in relative markups. However, we use a different mechanism allowing to study the effect of nominal devaluations. By *pricing-to-market*, we mean the decision of a single exporter to change the relative price at which she sells her output abroad and at home in response to changes in the nominal exchange rate. Differently to Atkeson and

Burstein (2008), we assume exporters produce a single product under decreasing returns, are price takers in the international market but set domestic prices under monopolistic competition, and may be financially constrained on their exports. In a frictionless economy, since they are price takers in the foreign market, the export price is their opportunity cost for selling in the domestic market. Exporters set the domestic price as a constant markup on the international price, the markup depending as usual on the elasticity of substitution across varieties. Financially unconstrained exporters will then fully pass-through any nominal devaluation to both domestic and export prices, implying that their firm specific real exchange rate remains constant after a devaluation. However, financially constrained exporters cannot expand freely in the export market. The more financially constrained they are, the less they produce, the more they reduce their marginal costs and domestic prices, the more they sell in the domestic market, and implicitly the larger is the markup they charge when selling abroad. The markup charged on export prices positively depends on the marginal value of the financial constraint. This novel version of the *pricing-to-market* approach is at the root of the main contribution of this paper, i.e., understanding the negative correlation between firm specific real exchange rates and export shares observed in Uruguay after the 2002 large devaluation of the peso.

Exchange rate disconnect. Some papers in this literature stress the fact that large movements in nominal exchange rates have small effects on the price of exports and imports. The so-called *exchange rate disconnect*.[5] Rodríguez-Lopez (2011) emphazises the role played by movements in the extensive margin to explain the *disconnect* between exchange rate depreciations and both firm level and aggregate import prices. Amiti et al. (2014) base their contribution on the fact that large exporters are frequently large importers of inputs. Using firm level data for Belgium manufacturers exporting to high-income OECD countries outside the euro area, they observe that the pass-through to export prices (in euro) is of around 20%, larger for firms with larger import intensity. As reported by Lyonnet et al. (2021), it is important to notice that exporters located in the European Union invoice in euro around 90% of their exports outside the euro area. Their pass-through of nominal devaluations to export prices is dominated by producer-currency

[5] For a discussion on the exchange rate disconnect see the recent contribution by Itskhoki and Mukhin (2021). They adopt a more general view, referring to it as "the lack of correlation between exchange rate and other macro variables." See also the seminal work by Devereux and Engel (2002) providing a rationale to the observation that high exchange rate volatility may have little effect on macroeconomic variables.

pricing. Uruguayan exporters, indeed, invoice their exports in dollars and, as reported in Appendix A, their pass-through of nominal devaluations to export prices in pesos is full. For this reason, and in order to concentrate in the understanding of the pass-through of nominal devaluations to export and domestic prices, we omit imported inputs in our modelling strategy.

This paper stresses a different form of the exchange rate disconnect where financial frictions play a fundamental role. When large devaluations ocurre simultaneously with a financial crisis, exporters struggle increasing their exports, optimally expanding in the domestic market by not fully passing-through the devaluation to the domestic price. The larger the financial constraint is, the less they expand in the export market, and the less they pass-through the devaluation to the domestic market. In this sense, the negative correlation between firm specific export shares and real exchange rates observed in Uruguay around 2002 can be interpreted as a particular form of exchange rate disconnect.

Large devaluations. Burstein et al. (2005, 2007) study the pass-through of changes in the nominal exchange rate to prices during large devaluations episodes.[6] They conclude that the primary force behind the large real exchange depreciation that follows large devaluations is "the slow adjustment in the prices of nontradable goods and services." Concerning the manufacturing sector, which produces goods that are fundamentally tradable, Burstein and Gopinath (2014) report that following large devaluations "the rise in prices of imports at the dock is significantly higher than the increase of tradable consumer prices." This paper documents for the large devaluation of Uruguay in 2002 a symmetric effect for the export prices. It is important to notice that large devaluation episodes usually arise in emerging markets, very often subject to dominant-currency pricing for both exports and imports –as reported by Gopinath et al. (2020). Since imports and exports are invoiced in a dominant currency (frequently dollars), large devaluations of the local currency are largely passed-through to import and export prices but partially to domestic prices of domestically produced tradable goods.

Kohn et al. (2020) quantitatively assess the extent to which frictions in financial markets affect aggregate export dynamics in large devaluation episodes. To this end, they study a Melitz (2003) type trade model with financial frictions in an economy with both

[6] See also Borensztein and De Gregorio (1999). They study 41 episodes of currency crisis and conclude to the pass-through from devaluation to inflation is incomplete producing long lasting changes in the real exchange rate.

domestic-denominated and foreign-denominated debt. They use Mexican plant level data around the 1994 large devaluation of the peso to discipline the analysis. In their model, the negative impact of a large devaluation on exports comes through the balance-sheet effects of the increased domestic value of the foreign-denominated debt. However, since tougher financial frictions, and the associated balance sheet effect, operate by tightening total firm's output, they report a modest quantitative effect of the large devaluation on exports. As suggested by Kohn et al (2020), "frictions to the reallocation of sales across markets might play an important role in accounting for the dynamics of exports in large devaluations." In our paper, financial frictions by restricting export activities only make a nominal devaluation have reallocation effects. Financially unconstrained exporters move sales from the domestic to the export market, while highly constrained exporters do the opposite.

In the context of large devaluations, Blaum (2019) studies the joint export and import behavior of exporters. He observes that the reallocation of resources towards import intensive exporters, after a large devaluation, raises the aggregate share of imported inputs in total input spending. As pointed out above, most Uruguayan manufacturing exporters transform locally produced commodities. In Blaum (2019), large exporters are highly integrated in global production networks. This is not the case of most Uruguayan exporters, which provide a first manufacturing treatment to locally produced commodities. In the best scenario, their production moves downstream in a global production network.

3 Main facts

This section first describes some key aggregate facts around the 2002 financial and balance of payment crisis in Uruguay. Second, it presents motivating empirical evidence showing that after the large devaluation of the Uruguayan peso against the dollar in 2002, though as expected the export share of the manufacturing sector increased following a real depreciation of the exchange rate, at the micro level the correlation between firm specific export shares and real exchange rates was negative. We refer to this fact as the *Uruguayan paradox.*

3.1 General context

In 2002, Uruguay faced a balance of payment crisis, a financial crisis, and a large depreciation of the nominal exchange rate that strongly affected relative prices, production and exports.

Figure 1 shows the exchange rate of the Uruguayan peso *vis a vis* the US dollar, the Argentinean peso and the Brazilian real. In 1999, Brazil undertook a 66% depreciation of the real against the dollar; then, following the financial crisis in Argentina, in December 2001 the Argentinian peso depreciated around 400% against the dollar; finally, in June 2002, the Uruguayan peso depreciated 100% against the dollar. These nominal movements were associated with large movements in bilateral real exchange rates, coincident with the fact generally observed in the literature that domestic prices take time to adjust –see the discussion in Section 2.

The balance of payments crisis was accompanied by a financial crisis, including a bank run, public debt restructuring, and a sharp contraction of credit to the private sector, both nominated in domestic and foreign currencies. As shown in Figure 2, around 2002 total bank credit nominated in both Uruguayan pesos and dollars deeply declined, and the decline lasted long. The Argentinean devaluation added constraints to Uruguayan exporters: Argentinean markets collapsed in 2002 and Argentina devaluated more than Uruguay, substituting Uruguayan exports in some third markets. These two effects add to the financial constrains faced by Uruguayan exporters due to the financial crisis, making for them even more difficult to export.

Let us now give some direct evidence on the positive correlation between the export share and the real exchange rate at the aggregate level for the manufacturing sector in Uruguay during the period of study. Figure 3 displays the export share of the Uruguayan manufacturing sector (total FOB manufacturing exports divided by total manufacturing production) emerging from national accounts data, both at current and 1997-constant prices. We see that after the 2002 devaluation there is a significant reallocation of manufacturing production towards the international market.

For the manufacturing sector, Figure 4 shows the implicit National Accounts deflators of both domestic production and exports, as well as the real exchange rate –measured as the ratio of the export to the domestic deflators. After the 2002 depreciation, export prices double following the 100% devaluation of the Uruguayan peso against the American dollar, an indirect evidence of Uruguayan exporters being price takers in the international market. Domestic prices, that were likely overvalued before 2002, follow but at a slower path. The pass-through of the nominal devaluation to the domestic prices is initially partial. Consequently, the real exchange rate increases by more than 20% between 2002

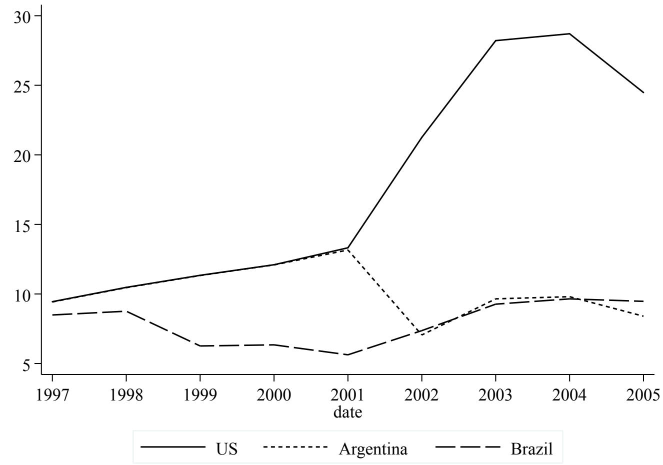

Figure 1: Exchange rate (Uruguayan peso) against US, Argentina and Brazil

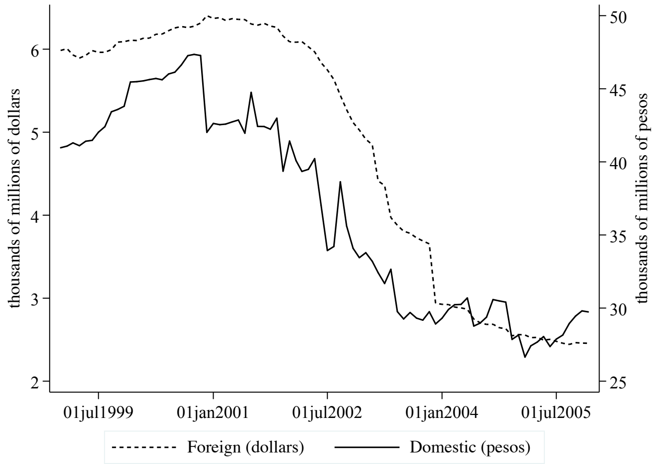

Figure 2: Banking credit to the resident private sector

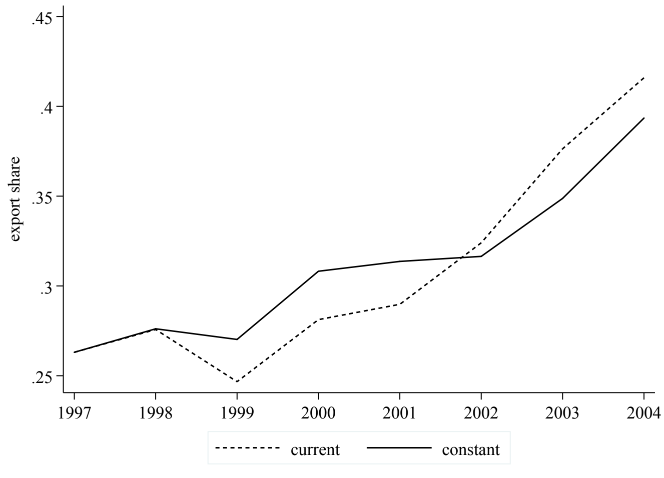

Figure 3: Export share of the manufacturing sector at current and constant prices

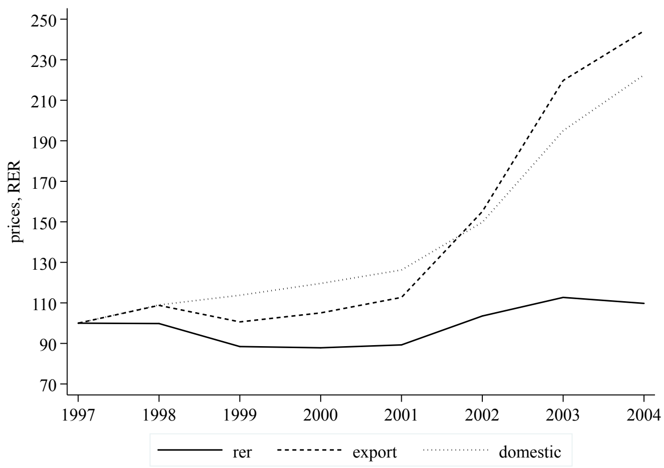

Figure 4: Domestic prices, export prices and real exchange rate of the manufacturing sector

and 2004.[7]

Combining these two pieces of information it is easy to see that between 1997 and 2004, the real exchange rate –measured as the price of exports relative to the price of domestic sales– and the export share of the Uruguayan manufacturing sector –measured as the ratio of exports to total production– are positively correlated. The 2002 nominal devaluation of the Uruguayan peso against the dollar is reflected in a large increase in the real exchange rate followed by a large raise in the export share. If we interpreted this evidence from the point of view of a model with a representative firm, this would indicate that manufacturing firms facing a depreciation of the real exchange rate would respond by increasing their export share. However, as we show below, we do not observe a positive correlation between the real exchange rate and the export share at the micro level.

3.2 Uruguayan paradox

This section provides evidence for Uruguayan manufacturing exporters of a significant negative correlation at the firm level between export shares and real exchange rates around the 2002 large devaluation of the Uruguayan peso. For this purpose, we use two different datasets produced by the Uruguayan Institute of National Statistics (Instituto Nacional de Estadística, INE): the Annual Economic Activity Survey (Encuesta Anual de Actividad Económica, EAAE) for period 1997-2005, and the Monthly Survey (Encuesta Mensual)

[7]Sector-level dollar FOB export price indexes (based on custom data) and domestic producer price indexes are provided by the Central Bank of Uruguay (BCU). Our measure of the manufacturing sector real exchange rate (RER) is the ratio of both.

for January 2002 to December 2005.

To emphasize that the main result is governed by the 2002 devaluation, we run a first-difference regression (before and after the 2002 devaluation) between firm specific export shares and real exchange rates, and obtain the result that after controlling for idiosyncratic characteristics, the micro relation between real exchange rates changes and export shares changes is negative.

Annual Economic Activity Survey (EAAE). The EAAE is an annual survey of manufacturing firms reporting, among other variables, revenue, employment, purchases of intermediate inputs (domestic and imported), investment, wages, and domestic and export sales.[8] The EAAE does not report individual prices. We proxy them using sectorial price data for domestic sales and exports constructed by the Central Bank of Uruguay, and use them to build a sectorial measure of the real exchange rate, measured as the ratio of export to domestic prices, both in pesos. We compute firm export shares using export and domestic sales in pesos both deflated by their respective price indexes.

Monthly Survey. The INE Monthly Survey, starting in January 2002, includes for each firm, sales and a specific producer price index for domestic sales and exports at 4-digit ISIC class product. We aggregate them into firm specific Paasche export and domestic price indexes. To avoid high variability of monthly data as well as entry and exit in the sample due to firms not exporting all months, we use quarterly averages.[9]

Estimations using the EAAE. For the EAAE sample, to emphasize the special nature of the large 2002 devaluation, we look for a before-after comparison, averaging annual firm data for 1999-2001 (period 1) and 2003-2005 (period 2). Let us start from a panel equation, for $t = 1, 2$, in which the export share of firm i in period t, xs_{it}, depends on the log of the firm specific real exchange rate, rer_{it}, including unobserved i.i.d. shocks u_{it} and firm time invariant unobserved heterogeneity c_i. Then, by defining first differences $\Delta xs_i = xs_{i2} - xs_{i1}$ and $\Delta \log rer_i = \log rer_{i2} - \log rer_{i1}$, we obtain the first difference

[8] In the EAAE, two firm strata are defined within each 4-digit ISIC sector: firms larger that hundred employees are all in the survey, while a representative random sample is taken from the set of smaller firms. We consider exporters firms that have positive exports at least one year in the sample, so both zero and one export share values are present in the data. Constant prices export shares are deflated by sectorial prices, consistently with rest of the database.

[9] In quarters in which firms do not both export and sell domestically, observations remain missing.

equation

$$\Delta xs_i = \beta \Delta \log rer_i + \Delta u_i, \tag{1}$$

where the firm fixed effect is differenced out. Estimating (1) by OLS, β gives the correlation between real exchange rates and export shares.

In the first column of Table 1, we observe that in the EAAE, changes in firm specific export shares and changes in sectorial real exchange rates are negatively correlated, with a highly significant estimated β of minus 0.145. Given the functional form, it means that a unit increase in the difference in logs of the real exchange rate (i.e. approximately doubling the real exchange rate) is associated to a reduction in the firm's export share in about 14.5 percentage points.

Since the negative unconditional correlation can well become positive when conditioning on other regressors, we investigate if the sign of the estimated unconditional correlation is robust to the inclusion of other firm specific covariates describing the firm's environment when allocating output between domestic and export sales. We consider firm specific measures of the real wage, total factor productivity and imported inputs share. To measure the firm specific real wage, we use the firm specific nominal wage per worker deflated by the firm's sectorial product price index. Firm specific productivity is estimated using the Olley and Pakes (1996) methodology. Some literature suggests a role for imported inputs in determining the exchange rate pass-trough –see for example Amiti et al. (2014). For this reason, we also include the firm specific imported input share as a control in our estimation. As can be observed in the second column of Table 1, positive and significant coefficients are obtained for the firm specific productivity and import share. Adding these controls does not however wipe the strong and significant effect of the real exchange rate on the export share.

We do not claim that our statistical results measure a causal effect, but rather establish a correlation and introduce adequate controls in its measurement. We do not add firm size as a control, since, as in trade models, firms' employment decisions are based on technology, production costs and prices, already included in the regression. We do not add financial variables as controls, since this information is not available in our dataset. As we will argue below, financial constraints play a decisive role in firm pricing decisions (*i.e.* the exchange rate pass-through to domestic prices) and hence determine the export share. Our model strategy will be to link firm's liquidity to productivity according to the observed fact in the literature that more productive firms are not only larger but also less financially constrained. In this sense, the effect of financial frictions is partially captured

Table 1: Manufacturing firm 3-year averages data (1999-2001 /2003-2005)

Dependent variable is firm first difference in export share Δxs_i All explanatory variables in first differences		
Estimation	OLS	OLS
Δ log rer	-0.145***	-0.099***
	(0.031)	(0.037)
Δ log real wage		-0.002
		(0.030)
Δ log tfp		0.091***
		(0.027)
ΔImported input share		0.096**
		(0.045)
Observations	380	371
R-squared	0.054	0.079
*** significant at 99%; ** significant at 95%; * significant at 90%		

by productivity.

Estimations using the Monthly Survery. We also investigate whether the negative correlation of specific real exchange rates and export shares obtained using the EAAE survey is an artefact of using sectorial instead of firm prices. To this purpose, we use the Monthly Survey data. The only observations in the Monthly Survey available from before the large 2002 devaluation are those of the first quarter of 2002, so they will become our benchmark comparison set. We undertake here the same estimation in differences as in Table 1, but differences in export shares and real exchange rates will be taken with respect to quarter 2002:1, four quarters ahead.[10] The only firm-level control variable available is sales to proxy for size.[11] Results are displayed in Table 2.

Our results show that the negative correlation between export shares and real exchange

[10]We have also performed estimations for two and three quarters ahead. As expected, the size of the negative correlation increases with the delay, since firms require some time to adjusts quantities and prices after a large devaluation.

[11]Firm level data on wages and productivity are not available in the Monthly Survery. However, productivity is expected to be highly correlated to sales.

Table 2: Manufacturing quarterly data (2002:1 vs 2003:1)

Dependent variable is Δ export share All explanatory variables are in differences		
Estimation	OLS	OLS
$\Delta \ln rer_i$	-0.178***	-0.123***
	(0.050)	(0.047)
$\Delta \ln sales_i$		0.128***
		(0.024)
Observations	137	137
*** significant at 99 %; ** at 95 % ;* at 90 %		

rates holds also when firm specific prices are used instead of sectorial prices. The negative correlation is slightly larger (in absolute terms) than using sectorial prices, meaning that sectorial prices capture the effect only partially. Moreover, the negative correlation declines when using sales as controls (as it declines when using productivity and imported input shares in the EAAE estimation above).

Summary: This subsection documents the Uruguayan paradox. Around the large devaluation of the Uruguayan peso in 2002, though the export share of the manufacturing sector increased following the depreciation of the real exchange rate, at the micro level the correlation between export shares and real exchange rates was negative. The following sections develop a trade model of heterogeneous firms aimed at replicating these observations.

4 Model economy

The trade model in this paper aims at understanding the pass-through of nominal devaluations to the domestic price of exporters in a small open economy where exporters are price takers in the international market, price makers in the domestic market, and face financial constraint to export.

4.1 General description

In a static framework, this section describes a small open economy trading with the rest of the world. We will refer to it as the home economy.

Households. In the home economy, there is a continuum of identical households of unit mass. Preferences of the representative household are logarithmic on a domestic composite good c_d and a homogeneous imported good c_m. They are represented by the utility function

$$u(c_d, c_m) = \beta \log c_d + (1-\beta) \log c_m, \tag{2}$$

where β, $\beta \in (0,1)$, is the weight of the domestically produced composite good in consumption utility. Let us denote by P_d and P_m the prices of the domestic composite good and the imported good, respectively, both measured in the local currency. The import price can be decomposed into two terms, the nominal exchange rate e and the foreign currency import price p_m, i.e., $P_m = ep_m$. Both e and p_m are exogenously given. Under logarithmic preferences, total expenditure in the domestic good is proportional to total expenditure in the imported good, i.e.,

$$P_d c_d = \frac{\beta}{1-\beta} P_m c_m.$$

Preferences for domestically produced goods are represented by

$$c_d = \left(\int_z q_d(z)^\rho \, \mathrm{dF}(z) \right)^{\frac{1}{\rho}},$$

where $q_d(z)$ is domestic consumption of variety z, F(z) is the equilibrium distribution of firms along dimension z, and $\frac{1}{1-\rho}$, $\rho \in (0,1)$, is the elasticity of substitution between domestic varieties. Consumers maximize c_d subject to a standard budget constraint. At given domestic prices $p_d(z)$, the optimal inverse demand of domestic variety z is

$$p_d(z) = P_d c_d^{1-\rho} \, q_d(z)^{\rho-1}, \tag{3}$$

where

$$P_d = \left(\int p_d(z)^{\frac{\rho}{\rho-1}} \, \mathrm{dF}(z) \right)^{\frac{\rho-1}{\rho}}$$

is the true price index of the composite domestic good.

Firms. We see Uruguayan exporters as price takers in the international market, exporting commodity-type goods based on natural resource comparative advantages. Consequently, they fully pass-through nominal exchange rate devaluations to export prices.

This view is consistent with Uruguayan custom data showing no response of dollar export prices to nominal devaluations.[12] However, we argue that domestic prices are endogenous, depending on firm characteristics. This affects the real exchange rate that is the ratio of the two.

Let us assume there is a unit mass of domestic firms. They operate under monopolistic competition in the domestic market but are price takers in the export market. Firm z jointly produces quantities $q_d(z)$ and $q_x(z)$ for the domestic and foreign markets, respectively. Its production technology is

$$q_d(z) + q_x(z) = z^{1-\alpha}\, \ell_p(z)^{\alpha}, \tag{4}$$

where ℓ_p is the total amount of flexible labor required to produce $q_d + q_x$; $q_d \geq 0$, $q_x \geq 0$ and $\alpha \in (0,1)$. Domestic firms cannot import, instead of exporting, and sell the imported good in the domestic market. To save notation, we use z to denote both the firm type and the productivity of the firm. Firm specific productivity z is drawn from the distribution $\Phi(z)$, $z \in (\underline{z}, \infty)$, $\underline{z} > 0$.

Local firms take the export price nominated in the domestic currency ep_x as given, where $p_x(z)$ is the FOB international price of exports measured in the foreign currency, and e is the nominal exchange rate. Moreover, they face an iceberg variable trade cost $\tau > 1$. The CIF export price is then $\tau p_x(z)$.

Local firms also face fixed production costs and fixed export costs. Fixed production costs are equal to wh_p where w is the equilibrium domestic nominal wage and h_p an exogenous amount of labor. Fixed export costs are given by $ef_{\$}$, where $f_{\$} > 0$ is an exogenously fixed cost measured in the foreign currency. All domestic firms share the same fixed export costs.

Financial constraints. Let us assume that liquidity is needed for covering both variable and fixed trade costs $e\Big((\tau - 1)p_x(z)q_x(z) + f_{\$}\Big)$. Similar arguments can be found in Chaney (2016) and Manova (2013). Firm z is endowed with a firm specific liquidity $A(z)$ in units of the domestic currency, $A(z)$ having a positive derivative with respect to productivity z. As in Chaney (2016), more productive, more profitable firms are less

[12] The price taking behavior of Uruguayan exporters is documented in Appendix A. This assumption is also consistent with the finding in Amiti et al. (2014) that small Belgium exporters with no imported inputs have a nearly full pass-through of nominal devaluations to export prices, since Uruguayan exporters are small in the international market and fundamentally manufacture local commodities.

constrained. Since $A(z)$ is nominated in the domestic currency, we implicitly assume that domestic firms have only access to the domestic financial market. In the following, we assume that $A(z) = Az^{\nu}$, with $A > 0$ measuring aggregate liquidity and $\nu > 1$. Consequently, a firm endowed with liquidity $A(z)$ can export up to

$$q_x(z) \leq \bar{q}_x(z) \equiv \frac{Az^{\nu}/e - f_{\$}}{(\tau - 1)p_x(z)}. \tag{5}$$

If firms have liquidity enough to pay for the export fixed costs, then $\bar{q}_x > 0$. Firms with productivity $z \leq \left(ef_{\$}/A\right)^{\frac{1}{\nu}}$ don't export, since they cannot finance the fixed export cost.

The assumption that export costs (fixed and variable) are in foreign currency, and need to be financed in advance, combined with the assumption that liquidity is in the local currency, are critical for the *expenditure switching channel* to work in this model. Under these assumptions, a devaluation is coupled with a financial crisis. As we show below, a devaluation, by reducing the liquidity needed to access the export market, restricts the ability of exporters to expand in the foreign market. They then reduce the domestic price to expand in the local market, making their demand switch from foreign to domestic.

4.2 Firm behavior

In this section, we study the behavior of firms, which depending on firm specific productivity z may produce for the domestic market only, or produce for both the domestic and foreign markets. We will refer to firms as non-exporters and exporters, respectively. Exporters, indeed, may be liquidity constrained or unconstrained. The functional form of $q_d(z)$, $q_x(z)$, $p_d(z)$ and $\ell_p(z)$ will critically depend on the firm being non-exporter or exporter, constrained or unconstrained.

Firm z maximizes net revenues conditional on the domestic demand function (3) and the liquidity constraint (5). The problem of the firm reads

$$\pi(z) = \max_{q_d(z), q_x(z)} \; P_d c_d^{1-\rho} q_d(z)^{\rho} + e p_x(z) q_x(z) - w z^{\frac{\alpha-1}{\alpha}} \left(q_d(z) + q_x(z)\right)^{\frac{1}{\alpha}}$$

subject to the export constraint

$$q_x(z) \leq \bar{q}_x(z),$$

and the non-negativity constraints $q_d(z) \geq 0$, $q_x(z) \geq 0$. The aggregate $P_d c_d^{1-\rho}$ and the nominal wage w, on top of the export price $ep_x(z)$, are taken as given. The first order conditions with respect to q_d and q_x, respectively, are

$$p_d(z) = \underbrace{\frac{1}{\rho}}_{\text{markup}} \underbrace{\frac{z^{\frac{\alpha-1}{\alpha}} w}{\alpha} \left(q_d(z) + q_x(z)\right)^{\frac{1-\alpha}{\alpha}}}_{\text{marginal production cost}}, \tag{6}$$

$$ep_x(z) = \frac{z^{\frac{\alpha-1}{\alpha}} w}{\alpha} \big(q_d(z) + q_x(z)\big)^{\frac{1-\alpha}{\alpha}} + \eta(z), \tag{7}$$

plus the Kuhn-Tucker condition

$$\eta(z)\big(q_x(z) - \bar{q}_x(z)\big) = 0,$$

where the Kuhn-Tucker multiplier associated to the export constraint $\eta(z)$, $\eta(z) \geq 0$, is firm specific. Profiting from its monopoly power, a domestic firm charges a markup over marginal costs in the domestic market. In the foreign market, indeed, the firm equalizes the marginal cost to the given export price, but when financially constrained, marginal costs are increased by the shadow value of the financial constraint. The export price of constrained exporters implicitly charges then a variable markup on marginal costs. The export markup is increasing on the marginal value of the financial constraint.

Of course, optimal net revenues have to be large enough to cover the fixed export costs for firms to optimally export. In what follows, we analyze the behavior of domestic non-exporters and exporters (constrained and unconstrained).

Non-exporters. Non-exporters optimally set $q_x = 0$. Combining the demand function (3) with the optimal condition (6), non-exporters produce for the domestic market the quantity

$$q_d(z) = \left(\alpha\rho \, \frac{P_d c_d^{1-\rho}}{w}\right)^{\frac{\alpha}{1-\alpha\rho}} z^{\frac{1-\alpha}{1-\alpha\rho}}. \tag{8}$$

Non-exporters simply equalize marginal income to marginal cost in the domestic market. As expected, more productive firms produce more, and consequently charge a lower price p_d, where

$$\frac{p_d(z)}{P_d c_d^{1-\rho}} = q_d(z)^{\rho-1} = \left(\frac{1}{\alpha\rho} \, \frac{w}{P_d c_d^{1-\rho}}\right)^{\frac{\alpha(1-\rho)}{1-\alpha\rho}} z^{-\frac{(1-\alpha)(1-\rho)}{1-\alpha\rho}}.$$

The domestic price of non-exporters $p_d(z)$ is not directly affected by a nominal devaluation of the exchange rate, since it does not depend on e. Indeed, the relative price $p_d(z)/P_d$ is homogeneous of degree zero on w and P_d; if wages and the aggregate domestic price move at the same rate, the domestic price of non-exporters will raise at this rate too. A devaluation has no direct effect on non-exporters prices. The pass-through operates through wages and the effect of the domestic price of exporters in the domestic price index P_d.

The labor demand of non-exporters is

$$\ell_p(z) = \left(\alpha\rho \, \frac{P_d c_d^{1-\rho}}{w}\right)^{\frac{1}{1-\alpha\rho}} z^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}.$$

Substituting optimal quantities in the net revenue function, it reads

$$\pi_n(z) = (\alpha\rho)^{\frac{\alpha\rho}{1-\alpha\rho}} (1-\alpha\rho) \left(\frac{P_d c_d^{1-\rho}}{w} \right)^{\frac{\alpha\rho}{1-\alpha\rho}} P_d c_d^{1-\rho} \; z^{\frac{\rho(1-\alpha)}{1-\alpha\rho}}, \tag{9}$$

where subindex n is used to denote net revenues of non-exporter firms, which positively depend on the firm specific productivity z. Changes in ep_x may affect the status of the firm, but they don't directly affect profits if the firm remains a non-exporter.

Unconstrained exporters. Unconstrained exporters optimally set $\eta = 0$. Combining (6) and (7), we get

$$p_d(z) = \frac{ep_x(z)}{\rho}. \tag{10}$$

When setting the domestic price, unconstrained exporters charge a markup $1/\rho$ on the opportunity cost ep_x of exporting the marginal produced unit. Since domestic sales and exports are jointly produced, their prices have to equalize after correcting for trade costs, implicit in p_x, and the domestic markup. Consequently, the domestic price set by an unconstrained exporter does not depend on firm's productivity z, as represented in technology (4), but on the export price p_x. Unconstrained exporters pass a nominal devaluation directly to their domestic prices. Notice that, given the structure of demand, exporting firms always find it optimal to serve the domestic market, and the supplied quantity critically depends on the export price ep_x.

Equilibrium domestic sales are then given by inverting the domestic demand function (3) evaluated at the optimal domestic price derived above

$$q_d(z) = \left(\frac{\rho P_d}{ep_x(z)} \right)^{\frac{1}{1-\rho}} c_d, \tag{11}$$

which is independent of the firm specific productivity z but decreasing in the export price p_x. From the optimal conditions (6) and (7), and the equilibrium domestic sales above, exports are

$$q_x(z) = \left(\frac{\alpha ep_x}{w} \right)^{\frac{\alpha}{1-\alpha}} z - \left(\frac{\rho P_d}{ep_x} \right)^{\frac{1}{1-\rho}} c_d, \tag{12}$$

increasing in both z and p_x. Labor demand of unconstrained exporters reads

$$\ell_p(z) = \left(\frac{\alpha ep_x}{w} \right)^{\frac{1}{1-\alpha}} z.$$

Net revenues of unconstrained exporters are obtained by substituting q_d and q_x into the net revenue function, which after some algebra becomes

$$\pi_u(z) = \underbrace{\frac{1-\rho}{\rho}\,\left(\rho P_d c_d^{1-\rho}\right)^{\frac{1}{1-\rho}}\,\left(ep_x(z)\right)^{\frac{\rho}{\rho-1}}}_{(p_d - ep_x)q_d} + \underbrace{(1-\alpha)\left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}}\left(ep_x(z)\right)^{\frac{1}{1-\alpha}}\,z}_{ep_x(q_d+q_x) - w\cdot z^{\frac{\alpha-1}{\alpha}}(q_d+q_x)^{\frac{1}{\alpha}}}, \tag{13}$$

where subindex u indicates that the firm is an unconstrained exporter. As explained above, profiting from their local market power, unconstrained exporters set a domestic price larger than the export price. The first term in the previous equation corresponds to the gain of selling q_d in the domestic market instead of exporting it. The second term corresponds to the optimal net revenues of producing and exporting $q_d + q_x$. The first derivative of π_u with respect to p_x is positive.

Domestic prices of exporters increase with the export price and do not respond to productivity, while domestic prices of non-exporters do not change with the export price and go down when productivity increases.

Firm specific real exchange rates and export shares of unconstrained exporters are, respectively,

$$r(z) = \rho \quad \text{and} \quad xs(z) = 1 - \mathcal{C}\left(ep_x(z)\right)^{-\left(\frac{1}{1-\rho}+\frac{\alpha}{1-\alpha}\right)} 1/z,$$

where $\mathcal{C} = \left(\rho P_d\right)^{\frac{1}{1-\rho}} c_d \left(w/\alpha\right)^{\frac{\alpha}{1-\alpha}}$, which only depends on the aggregates c_d, P_d and w. Unconstrained exporters fully pass-through nominal devaluations to domestic prices, implying that their firm specific real exchange rates $r(z)$ remain unchanged after a devaluation. In fact, the real exchange rate is equal to the inverse of the markup. However, the raise in the domestic prices of unconstrained exporters that follows a nominal devaluation, ceteris paribus, reduces domestic sales raising export shares.

Constrained exporters. An exporter is said to be liquidity constrained if unconstrained exports $q_x(z)$ are strictly larger than the constraint $\bar{q}_x(z)$, in which case the firm will export $\bar{q}_x(z)$, making the shadow value of the constraint $\eta(z) > 0$. Combining both optimal conditions (6) and (7)

$$p_d(z) = \frac{ep_x(z) - \eta(z)}{\rho}. \tag{14}$$

Firms facing a stringent export constraint will set a low domestic price relative to the export price (multiplied by the markup) to spill constrained exports over the domestic market.

From the optimal condition for domestic sales (6), $q_d(z)$ is implicitly determined by

$$\alpha\rho\, z^{\frac{1-\alpha}{\alpha}}\,\frac{P_d c_d^{1-\rho}}{w}\; q_d(z)^{\rho-1} = \left(q_d(z) + \bar{q}_x(z)\right)^{\frac{1-\alpha}{\alpha}}. \tag{15}$$

The left-hand-side is positive and decreasing in q_d, going to infinity when $q_d \to 0$ and to zero when $q_d \to \infty$. The right-hand-side is increasing and positive. Then, for any admissible productivity z and export price $p_x(z)$, an interior solution for $q_d(z)$ exists and is unique.

Inverting the demand function, the equilibrium domestic price reads

$$p_d(z) = P_d c_d^{1-\rho} q_d(z)^{\rho-1}.$$

The labor demand of constrained exporters reads

$$\ell_p(z) = z^{\frac{\alpha-1}{\alpha}} \big(q_d(z) + \bar{q}_x(z)\big)^{\frac{1}{\alpha}} = z\big(\alpha\rho\big)^{\frac{1}{1-\alpha}} \left(\frac{P_d c_d^{1-\rho}}{w}\right)^{\frac{1}{1-\alpha}} q_d(z)^{\frac{\rho-1}{1-\alpha}}.$$

Finally, net revenues of constrained exporters are

$$\pi_c(z) = P_d c_d^{1-\rho} q_d(z)^{\rho} + e p_x \bar{q}_x(z) - z^{\frac{\alpha-1}{\alpha}} \big(q_d(z) + \bar{q}_x(z)\big)^{\frac{1}{\alpha}} w, \tag{16}$$

where the subindex c indicates a constrained exporter.

The real exchange rate and the export share of a constrained exporter z are, respectively,

$$r(z) = \rho + \frac{\eta(z)}{p_d(z)} \quad \text{and} \quad xs(z) = \left(1 + \frac{q_d(z)}{\bar{q}_x(z)}\right)^{-1},$$

where $\eta(z)$ is the marginal value of the financial constraint, $q_d(z)$ is implicitly determined by (15), and the export constraint is given by (5). More productive firms face lighter financial constraints and export more, facing a lower real exchange rate and a larger export share. In the cross-section, the real exchange rate and the export share of constrained exporters are negatively correlated.

It is important to notice that export price heterogeneity also cause the real exchange rates and the export shares to negatively correlate. For this reason, as found in Subection 3.2, the observed negative correlation between firm specific export shares and real exchange rates subsists after controlling for the firm specific productivity.

4.3 Equilibrium

This sections studies the main properties of an equilibrium with financially constrained exporters. In order to simplify the argument, let us assume from now that the export price is the same for all exporters. Let us normalise it to one. There are three productivity cutoffs at equilibrium: A production cutoff z^*, a constrained export cutoff z_c^*, and an unconstrained export cutoff z_u^*, such that $\underline{z} \leq z^* \leq z_c^* \leq z_u^*$. Firms produce but do not export if $z \in (z^*, z_c^*)$, export but are financially constrained if $z \in (z_c^*, z_u^*)$, and export without facing any financial constraint if $z \geq z_u^*$.

Marginal non-exporter. A firm optimally produces for the domestic market if net revenues are larger than the firm production cost $wh_p > 0$. From the net revenue function of a non-exporter in (9), the production cutoff z^* is given by

$$z^* = \left(\frac{h_p}{1-\alpha\rho}\right)^{\frac{1-\alpha\rho}{(1-\alpha)\rho}} (\alpha\rho)^{\frac{\alpha}{\alpha-1}} \left(\frac{\hat{w}}{\hat{P}_d}\right)^{\frac{1}{(1-\alpha)\rho}} c_d^{\frac{\rho-1}{(1-\alpha)\rho}}, \tag{EC}$$

where $\hat{P}_d = P_d/e$ and $\hat{w} = w/e$ are the price of the domestic composite consumption good and wages measured in foreign currency. As expected, an increase in fixed production costs h_p makes it more costly to produce, increasing the production cutoff z^*.

The nominal exchange rate has no direct effect on z^*, but may affect it at equilibrium if the pass-through is partial. It operates through two different channels. On one side, when the pass-through is partial, the relative price of domestic consumption declines, raising domestic consumption c_d and then profits, making z^* to decline. On the other side, the partial pass-through may raise the real wage as measured in units of the domestic consumption good, reducing profits and then increasing z^*. These two effects may counterbalance each other, producing a minor change in z^* even after a large devaluation and a strong partial pass-through.

Marginal constrained exporter. Profits of the marginal non-exporter and the marginal constrained exporter, $\pi_n(z) - wh_p$ and $\pi_c(z) - wh_p - ef_\$$, respectively, must be equal to define the equilibrium (constrained) export cutoff z_c^*. From (9) and (16), the export constrained cutoff solves

$$\hat{P}_d\, c_d^{1-\rho} q_d(z_c^*)^\rho + p_x \bar{q}_x(z_c^*) - {z_c^*}^{\frac{\alpha-1}{\alpha}} \left(q_d(z_c^*) + \bar{q}_x(z_c^*)\right)^{\frac{1}{\alpha}} \hat{w} - f_\$ =$$

$$(\alpha\rho)^{\frac{\alpha\rho}{1-\alpha\rho}} (1-\alpha\rho) \left(\frac{\hat{P}_d c_d^{1-\rho}}{\hat{w}}\right)^{\frac{\alpha\rho}{1-\alpha\rho}} \hat{P}_d c_d^{1-\rho}\; {z_c^*}^{\frac{\rho(1-\alpha)}{1-\alpha\rho}}. \tag{XC$_c$}$$

The constrained domestic output function $q_d(z)$ is implicitly defined in equation (15). Firms with productivity $z \in (z^*, z_c^*)$ are non-exporters, those with productivity $z > z_c^*$ are exporters. Ceteris paribus, a devaluation through (5) reduces firm's liquidity, moving the export constrained cutoff z_c^* to the right.

Marginal unconstrained exporter. Unconstrained exporters optimally export less than $\bar{q}_x(z)$, while constrained exporters would like to export more than $\bar{q}_x(z)$ but cannot because they are financially constrained. The marginal unconstrained exporter optimally chooses to produce $\bar{q}_x(z)$ if productivity $z = z_u^*$, such that

$$\underbrace{\frac{(A/e)z_u^{*\nu} - f_\$}{p_x(\tau-1)}}_{\bar{q}_x} = \underbrace{\left(\frac{\alpha p_x}{\hat{w}}\right)^{\frac{\alpha}{1-\alpha}} z_u^*}_{q_d+q_x} - \underbrace{\left(\frac{\rho \hat{P}_d c_d^{1-\rho}}{p_x}\right)^{\frac{1}{1-\rho}}}_{q_d}. \tag{XC$_u$}$$

Notice that constrained exports, at the left-hand-side, are increasing in z and convex, with negate intercept $\frac{f_\$}{p_x(\tau-1)}$. Unconstrained exports, indeed, are linearly increasing in z with negative intercept. Consequently, if $f_\$$ is large enough, such that at equilibrium

$$\frac{f_\$}{p_x(\tau-1)} > \left(\frac{\rho \hat{P}_d c_d^{1-\rho}}{p_x}\right)^{\frac{1}{1-\rho}},$$

a solution for z_u^* exists and is unique. Under this assumption, exporters are unconstrained or constrained depending on z being larger or smaller than z_u^*. Notice that by reducing τ, $\frac{f_\$}{p_x(\tau-1)}$ can become arbitrarily large, but domestic production q_d is bounded at equilibrium by the available mass of resources. In other words, if τ is one, firms are not financially constrained in their exports since no financial resources would be needed to cover variable trade costs, provided the firm can finance the fixed export cost.

The (XC$_u$) condition determines the productivity cutoff defining the border between the constrained and unconstrained exporters, which depends on p_x. We will refer to it as the unconstrained cutoff. An exporter is unconstrained if $z > z_u^*$, constrained otherwise, since available funds increase proportionally more than optimal exports when firm's productivity increases.

Profits and cutoffs. Figure 5 represents, as a function of productivity z, equilibrium profits of non-exporters, constrained exporters and unconstrained exporters. The corresponding net revenues are taken from equations (9), (13) and (16), respectively. They all depend on the equilibrium aggregates c_d, P_d and w. Non-exporters' net revenues in (9) are increasing and concave in z, being zero at $z = 0$. The associated profits subtract fixed production costs wh_p from net revenues in (9) . They are then negative for values of z smaller than the production cutoff z^*.

Profits of unconstrained exporters subtract fixed production costs wh_p and fixed export costs $ef_\$$ from net revenues in (13). They are linearly increasing in productivity z, and always larger than profits of constrained exporters –which net revenues are in (16). For $z < z_u^*$, constrained exporters would like to export more but they cannot since they do not have access to enough liquidity to cover fixed and variable trade costs. From (5),

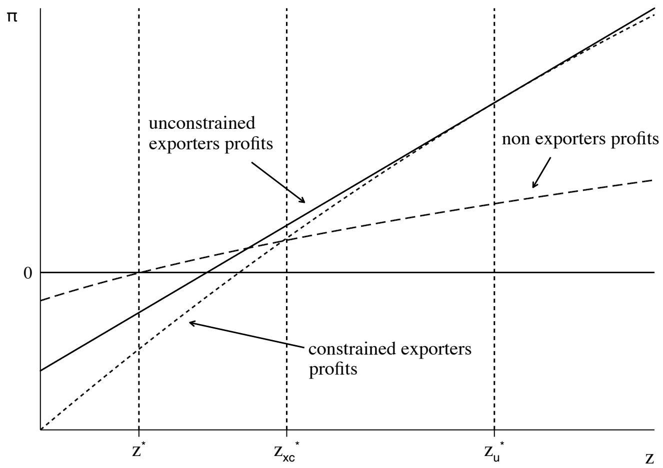

Figure 5: Constrained equilibrium profits and cutoffs

liquidity grows faster than z, implying that there is a cutoff productivity $z = z_u^*$ in which the unconstrained exporter is optimally using all its available liquidity. For any $z > z_u^*$, expanding exports to fully use the available liquidity is not optimal.

According to equation (12), unconstrained exports linearly depend on productivity z. Constrained exports in (5), indeed, exponentially increase with productivity z. If $f_\$$ is large enough, constrained exports cut unconstrained exports from below at the cutoff productivity z_u^*, implying that $\bar{q}_x(z) > q_x(z)$ for $z > z_u^*$, while $\bar{q}_x(z) \leq q_x(z)$ for $z \in (z_c^*, z_u^*)$. The most productive firms are then unconstrained exporters.

Firm sorting is represented in Figure 6. As usual in this literature, fixed production costs make low productivity firms exit the market, and fixed export costs make more productive firms to export. As represented in Figure 6, firms exit if $z \leq z^*$, only produce for the domestic market if $z^* < z \leq z_c^*$, and export if $z > z_c^*$. The novelty is that low productivity exporters face tougher financial constraints, making their exports to be constrained. Highly productive firms, indeed, have large available financial resources, allowing them to access the export market without any financial restriction. As represented in Figure 6, firms produce for the local market and export under financial constraints if $z_c^* < z \leq z_u^*$; finally, firms produce for the local market and export without any financial constraint if $z > z_u^*$.

Equilibrium definition. A constrained equilibrium is a vector $\{\hat{w}, \hat{P}_d, c_d, z^*, z_c^*, z_u^*\}$ satisfying the cutoff conditions (EC), (XC$_c$) and (XC$_u$) and the labor market clearing condition (LM), the domestic price index condition (DP) and the balanced trade condition

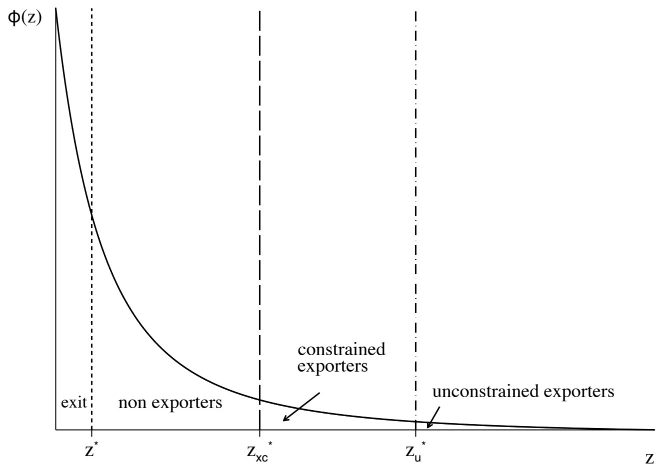

Figure 6: Constrained and Unconstrained subsets

(TB),

$$1-h_p\Big(1-\Phi(z^*)\Big)=\left(\alpha\rho\,\frac{\hat P_d}{\hat w}\right)^{\frac{1}{1-\alpha\rho}} c_d^{\frac{1-\rho}{1-\alpha\rho}}\,\Lambda_1+(\alpha\rho)^{\frac{1}{1-\alpha}}\left(\frac{\hat P_d c_d^{1-\rho}}{\hat w}\right)^{\frac{1}{1-\alpha}}\Lambda_2+\Big(\frac{\alpha p_x}{\hat w}\Big)^{\frac{1}{1-\alpha}}\,\Lambda_3 \quad \text{(LM)}$$

$$1=\left(\alpha\rho\,\frac{\hat P_d}{\hat w}\right)^{\frac{\alpha\rho}{1-\alpha\rho}} c_d^{\frac{\rho(\alpha-1)}{1-\alpha\rho}}\,\Lambda_1+\ c_d^{-\rho}\,\Lambda_4+\Big(\rho\,\hat P_d\Big)^{\frac{\rho}{1-\rho}}\,p_x^{\frac{\rho}{\rho-1}}\,\Big(1-\Phi(z_u^*)\Big) \quad \text{(DP)}$$

$$\underbrace{\frac{1-\beta}{\beta}\,\hat P_d\,c_d}_{P_m c_m/e}=\underbrace{p_x\Lambda_5+\Big(\frac{\alpha}{\hat w}\Big)^{\frac{\alpha}{1-\alpha}}\,p_x^{\frac{1}{1-\alpha}}\Lambda_3-\Big(\rho\,\hat P_d\Big)^{\frac{1}{1-\rho}}\,p_x{}^{\frac{\rho}{\rho-1}}\,c_d\,\Big(1-\Phi(z_u^*)\Big)\ -\ f_{\$}\Big(1-\Phi(z_c^*)\Big)}_{\text{exports}} \quad \text{(TB)}$$

where

$$\Lambda_1=\int_{\underline{z}}^{z_c^*} z^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}\,\mathrm{d}\Phi(z),\qquad \Lambda_2=\int_{z_c^*}^{z_u^*} zq_d(z)^{\frac{\rho-1}{1-\alpha}}\,\mathrm{d}\Phi(z),\qquad \Lambda_3=\int_{z_u^*}^{\infty} z\ \mathrm{d}\Phi(z),$$

$$\Lambda_4=\int_{z_c^*}^{z_u^*} q_d(z)^{\rho}\,\mathrm{d}\Phi(z)\quad\text{and}\quad \Lambda_5=\int_{z_c^*}^{z_u^*}\bar q_x(z)\mathrm{d}\Phi(z)=\frac{A/e}{p_x\tau}\int_{z_c^*}^{z_u^*} z^{\nu}\mathrm{d}\Phi(z)-\frac{f_{\$}}{p_x\tau}\int_{z_c^*}^{z_u^*}\mathrm{d}\Phi(z).$$

Appendix C studies the case in which trade is unbalanced, assuming a trade deficit before the devaluation and a trade surplus after, calibrating both to Uruguayan data. As it can be observed in Appendix C, the main quantitative results in Section 5 remain unchanged when moving from balanced trade to unbalanced trade.

Large devaluations. A nominal devaluation has two direct effects in our model. First, since exporters are price takers in the international market, it raises the export price in domestic currency proportionally –there is full pass-through to export prices. Second, since it reduces aggregate liquidity, it tightens the financial constraints faced by exporters. In our quantitative exercise (see Section 5.2), a large devaluation is modelled as a situation where exporters are initially unconstrained, but the substantial reduction in liquidity that follows the large devaluation turns most of them to be constrained. This modelling strategy is consistent with the simultaneous occurrence of a large devaluation and a financial crisis, as documented in Section 3.1 for Uruguay in 2002. Since constrained exporters pass-through the devaluation only partially, the pass-through to the domestic price index P_d and the equilibrium wage w is also partial.

More formally, a large devaluation of the local currency, a sizeable increase in e, makes liquidity more stringent, substantially reducing $\bar{q}_x(z)$ for all firms –see equation (5). The constraint locus shifts down, making it more difficult for firms to export. Most unconstrained exporters become constrained, and the marginal constrained exporter becomes non-exporter. Hence both z_c^* and z_u^* cutoffs shift rightward, with z_u^* largely moving. Only a small subset of high-productivity firms will still remain as unconstrained exporters after the large devaluation. They find it optimal to largely expand in the export market. This is consistent with the observed fact that after 2002, the aggregate export recovery in Uruguay was based heavily on the response of the largest exporters.

Let us be more precise in our argument. The marginal unconstrained exporter sets domestic prices and quantities independently of z –see equations (10) and (11). A devaluation fully passes-through to the domestic price, reducing domestic sales of unconstrained exporters. When the financial constraint is operative, $q_x(z)$ is equal to $\bar{q}_x(z)$ in (6), making the domestic price $p_d(z)$ to depend positively on z. Notice that $\bar{q}_x(z)/z$ positively depends on z, since $\nu > 1$ and $f_\$ > 0$. For an exporter that stays below the unconstrained cutoff z_u^* after the large devaluation, the financial constraint puts pressure on the domestic price $p_d(z)$ to decline and on domestic sales $q_d(z)$ to increase both relative to the unconstrained exporter. The lower z is, the more the domestic price $p_d(z)$ declines and the domestic quantity $q_d(z)$ raises. The negative effect on the domestic price is consistent with the fact that, under these assumptions, a decline in z makes the financial constraint tighter, increasing its shadow value $\eta(z)$ in (14).

Consequently, after a large devaluation most exporters become financially constrained. The more constrained they become, the less they raise their exports and the less they pass-through the large devaluation to their domestic prices, depreciating their firm specific real exchange rate. This is the mechanics behind the Uruguayan paradox documented in Section 3.

In other words, following the large devaluation, financial constraints become tight, most exporters become constrained being forced to reduce production and exports relative to the unconstrained exporters, freeing labor and partially counterbalancing the direct effect of the exchange rate devaluation on wages. At the same time, they increase their supply in the domestic market by pushing domestic prices down. The reduction in the wage rate and in domestic prices leads non-exporters to passing the devaluation only partially too, which reinforces the negative effect on the domestic price.

Distortions and welfare. It is important to notice that in our economy equilibrium is distorted by both the domestic markup and the liquidity constraint. The first distortion, by raising the price of domestic consumption, reallocates production towards the export market. Under balanced trade, it implies that the consumption of the imported good is too large relative to the consumption of the domestic composite good. If all exporters were unconstrained and the domestic market perfectly competitive, all exporters will set a domestic price equal to the export price. Exporters will then face a real exchange rate equal to one. When all exporters are unconstrained but the domestic market is monopolistically competitive, the real exchange rate of exporters is equal to the inverse of the domestic markup, making domestic consumption relative to exports smaller than optimal.

The second distortion, the liquidity constraint, by restricting exports, reassigns production towards the domestic market. On average, small financial distortions partially compensate for the domestic markup distortion. Of course, if financial constraints are too large, exporters have little access to the foreign market. Then, through the trade balance, it reduces the consumption of the imported good below its optimal level. But, financial constraints also affect exporters unequally. Low productivity exporters face large financial constraints setting high real exchange rates, while highly productive exporters are likely unconstrained setting a real exchange rate equal to the inverse of the domestic markup. Exporters set then different real exchange rates, and their dispersion negatively affects welfare.

In our framework, a depreciation makes the liquidity constraint more stringent, reducing exports and consequently imports. However, this new distortion by reducing imports may be counterbalancing the negative welfare effect of domestic markups. This is so because constrained exporters by partially passing the international price to the domestic price, set a lower price in the domestic market, raising domestic consumption.

5 Model simulation

5.1 Calibration

Parameter values in Table 3 were set taking into account some previous estimates in the literature, in particular some research on the Uruguayan case, and by making the model predict some observed moments of the Uruguayan manufacturing data. Following Lucas (1978) "span of control" model, parameter α measures decreasing returns on firm's flexible labor input. In line with Hsieh and Klenow (2009), we set it to 0.55.[13] Consistently with previous research on manufacturing markups in Uruguay, we set the demand elasticity parameter ρ to 0.617.[14]

Table 3

Calibration									
α	ρ	h_p	$f_\$$	β	τ	A	ν	κ	$\underline{z}$
0.55	0.617	0.511	0.13	0.633	1.093	0.147	1.14	2.33	1

The fixed entry cost h_p is set to 0.511 so that the exit rate predicted by the model matches the exit rate of the Uruguayan economy measured by Casacuberta and Gandelman (2015) for the period 1999-2005. Similarly, parameter $f_\$$ is set to 0.13 in order to match the fraction of exporting firms observed in Uruguayan manufacturing (Manufacturing Survey 1997-2005, Uruguayan National Statistic Institute). Parameter β is set to 0.633, the average domestic consumption expenditure share measured by the Central Bank of Uruguay for manufacturing, 1999-2001. Following Lalanne et al. (2008), parameter τ is set to 1.093, measuring the variable trade costs (tariff and non-tariff) faced by Uruguayan manufacturing exporters. The scale parameters A is set to 0.147, and ν is set to 1.14, to the aggregate export share and real exchange rate, when moving from $e = 1$ to $e = 2$, increase as in the data.[15]

The entry productivity distribution is assumed to be Pareto, in the support $z > \underline{z} = 1$,

[13] In Appendix I, Hsieh and Klenow (2009) say that their calibration of the span of control parameter corresponds to 0.5, lower that the 0.8 of Atkeson and Kehoe (2008).

[14] Hoekman et al. (2004) provide an estimate of the average industry markup for a set of countries. They estimate for Uruguay an average markup of 1.62 corresponding to $\rho = 0.617$.

[15] Notice that the aim of this paper is not to explain the behaviour of the aggregates, but the pass-through at the firm level. We then set parameters to the aggregates move consistently with the data, and ask the model to explain the join behaviour of export shares and real exchange rates at the micro level.

and the tail parameter κ was estimated to 2.33 by applying the method of moments to the TFP distribution of Uruguayan manufacturing firms.[16] Without any loss of generality, the nominal exchange rate e and the foreign price p_x are normalized to one.

The first row of Table 4 shows the values of the main aggregates and cutoffs at the benchmark equilibrium. In the model economy, before the large devaluation of 2002, Uruguayan exporters where not financially constrained in the export market. This was a time of foreign capitals flowing to the country, converted into Uruguayan pesos by the Central Bank of Uruguay (international reserves were at the highest), and a highly liquid domestic financial market with the highest levels of domestic credit.

5.2 Large devaluations

A large devaluation of the nominal exchange rate has real effects, since by strongly reducing liquidity it tightens financial constraints making unconstrained exporters to become constrained. Table 4 reports the effects on the benchmark model of devaluating the nominal exchange rate by 100%, from $e = 1$ to $e = 2$.

Table 4

Equilibrium aggregates and cutoffs and exchange rate										
e	active	export	unconst	z^*	z_c^*	z_u^*	P_d	c_d	w	RER
1	95.5	25.2	100	1.020	1.843	1.843	1.00	1.00	1.00	1.00
2	97.5	20.1	6.1	1.011	2.012	6.700	1.574	1.092	1.621	1.27

As it can be observed in Table 4, at $e = 1$ the economy is at the unconstrained equilibrium (100% of firms are unconstrained) with an exit rate of 4.5% and a fraction of exporters of 25.2%. After a 100% devaluation of the peso (second raw), liquidity tightens making the fraction of unconstrained exporters to collapse, moving down to 6.1%. This prediction is consistent with the Uruguayan economy entering on a deep financial crisis in 2002 as discussed in Section 3. Since financial resources are more scarce for less productive exporters, the collapse in liquidity pushes the marginal exporters out of the export market, the faction of exporters reducing form 25.2% to 20.1%.[17]

[16]Firm specific TFP was estimated using data from the Manufacturing Survey following Olley and Pakes (1996). For the case of a Pareto distribution, the particular forms of the Λ terms in the equilibrium definition in Section 4.3 are given in Appendix B.

[17]The reduction of the share of exporters is an artefact of the assumption that the trade is balanced.

As a consequence of tighter financial constraints, the pass-through is incomplete, with both wages and the domestic price following the devaluation but partially. At the second row of Table 4, a 100% devaluation of the nominal exchange rate increases the domestic price by 57.4% and the domestic wage by 62.1%, both nominated in the local currency. The model replicates well the evolution of export and domestic prices in Uruguay after the 2002 devaluation, as represented in Figure 4. This reflects in an increase of domestic prices for both constrained exporters (partial *pass-through*) and unconstrained exporters (full *pass-through*), and an increase in wages due to the pressure of exporters in the labor market raising also the price of non-exporters in the domestic market.

The extend of the *pass-through* of a nominal devaluation is described by the change of the aggregate real exchange rate. The price in the local currency of exports is ep_x. The average price faced by domestic firms in the domestic market is the price of the domestic composite good P_d. Hence, we measure the aggregate real exchange rate faced by domestic firms as ep_x/P_d. Since the price of the domestic composite good P_d does not track e fully in the constrained economy, the real exchange rate depreciates by 27% when the nominal exchange rate depreciates by 100%, close to the real depreciation observed after the 2002 depreciation of the Uruguayan peso –see Figure 4.

All together these effects result in a 9.2% increase in consumption of the domestically produced composite good due to the decline of the price of the domestic composite good relative to the price of the imported good.[18]

5.3 Pass-through and export response

Let us now explore the joint evolution of firm specific export shares and firm specific real exchange rates that follows a large devaluation of the nominal exchange rate. Exporters face a perfectly competitive export market but a monopolistically competitive domestic

When a devaluation is only partially passed to the domestic price, under log preferences, consumers substitute out of the imported good. Since trade is balanced, exports reduce following the reduction in imports, which is achieved by a reduction in the mass of exporters. As shown in Appendix C, when the trade balance before and after the nominal exchange rate devaluation is taken from the data, mapping the fact that the trade balance was in a large deficit before the devaluation moving to a surplus after, the share of exporters slightly increase instead of decreasing as in Table 4.

[18]As for the reduction in the share of exporters, the raise in domestic consumption is an artefact of the assumption of balanced trade. As report in Appendix C, when the simulation takes into account the observed change in the trade balance, domestic consumption declines by 2.5% instead of growing.

market. When financially unconstrained, an exporter fully pass-through a nominal devaluation to the domestic price. But, when financially constrained in its export activities, it passes-through the devaluation partially to the domestic price, expanding mainly in the domestic market. As a consequence, firms that see their export shares to expand more are those that see their firm specific real exchange rate to depreciate less.

Firm specific real exchange rate. Let us define the firm specific real exchange rate as the ratio of the firm specific export price to the firm specific domestic price, both nominated in local currency, i.e., ep_x/p_d. For all exporters, the export price nominated in local currency is equal to ep_x. When selling to the domestic market, unconstrained exporters charge a fixed markup to the opportunity cost of exporting, *i.e.*, their domestic price is $p_d = ep_x/\rho$. Hence, the unconstrained firm specific real exchange rate ep_x/p_d is constant and equal to the inverse of the markup, ρ, with unconstrained exporters fully passing the devaluation to the domestic price. Constrained exporters, indeed, partially pass the nominal devaluation to the domestic price in order to reallocate production towards the domestic market, setting a domestic price smaller than ep_x/ρ. The exchange rate pass-through of constrained exporters will be then incomplete. The effect is stronger the more financial constraints are tighten.

Firm level export share. Consistently with the measurement of export shares in Section 3, we have created a firm specific measure of the export share at constant prices. More productive firms export a larger fraction of their output. After a devaluation, the export share of unconstrained exporters change through changes in the aggregates c_d, P_d and w. It goes up after a nominal devaluation since the pass-through to domestic price P_d and wages w is partial, as reported in Table 4.

For exporters that were unconstrained before the nominal devaluation but become constrained after, the behavior of the firm specific export share depends on how close they are to the new marginally unconstrained exports. The closer the productivity z of a constrained exporter is to z_u^*, the higher the increase in the export share.

Changes in firm specific export shares and real exchange rates. As shown in Table 4, before the devaluation of the nominal exchange rate all exporters are unconstrained. After the nominal exchange rate devaluation, some of these exporters stop exporting and

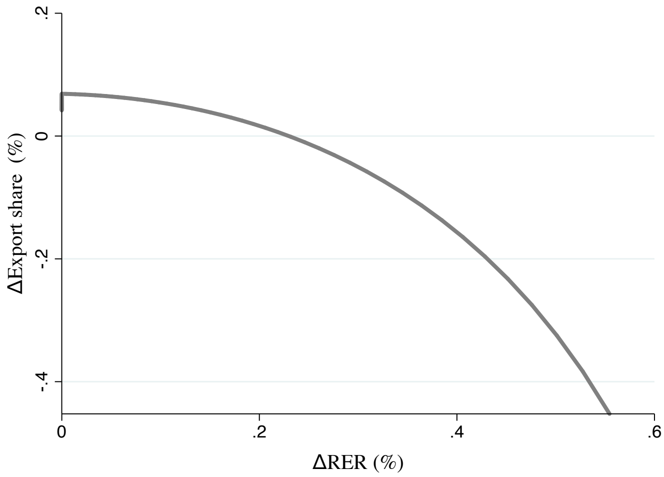

Figure 7: Changes in real exchange rates (x-axis) vs changes in export shares (y-axis) after a 100% nominal devaluation

most of the others become financially constrained.[19] The large nominal devaluation of the domestic currency goes along with a large drop in liquidity, mirroring the exchange rate and financial crisis suffered by the Uruguayan economy around 2002, strongly reducing the access of exporters to the needed liquidity.

Figure 7 shows for all post-devaluation exporters the relation between changes in the firm specific real exchange rate (ΔRER in the x-axis) and changes in the firm specific export share (y-axis). For the small group of exporters that remain unconstrained, export shares increase but real exchange rates remain unchanged (equal to the inverse of the domestic markup ρ). They are represented in Figure 7 by a small vertical bar at $\Delta\text{RER} = 0$. Most exporters become financially constrained. Differently to unconstrained exporters, their pass-through of the nominal devaluation to domestic prices is incomplete. The depreciation of firm specific real exchange rates induces a raise in domestic sales reducing export shares. This effect is stronger for less productive constrained exporters. For all of them, the relation between changes in the firm specific export share and changes in the firm specific real exchange rate is negative as shown in Figure 7. This finding is consistent with the micro evidence on a negative relation between market shares and real exchange rates presented in Section 3.

[19]As explained above, the reduction in the mass of exporters is an artefact of the assumption that trade is balanced. As shown in Appendix C, if trade is unbalanced and the economy moves from a trade deficit to a trade surplus after the nominal devaluation, consistently with Uruguayan data, the fraction of exporters slightly increases instead of declining.

6 Conclusion

This paper uncovers, documents and provides an explanation to the paradoxical fact that took place around the large 2002 devaluation in Uruguay: despite the simultaneous observation of a depreciation of the real exchange rate and an expansion of aggregate exports, the micro level correlation between firm specific export shares and real exchange rates is negative. Exporters reporting large expansions in their export shares are those facing small depreciations in their real exchange rates.

To replicate the observed Uruguayan paradox, this paper develops a small open economy model with heterogenous firms and financial frictions. The main mechanism relies on a firm specific incomplete *pass-through* from the nominal exchange rate to domestic prices. Exporters fully pass-through a nominal devaluation to the export price, but they partially pass it through to the domestic price depending on their capacity to expand on the export market, which critically depends on their liquidity.

The suggested model is calibrated to the Uruguayan economy around 2002. When subject to a large devaluation of the Uruguayan peso, the model replicates the negative relation between changes in the export shares and real exchange rates.

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Appendix

A Price taking exporters

Based on the observation that a large fraction of Uruguayan exporters manufacture commodity-type goods based on natural resource comparative advantages, we model exporters as price takers in the international market. Table 5 reports the share on total exports of the main exporting manufacturing sectors for the period 1997-2005. As can be observed, about three-quarters of total manufacturing exports are based on locally produced commodity-type goods. In our view, a small supplier in such markets is unlikely to offer a highly differentiated product enjoying a significant degree of market power.

Table 5

Uruguayan Manufacturing exports 1997-2005 Commodity-type 4–digit ISIC codes		
ISIC Rev. 2	Share	Accum. share
Slaughtering, preparing and preserving meat	23.1%	23.1%
Spinning, weaving and finishing textiles	11.4%	34.6%
Grain mill products	7.1%	41.6%
Manufacture of dairy products	6.4%	48.0%
Tanneries and leather finishing	5.0%	53.1%
Canning, preserving, processing of fish and similar food	4.6%	57.7%
Manufacture of food products n.e.c.	3.2%	61.0%
Sawmills, planing and other wood mills	3.0%	63.9%
Manufacture of wearing apparel, except footwear	2.9%	66.8%
Manufacture of pulp, paper and paperboard	2.2%	69.0%
Malt liquors and malt	1.7%	70.8%
Tobacco manufactures	1.2%	72.0%
Canning and preserving of fruits and vegetables	1.2%	73.2%
Other commodity-type manufacturing exports	2.5%	75.7%
Source: ECLAC and Central Bank of Uruguay		

Further evidence of price taking behavior is provided by comparing the evolution of export and domestic prices by sector before and after the large devaluation. In a context of price taking behavior in foreign markets, we should expect close to full pass-through of the devaluation to export prices. If exporters are financially constrained, we should also expect less than complete pass-through to domestic prices. We should also expect smaller dispersion of export price changes relative to dispersion of domestic price changes.

To this purpose, we use Central Bank and INE data to measure sectorial domestic and export price changes and their standard deviations. Table 6 reports sectorial export and domestic price increases for manufacturing sectors between 2001 and 2003. It can be observed that most sectorial export price changes follow closely the devaluation of the Uruguayan peso, reported to be 111% in the same period, and the domestic price pass-through is less than complete in all sectors. We also observe less dispersion in export price changes than in domestic price changes. It is interesting to notice also that those sectors non-based on locally produced commodities, like chemicals, motor vehicles or machinery

Table 6

Uruguayan Manufacturing: Export and domestic 2003/2001 price increases 2–digit ISIC codes			
	Export	Domestic	% Exports
Food products and beverages	119%	60%	50.2%
Textiles	165%	80%	11.4%
Chemicals and chemical products	96%	49%	6.7%
Tanning and dressing of leather, luggage, footwear	111%	16%	5.4%
Motor vehicles and transpor equipment	113%	63%	4.6%
Rubber and plastics products	113%	65%	3.2%
Wearing apparel; dressing and dyeing of fur	118%	11%	3.1%
Wood: products of wood and cork, exc. furniture	113%	48%	2.7%
Paper and paper products	80%	44%	2.6%
Machinery and equipment n.e.c.	113%	77%	2.7%
Basic metals	132%	81%	2.4%
Tobacco products	111%	21%	1.5%
Other non-metallic mineral products	84%	78%	0.9%
Fabricated metal products, except machinery	95%	74%	0.5%
Publishing, printing and repr. of recorded media	71%	41%	0.4%
Average	1.10	0.58	
Coeff variation	0.18	0.38	
Source: INE and Central Bank of Uruguay			

and equipment, show a pattern similar to those based on locally produced commodities.

Additional evidence on price taking behavior by Uruguayan firms can be obtained from the Customs Declaration database, which records firm's tax number, date, value, measurement unit, quantity, destination country, HS 10-digit product code and description for each shipment. We consider observations in which all identifiers coincide as being the same product, and compute unit values by dividing dollar shipment values by declared quantities.[20] If we eliminate products present in the sample only once, not present beyond June 1st, 2002, and not present before June 1st, 2002, we obtain 67,922 observations on

[20]Same firm's tax number, measurement unit, quantity, destination country, HS 10-digit product code and description. Product descriptions may have small variations, and transactions in which the same product was sold may be classified as different. The criterion can be considered restrictive.

Table 7

Impact of nominal exchange rate changes on dollar export price changes (5/1/1998 to 31/12/2003) OLS - dependent variable is Δ dollar export price		
Δ dollar exchange rate	-.01670	.01511
Lagged Δ dollar exchange rate		.01472
Days since last transaction	-.00005	-.00009
Constant	.01818 ***	-.01123
Firm dummies	yes	yes
Year, month and day dummies	yes	yes
Number of observations:	60914	56539

*** significant at 99%; ** significant at 95% ; * significant at 90%

Source: Customs export transaction database

4428 *products* so defined, between January 5th, 1998 and December 31st, 2003. We match these to the daily dollar exchange rate database from the Bank of the Republic. For each transaction we compute the number of days d since the preceding sale, price, exchange rate and the monthly equivalent growth rates between dates 1 and 2 as

$$\Delta p = (p_2/p_1)^{\frac{30}{d}} - 1.$$

Table 7 shows the results from regressing price changes (in dollars) between two consecutive sales (the same product to same destination from same firm) on the dollar exchange rate increase along the same time interval. In the estimation we control for the number of days between transactions, as well as for firm and period dummies. Table 7 shows that dollar price adjustments in export sales do not seem to respond to dollar exchange rate changes.

B Algorithm to Solve the Constrained Model

We seek to solve the system of equations (EC), (XC_c), (XC_u), (LM), (DP), and (TB) for variables $\{\hat{w}, \hat{P}_d, c_d, z^*, z_c^*, z_u^*\}$. Under the assumption that the entry distribution is Pareto,

$$1 - \Phi(z) = z^{-\kappa}, \qquad \Lambda_1 = \left(\frac{\kappa(1-\alpha\rho)}{\kappa(1-\alpha\rho)+\alpha\rho}\right)\left(z^{*\frac{(1-\alpha)\rho}{1-\alpha\rho}-\kappa} - z_c^{*\frac{(1-\alpha)\rho}{1-\alpha\rho}-\kappa}\right),$$

$$\Lambda_3 = \frac{\kappa}{\kappa-1} z_u^{*-\kappa+1} \quad \text{and} \quad \Lambda_5 = \frac{A(1-\tau)}{ep_x\tau}\frac{\kappa}{\kappa-\nu}\left(z_c^{*-\kappa+\nu} - z_u^{*-\kappa+\nu}\right) - \frac{f_\$(1-\tau)}{p_x\tau}\left(z_c^{*-\kappa} - z_u^{*-\kappa}\right).$$

However, there are no explicit expressions for

$$\Lambda_2 = \int_{z_c^*}^{z_u^*} z q_d(z)^{\frac{\rho-1}{1-\alpha}} \, \mathrm{d}\Phi(z) \quad \text{and} \quad \Lambda_4 = \int_{z_c^*}^{z_u^*} q_d(z)^{\rho} \, \mathrm{d}\Phi(z),$$

where the constrained domestic sales $q_d(z)$ solve equation (15).

For the numerical solution, the support of the distribution of z is defined on a grid of n points at intervals of fixed length h between $\underline{z} = 1$ and a large enough $\overline{z}$. We denote by z_g to the z points in the grid.

Before running the algorithm below, use (5) to solve for $\bar{q}_x(z)$, which is independent of the equilibrium solution.

1. Solve the economy under the assumption that all exporters are unconstrained and use the solution vector $\left(\hat{P}_d, \hat{w}, c_d\right)$ to initialise the algorithm in point 2. below.

2. Proceed as follows:

   (a) Set an initial vector $\left(\hat{P}_d, \hat{w}, c_d\right)$.

   (b) Use (8), (11) and (15) to solve for the function $q_d(z)$ in the three different regime for all points in the grid.

   (c) Then, use (EC), (XC$_c$) and (XC$_u$) to calculate the cutoffs z^*, z_c^* and z_u^*.

   (d) Given the cutoffs, compute $1-\Phi(z^*)$, $1-\Phi(z_c^*)$, $1-\Phi(z_u^*)$ and the integrals Λ_1, Λ_3 and Λ_5.

   (e) Approximate Λ_2 and Λ_4 by adding the areas in the disjoint intervals $[z_{gz_c}, z_{gz_c}+h]$, ..., $[z_{gz_u}-h, z_{gz_u}]$, being z_{gz_c} the point in the z grid closer but larger than z_c^* and z_{gz_u} the point in the z grid closer but smaller than z_u^*. The integrals in each subinterval are approximated by the product of the interval length, h, times the average of the function at the interval endpoints:

   $$\hat{\Lambda}_2 = \sum_{z_c^* < z_g < z_u^*} h \cdot \kappa \cdot \left[\left(q_d(z_g)\right)^{\frac{\rho-1}{1-\alpha}} z_g^{-\kappa} + \left(q_d(z_g+h)\right)^{\frac{\rho-1}{1-\alpha}} (z_g+h)^{-\kappa}\right]/2$$

   and

   $$\hat{\Lambda}_4 = \sum_{z_c^* < z_g < z_u^*} h \cdot \kappa \cdot \left[\left(q_d(z_g)\right)^{\rho} z_g^{-1-\kappa} + \left(q_d(z_g+h)\right)^{\rho} (z_g+h)^{-1-\kappa}\right]/2.$$

(f) Then, solve the three equilibrium conditions (LM), (P_d), and (TB) to obtain the equilibrium vector $\left(\hat{P}_d, \hat{w}, c_d\right)$.

(g) If the norm of the difference between the equilibrium vector $\left(\hat{P}_d, \hat{w}, c_d\right)$ in point (f) above and the initial vector in (a) is less than the tolerance value 10^{-48}, STOP. Otherwise, go back to point (a) above and use the equilibrium vector in (f) as a new initial vector.

C Trade balance

Before year 2002, the Uruguayan real exchange rate was overvaluated, being responsible for a high trade deficit in manufacturing goods. After the 2002 depreciation of the Uruguayan peso, the trade balance redressed, the large deficit becoming a surplus. Since in our model, the aggregate behavior of the export share in manufacturing critically depends on the trade balance, this appendix evaluate the effects on the micro correlation between firm specific real exchange rates and export shares of relaxing the assumption of balanced trade. With this objective in mind, we substitute equation (TB) for

$$\underbrace{(1-d)\,\frac{1-\beta}{\beta}\,\hat{P}_d\,c_d}_{P_m c_m/e} = \underbrace{p_x\Lambda_5 + \left(\frac{\alpha}{\hat{w}}\right)^{\frac{\alpha}{1-\alpha}} p_x^{\frac{1}{1-\alpha}}\Lambda_3 - \left(\rho\,\hat{P}_d\right)^{\frac{1}{1-\rho}} p_x^{\frac{\rho}{\rho-1}}\,c_d\left(1-\Phi(z_u^*)\right) - f_\$\left(1-\Phi(z_c^*)\right)}_{\text{exports}}, \tag{TB'}$$

where d represents the trade deficit relative to total imports. We then simulate the economy taking d in (TB') from the data, moving from $d = 0.314$ to $d = -0.09$ (a surplus) when the nominal exchange rates moves from $e = 1$ to $e = 2$.

Table 8

Calibration									
α	ρ	h_p	$f_\$$	β	τ	A	ν	κ	$\underline{z}$
0.55	0.617	0.551	0.105	0.633	1.093	0.147	1.14	2.33	1

Parameters values are the same as in the main text, but the fixed entry cost h_p and the fixed export cost $f_\$$ were slightly recalibrated to the exit rate and the fraction of exporting firms predicted by the model match the corresponding Uruguayan moments mentioned in the main text –see Table 8.

Table 9 reports the effects on the model with trade deficit of devaluating the nominal exchange rate by 100%, from $e = 1$ to $e = 2$. Notice that we are implicitly assuming that the devaluation is followed by a redressing in the trade balance. As it can be observed by

Table 9

Equilibrium aggregates and cutoffs and exchange rate										
e	active	export	unconst	z^*	z_c^*	z_u^*	P_d	c_d	w	RER
1	94.5	20.3	100	1.025	2.030	2.030	1.00	1.00	1.00	1.00
2	95.5	21.1	3.8	1.020	1.986	8.101	1.413	0.975	1.469	1.41

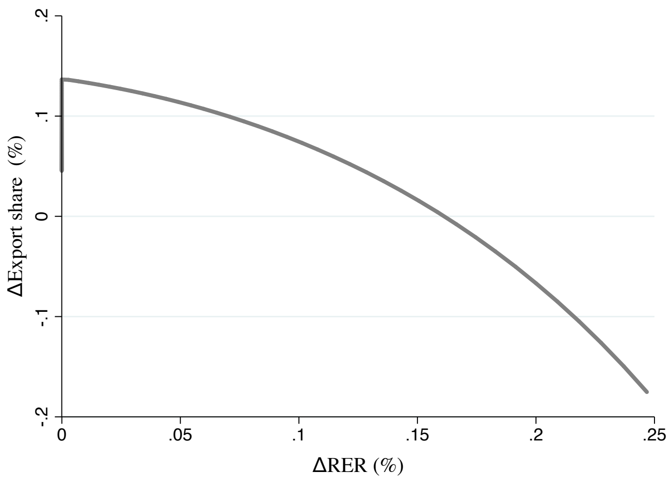

Figure 8: Changes in real exchange rates (x-axis) vs changes in export shares (y-axis) after a 100% nominal devaluation - trade deficit corrected

comparing Tables 4 and 9, moving from a trade deficit to a trade surplus makes the share of exporters to raise instead of declining, with a quite similar fraction of unconstrained exporters at the post-devaluation equilibrium.

As in the main text, the pass-through is incomplete, with both wages and the domestic price following the devaluation but partially, and the real exchange rate depreciating by 41%. Redressing the trade balance has a negative effect on domestic consumption, which slightly reduces.

More important, as in the main text, Figure 8 shows the negative relation between changes in the firm specific real exchange rate (x-axis) and changes in the firm specific export share (y-axis) for exporters after the devaluation. The main result of the paper is robust to the balanced trade assumption.