

Labor Income Risk in Large Devaluations*

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Abstract

Large devaluations are associated with reallocation of labor across employment status, sectors and firms. We measure monthly labor income risk across two large devaluations in Argentina, using a novel administrative employer-employee matched dataset covering the universe of formal workers during the 1996-2018 period. We find a substantial increase (resp. decrease) in job finding (resp. separation) rates following these episodes. Additionally, we find an increase in the standard deviation and a decrease in the skewness of the monthly earnings distribution. We rationalized these facts in a search model with risk averse workers and incomplete markets. The model provides an unify theory of endogenous labor income risk and current account determination during large devaluation.

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1 Introduction

What are the costs associated with a large devaluation? In the international macroeconomics literature much attention has been put on understanding inefficient fluctuations of consumption and labor supply (Uribe and Yue (2006)), low levels of investment and capital formation (Mendoza (2010)), misallocation of resources (Oberfield (2013)), and distributional costs associated with an increase in inequality (Cravino and Levchenko (2017), Drenik (2015)). However, there is a dimension not explored in this literature: How does the distribution of labor earnings evolve during large devaluation? Given the low level of development of insurance markets in emerging economies, together with the large cyclicity of the income risk documented in existing papers, this is a first order question.

This paper seeks to expand our knowledge of this set of issues in two separate directions. First, the existing empirical literature is based entirely on data from the US and European countries, where large recessions associated with depreciations of the currency were not present. This paper analyzes labor income risk in the context of one of the main sudden stop episodes in recorded history: the Argentinian 2001 economic crisis. To the best of our knowledge, this study provides the first measurement of labor income risk during a sudden stop. Second, the availability of high frequency administrative income information allows us to avoid problems associated with survey-based data, and to provide a high-frequency analysis of labor income risk. As a first step, we provide a statistical description of the monthly growth rates of real income during two sudden stop episodes in Argentina. We document that in both episodes the labor market is positively affected after a devaluation in terms of higher job finding rates and lower separation rates. On the other hand, a devaluation has negative effects on wages of employed workers. Average real wages decline by up to 30%, the cross-sectional standard deviation increases and the skewness of the income distribution declines. These facts show that after devaluations workers are accepting to work at lower wages, particularly so at the lower end of the wage distribution.

As a second step, we develop a model of labor income risk during large devaluations in a search and matching framework with risk averse agents and incomplete markets. First, it provides a mapping between endogenous parameters and labor earnings that takes into account the risky decisions of workers in the labor market. Thus, we control for workers' choices of which types of jobs to search for while unemployed and employment mobility across sectors. Second, it provides a mapping between the distribution of histories of income to aggregate consumption; thus, a theory of current account determination. When we calibrate the model to match salient features in the income data and of real exchange rates, we find that the model is able to generate a large increase in the standard deviation of income together with a decrease in the skewness of labor income, as we observe in the 2002 devaluation.

Literature review. [TBC]

2 Labor income dynamics during large devaluations.

This section describes the microdata used to analyze labor income risk. It then describes summary statistics describing moments of labor income during two large devaluations in Argentina.

2.1 Data Description, Cleaning and Coverage

Data description. We use monthly administrative employer-employee matched data from Argentina for the 1996-2018 period. Our data source is the National Social Security System (“Sistema Integrado Previsional Argentino”, SIPA data from hereon). After the 1993 social security reform, national authorities in charge of the Social Security System started keeping employer and employee administrative records.

By law, all employers in the formal (private and public) sector must present sworn statements providing information included in workers’ paycheck to SIPA every month. This information is used for tax purposes and contributions to the social security system by employees. Regarding the compensation measures used in our analysis, SIPA reports total wages earned in each month, which include all forms of payment that are taxable income or are subject to Argentinean social security contributions. In addition, SIPA provides several kinds of income variables by different types of earnings: base wage, extraordinary additions, bonuses, overtime compensation, and the 13th salary paid in June and December. These variables are available starting in 2008.

Importantly, there is no top-coding of income variables in the data. The dataset also includes information about workers (gender and age) and their jobs (type of contract, part-time/full-time indicator, different monthly compensation measures), as well as some characteristics of the firm such as sector and state. Importantly, SIPA also provides firm and worker identifiers.

Coverage. The dataset covers the universe of formal worker employed in all regions, industries and types of contracts (internships, temporary workers, full-time employees, etc.). This corresponds to more than 15 million workers and 40 million job spells. One of the benefits of analyzing the Argentine labor market is that, relative to other Latin American economies, the informality rate is not high. For example, the share of informal employment among male salaried workers was 32% at the peak of the 2002 recession, whereas the informality rate in Mexico in 2002 was 55% (see [Gasparini and Tornarolli \(2009\)](#)). Thus, our data covers a large share of the overall population.

Data cleaning. We restrict our sample to male workers aged between 25 and 59 years who have never worked in the public sector. This condition allows us to focus in workers with strong attachment to the private sector. We also eliminate outliers, defined as workers who earn less than half a minimum wage. Because the minimum wage in Argentina has changed over different administrations, we use the 1995 value in real terms for the entire sample. This value was approximately 1,25 dollars per hour.

Construction of Income. We use total monthly compensation except for the 13th salary paid in June and December. This bonus, known as *aguinaldo*, is mandated by law and usually equals one half of the highest wage paid over that semester. Unfortunately, we only observe total income before 2008, which means we have to estimate *aguinaldo* using the same formula that the law establishes. Equation (1) displays the formula we used:

$$\text{Aguinaldo} = \frac{\sum_{i \in 1:6} I_i}{12} \times \max_{i \in 1:6} w_i. \quad (1)$$

Here I_i is an indicator variable for whether the person worked in month i . A person working for the entire semester receives half of the maximum wage she earned during the semester. We express total compensation in real terms using 1995 as the base year.¹

Construction of Exchange rate. We use the average monthly nominal exchange rate measured as unit of local currency per US dollar. To construct time series of the real exchange rate we use the CPI from Argentina described above and US CPI inflation obtained from FRED. We normalize the real exchange rate to the historical mean.

Table I – CROSS-SECTIONAL LABOR INCOME STATISTICS: ARGENTINA AND UNITED STATES

Moments	Argentina	US
Growth rates moments		
Standard Deviation	0.61	0.53
Skewness	0.01	-0.31
Per. 10	-37.00	-43.45
Per. 50	0.05	2.02
Per. 90	63.00	47.43
Log-levels moments		
mean change	0.04	-0.11
Standard Deviation	1.02	0.91
Skewness	-0.70	0.57
min minus Per. 50	-3.25	-3.24
max minus Per. 50	4.30	5.55
Per. 1 minus Per. 50	-2.97	-2.84
Per. 10 minus Per. 50	-1.67	-1.30
Per. 25 minus Per. 50	-0.65	-0.54
Per. 75 minus Per. 50	0.49	0.44
Per. 90 minus Per. 50	0.96	0.85
Per. 99 minus Per. 50	1.84	1.97

Notes: The table describe mean moments of yearly labor income for working males in Argentina and US. The data for US is from [Güvenen et al. \(2014\)](#). The data for Argentina is form SIPA. We set up the yearly minimum income each year to match the difference of minimum income and median equal to US.

Mean labor income risk. Before analyzing labor income risk during large devaluations, we describe mean statistics across the sample period and compare them with the statistics computed for the US by [Güvenen et al. \(2014\)](#). For this exercise, and this exercise only, we apply the same filter as the ones used in the US and report statistics at an annual frequency. We construct annual income for male workers by aggregating monthly income of workers satisfying the following criteria: (i) between 25 and 60 years of age, (ii) annual income is larger than a threshold value set following [Güvenen et al. \(2014\)](#) (they use one-half of the minimum wage as the threshold value), and lower than the percentile 99.999%. [Güvenen et al. \(2014\)](#). To replicate their methodology, we target a minimum wage such that it generates the same log difference between the minimum and the median annual income. Therefore, by construction, we generate the same statistics for the relative minimum annual income. Table I shows these statistics.

Labor income statistics in the US and Argentina are similar to each other, both in log levels and in growth rates. With respect to growth rates, the standard deviations are similar, as well as the 10th,

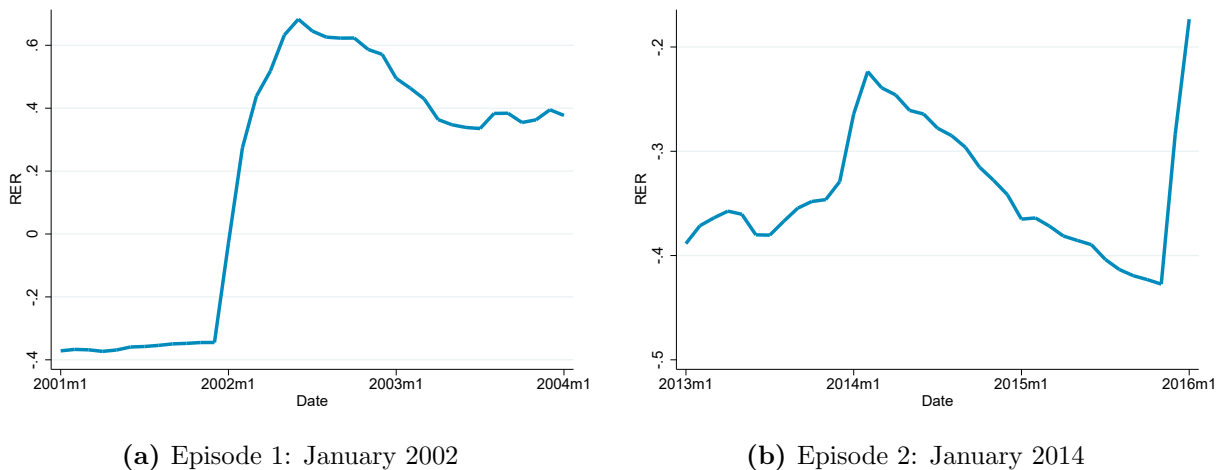
¹Due to the intervention of inflation statistics in Argentina in 2007, we use consumer price indices provided by national statistics before 2007 and PriceStats afterwards.

50th and 90th percentiles. The distribution of the level of log annual income is similar across countries, with the small difference that labor income in Argentina is more dispersed and negatively skewed. The similarity of the labor income distribution across the sample period in Argentina and the US does not translate to a business cycle frequency, specially during large devaluation episodes, as we show next.

2.2 Episodes of analysis

Figure I plots the time series of the real exchange rate for the two devaluation episodes we analyze. We focus on episodes where the exchange rate was devalued by more than 10% in a given month. In the current sample there are two such episodes: January 2002 and 2014.

Figure I – Real Exchange in Argentina 1995-2018



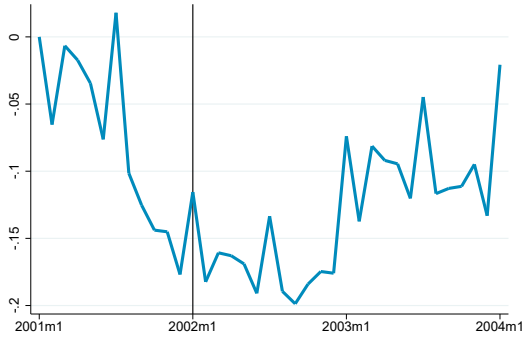
In the first month of 2002, Argentina abandoned its one-to-one peg to the US Dollar after two years of recession and a banking crisis. The resulting depreciation of the peso in that month was of almost 200%, ending a period of eleven years of nominal stability. As can be seen in the figure I, the real exchange rate closely followed the nominal exchange rate. The second episode occurred in January 2014, when the Argentine government relaxed restrictions to buy foreign currency. This announcement was followed by a devaluation of 20%. Although inflation was high, the figure shows how the real exchange rate increased as a result of the devaluation and it returned to the pre-devaluation level one year later.

2.3 Labor income risk during devaluations

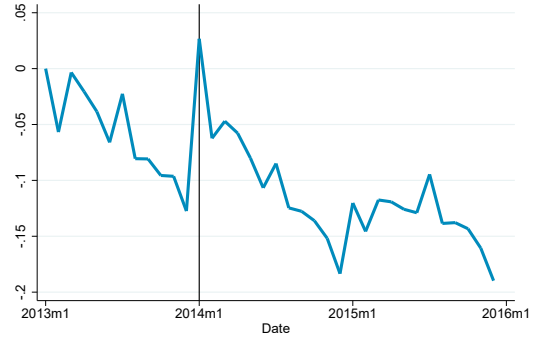
In this section we present summary statistics around the two episodes we have identified. First, we present the flows between employment and unemployment status, and then we focus on the distribution of labor income. Figure II shows the behavior of the (normalized) job finding and separation rates one year before and two years after the large devaluations. In both cases, the declining path of job finding rates reverts after a devaluation. Similarly, separation rates decline. The combination of both facts shows that devaluations have a positive effect on aggregate employment. However, the analysis of the income distribution does not depict such a positive picture. Figure II shows the mean, standard deviation and skewness of monthly real wages one year before and two years after large devaluations. First, we see

that devaluations have negative effects on average real wages. Real wages declined by 30% and 10% in the 2002 and 2014 devaluations, respectively. Second, there is an increase in the cross-sectional standard deviation and a decline in the skewness of monthly real wages. These facts show that after devaluations workers are accepting to work at lower wages, particularly so at the lower end of the wage distribution.

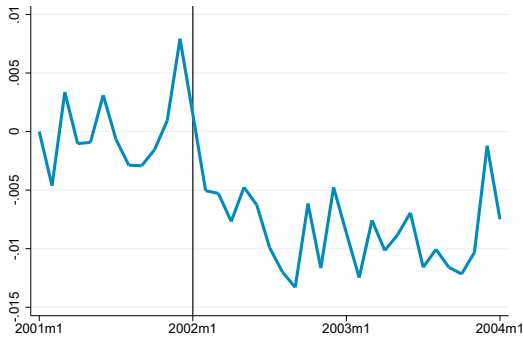
Figure II – Job Flows during Devaluations



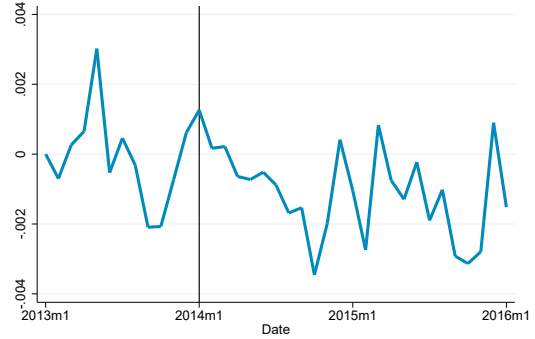
(a) Finding probability: Episode 1



(b) Finding probability: Episode 2



(c) Separation probability: Episode 1



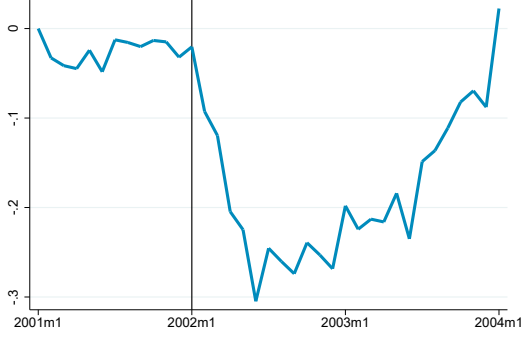
(d) Separation probability: Episode 2

Notes: The figures describe the normalized separation and job finding probabilities. We normalize the value of each rate one year before the devaluation to zero.

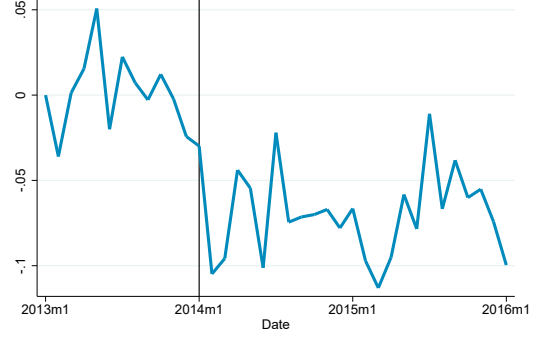
3 A process of labor income

This section provides a statistical model to describe the labor income dynamics. In the model wages are a function of an individual components that is maintained when the workers switches jobs, and a match component which is specific to a job. The latter combines a proper match specific job and a firm-level shock. Although our data allows for identification of both, for now we combine them in a single factor. To keep estimation tractable, we assume that there is no selection in the sense that all workers search for jobs randomly, accept any job offers, separations are exogenous, and job-to-job transitions are not allowed.

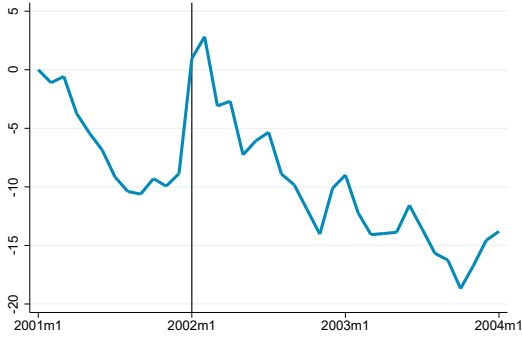
Figure III – Moments of the Labor Income Distribution during Devaluations



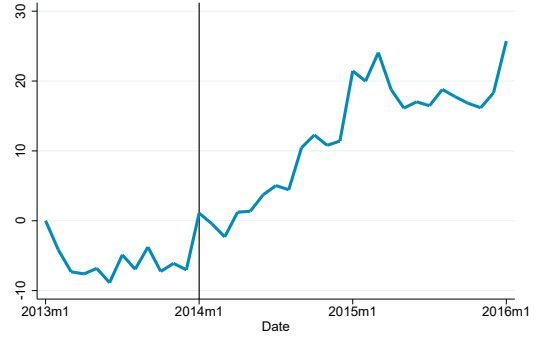
(a) Mean: Episode 1



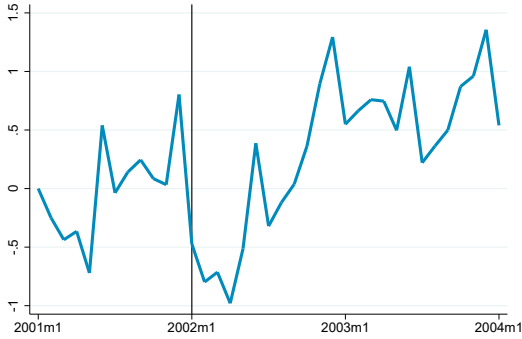
(b) Mean: Episode 2



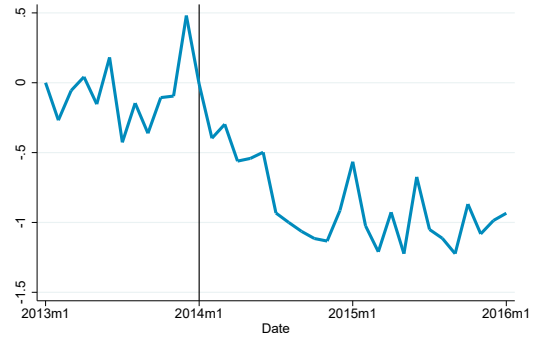
(c) Standard deviation ($\times 100$): Episode 1



(d) Standard deviation ($\times 100$): Episode 2



(e) Skewness: Episode 1



(f) Skewness: Episode 2

Notes: The figures describe the mean, standard deviation ($\times 100$), and skewness of the monthly log labor income. We normalize the value one year before the devaluation to zero.

3.1 A simple statistical model

The frequency of the model is monthly. Let $\log(w_{i,j(a_0),a,t})$ be the log earnings of worker i with age a at time t , working in firm j since age $a_0 \leq a$. The process for log earnings is given by

$$\log(w_{i,j(a_0),a,t}) = x_{i,a,t}\gamma + \theta_{i,a,t} + f_{i,j(a_0),a,t}, \quad (2)$$

where $x_{i,a,t}$ are observable worker characteristics such as age and gender. $\theta_{i,a,t}$ is shock independent of the labor status and $f_{i,j(a_0),a,t}$ is a firm-worker dependent shock. When workers are born, they draw an initial individual productivity $\theta_{i,0,t-a} \sim N(0, \sigma_\theta)$. In subsequent periods this components follows the law of motion

$$\theta_{i,a,t} = \rho\theta_{i,a-1,t-1} + \eta_{i,a,t}, \quad (3)$$

where $\eta_{i,a,t} \sim N(0, \sigma_\eta)$.

The match specific component $f_{i,j(a_0),a,t}$ is a combination of a permanent ($\xi_{i,j(a_0),a,t}^P$) and transitory ($\epsilon_{i,j(a_0),a,t}^T$) component:

$$f_{i,j(a_0),a,t} = \xi_{i,j(a_0),a,t}^P + \epsilon_{i,j(a_0),a,t}^T \sim N(0, \sigma_\epsilon^T), \quad (4)$$

where $\epsilon_{i,j(a_0),a,t}^T \sim N(0, \sigma_\epsilon^T)$.² Once the match is produced, the worker (and the firm) draw an initial match-specific permanent component

$$\xi_{i,j(a_0),a_0,t}^F \sim N(0, \sigma_\xi^F). \quad (5)$$

In subsequent periods, the evolution of the permanent match-specific component follows a random walk

$$\xi_{i,j(a_0),a,t}^P = \xi_{i,j(a_0),a-1,t-1}^P + \epsilon_{i,j(a_0),a,t}^P, \quad (6)$$

where $\epsilon_{i,j(a_0),a,t}^P \sim N(0, \sigma_\epsilon^P)$. We assume that all shocks are orthogonal to each other and independent and identically distributed across workers in the population.

3.2 Estimation strategy

Wages We use data on monthly earnings to obtain values of the stochastic component $\theta_{i,a,t} + f_{i,j(a_0),a,t}$ of wages. In order to do this, we regress log wages on an cubic polynomial in age and monthly time fixed effects to control for any aggregate shocks. Then, we obtain the residuals $\hat{\theta}_{i,a,t} + \hat{f}_{i,j(a_0),a,t}$ and use them as inputs in the estimation process.

Identifying moments There are 6 parameters to be estimated: ρ , σ_θ , σ_η , σ_ϵ^T , σ_ξ^F , and σ_ϵ^P . We estimate the model using GMM. The estimation of the model requires defining a set of moment conditions informative enough about the statistical relationship found in the data for the parameters to be identified. We use moments computed from the data regarding the covariance function for different ages, lags, and groups of workers. More specifically, we group workers by their age in months (we normalize age by $a = (age - 25) * 12$). For now, we do not use data for each age group, but group workers in bins by age: 25-29 ($a = 0$), 30-34 ($a = 60$), 35-39 ($a = 120$), 40-44 ($a = 180$), 45-49 ($a = 240$), 50-54 ($a = 300$), 55-59 ($a = 360$). We use moments on the life-cycle pattern of the variance and auto-covariance structure of

²Since a transitory shock to the worker's individual component is not separately identified from a transitory shock to the match-specific component, we include the transitory in the match-specific component without loss of generality. Also, given the high quality of the data, we do not include a component to account for measurement error.

monthly earnings. For job stayers we compute the auto-covariance at lags $j = 3, 6, 12$, whereas for job switchers we compute them at lags $j = 3, 6$.³

The variance of residual earnings for the youngest groups helps identifying the variance of initial individual-level shocks. In order to understand the identification strategy it is easier to focus first on the auto-covariance structure of residual earnings of job switchers. As shown in Appendix A, these auto-covariances do not include any terms associated with match-level components, and allow us to identify the parameters of the individual-specific components and the transitory component to the match specific component as in Heathcote *et al.* (2010) and Storesletten *et al.* (2004). Following a similar argument, the auto-correlation structure of residual earnings of job stayers relative to job switchers identifies the parameters associated with the permanent match-specific component.

We target the level of residual earnings variance at the beginning of the life cycle to identify the variance of initial productivity. The size of the autocorrelation coefficient in permanent productivity is identified through the life-cycle pattern of the variance of residual earnings. We further distinguish match-specific and individual-specific shocks by comparing average wage growth for stayers and movers. Wage information in transition years is not very reliable because we do not know the exact timing for job-to-job mobility. We therefore choose to not use wage information for these years and instead use mover information by looking at residual wage growth across periods before and after the switch occurred.

MCMC estimation We estimate the parameters of the model using GMM, in which we minimize the objective function

$$L_n(\Omega) = -\frac{1}{2} (\hat{m}_n - m^M(\Omega))' W_n (\hat{m}_n - m^M(\Omega)), \quad (7)$$

where \hat{m}_n is a vector of moments from the data, $m^M(\Omega)$ is the corresponding theoretical moments from the model as a function of model parameters Ω , and W_n is a weighting matrix. To minimize this function we use a Laplace-type estimator developed by Chernozhukov and Hong (2003), which is a derivative-free estimation procedure. The idea behind this method is to construct a Markov chain using Monte Carlo methods that converges to a stationary process of which the ergodic distribution has a mode that asymptotically converges to the GMM estimator.

3.3 Results

Table II presents the estimation results. The estimated initial dispersion in individual productivity is 0.5. The point estimate might seem high relative to previous estimates. However, it is important to notice that initial shocks are in part capturing differences in education across workers, which we cannot control for due to data limitations. The estimates show that shocks to the match-specific components are important. For example, the difference in the variance of wages due to the firm component during the first year of a job spell is 33% of the difference during the first year due to the individual component.

³We have found that wages in the first and last month of employment are different than the wages in the second and second to last month, reflecting in part the fact that workers may have been employed for a fraction of the month. In order to avoid these small measurement errors of the exact start and end date of a job spell, we use lags 3 and 6 when computing auto-covariances of residual earnings for job switchers.

Table II – Estimation Results

Parameter	Estimate	S.E.
ρ	0.996	0.015
σ_θ	0.506	0.058
σ_η	0.059	0.045
σ_{ϵ^F}	0.037	0.029
σ_{ϵ^P}	0.032	0.028
σ_{ϵ^T}	0.292	0.115

4 A Model of Labor Income Risk During Large Devaluations

This section provides a model of labor income risk during large devaluations in a search and matching framework with risk averse agents and incomplete markets. First, it provides a mapping between endogenous parameters and labor earnings that takes into account the endogenous risky decisions of workers. Thus, we control for workers' choices of which types of jobs to search for while unemployed and employment mobility across sectors. Second, it provides a mapping between the distribution of histories of income to aggregate consumption; thus, a theory of current account determination. In order to keep the model tractable, we borrow some modeling assumptions from [Menzio and Shi \(2010\)](#) and [Herkenhoff \(forthcoming\)](#).

4.1 Environment

Time is discrete and denoted by t . The economy is populated by a continuum of risk averse workers of measure one denoted by i and an endogenous measure of firms subject to competitive entry. The economy has S sectors denoted by $s = 1, 2, \dots, S$. Each firm can only produce in one sector by hiring only one worker. Firms are owned by a risk neutral agent. Let q_t denote the real exchange rate, the only exogenous shock in the economy that follows a Markov process.

Preferences. Workers die every period with probability ξ and they are replaced with new born workers. They maximize the present discounted value of utility over consumption, which is given by

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t (1 - \xi)^t u(c_{i,t}) \right], \quad (8)$$

where $c_{i,t}$ denotes consumption, $1 - \xi$ an i.i.d. probability of survival, and $u(c)$ is a period utility that satisfies $u'(x) \in (0, \infty)$, $u''(x) \in (-\infty, 0)$ with $u'(0) = \infty$.

The firms' owner has preferences over consumption and given by

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t C_t \right], \quad (9)$$

where C_t denotes the non-negative consumption.

Capital market and budgets. Markets are incomplete. There is a non-contingent asset with price Q that pays one unit of the consumption good. We assume a small open economy and, thus, take Q as exogenous and constant. The budget constraint of each worker is given by

$$c_{i,t} + Qa_{i,t} = a_{i,t-1} + w_{i,t}e_{i,t} + b(1 - e_{i,t}), \quad (10)$$

where $e_{i,t}$ denotes an employment indicator, $w_{i,t}$ the labor earnings during employment and b the home production during unemployment. $a_{i,t}$ denotes total assets and it is subject to a borrowing limit denoted by \underline{a}

$$a_{i,t} \geq \underline{a}. \quad (11)$$

The budget constraint of the firms' owner is given by

$$C_t + QA_t = A_{t-1} + \sum_{s=1}^S \left(\int_i (1 - \omega_{i,t}) y_{i,s} e_{i,t} di - \kappa \int v_{s,t}(\omega) d\omega \right), \quad (12)$$

where A_t denotes his wealth. His borrowing constraint is given by $A_t \geq \underline{A} = 0$. We assume that $1 > \beta Q$, so that $A_t = 0$.

Technology. Each firm in sector s produce a homogeneous good y using one worker as the only input. The output produced by the match is given by

$$y_{i,s} = y_s(q_t) \psi_{i,t}, \quad (13)$$

where $y_s(q_t)$ is a sector specific component that depends on the real exchange rate and $\psi_{i,t}$ is a match specific component. We make three assumptions regarding $\psi_{i,t}$. First, firms do not know the initial realization of the match-component at the moment of posting a vacancy (thus, matches are inspection goods). Second, at the moment of forming a match the worker and the firm draw a realization of $\psi_{i,t^{id}} = e^{\sigma_z, 0 \epsilon_{i,t^{id}}}$, where t^{id} is the start date of the match. Third, we assume that the match specific component evolves according to

$$\psi_{i,t} = \psi_{i,t-1} e^{\sigma_\psi \epsilon_{i,t}}, \quad (14)$$

where $\epsilon_{i,t}$ is an i.i.d random variable with standard normal distribution.

Labor market. Search is directed. In order to hire a workers, firms operating in sector s post vacancies $v_{s,t}(\omega)$ in submarket ω at a cost κ . Submarkets are characterized by a job finding probabilities and the fraction ω of output that is paid to workers as compensation for their labor. Thus, if worker i is matched with a firm in submarket ω and sector s , his income is given by $\omega_i y_s(q) \theta_{i,t}$. The remaining fraction of output is kept by the firm in the form of profits. We assume that firms and workers have perfect commitment.

Let $\theta_{s,t}(\omega)$ be the vacancy-unemployment ratio or tightness in submarket ω and sector s . In any given submarket and sector, workers and firms get matched with probability $f(\theta)$ and $q(\theta)$, respectively.⁴

⁴We assume $f(\cdot)$ is increasing, while $q(\cdot)$ is decreasing, and that $f(0) = 0$, $q(0) = 1$ with $q(\theta) = f(\theta)/\theta$.

Matches are subject to exogenous separation shocks, which arrive with probability $\delta \in (0, 1)$. Once a workers is separated, he must stay unemployed for one period.

Timing. Each period is divided into three stages. First, for a given number of matches, firms produce, workers get paid, and agents make consumption and savings decisions. Then, exogenous separation occur, firms post vacancies, workers search, and matches are produced. Finally, death shocks are realized and a measure ξ of new workers is born into the economy. We assume newly born workers are unemployed and have zero assets.

Firms' recursive problem. Let $J_{s,t}(\omega, \psi)$ be the present discounted value of the stream of firm's profits in sector s with sharing rule ω and match specific component ψ . The value of the match for the firm satisfies

$$J_{s,t}(\omega, \psi) = (1 - \omega)y_s(q_t)\psi_{i,t} + \beta(1 - \delta)(1 - \xi)\mathbb{E}_t [J_{s,t+1}(\omega, \psi e^{\sigma z^\epsilon})], \quad (15)$$

where $(1 - \delta)(1 - \xi)$ takes into account the survival and separation probabilities. This equation already makes use of the free entry condition, which requires that on expectation vacant firms make zero profits. Imposing competitive entry at time t in sector s determines the equilibrium tightness in each submarket according to

$$q(\theta_{s,t}(\omega))\beta\mathbb{E}[J_{s,t}(\omega, e^{\sigma z_0^\epsilon})] \leq \kappa \quad \forall \omega \quad (16)$$

with complementary slackness $\theta_{s,t}(\omega) \geq 0$.

Workers' recursive problem. Let $U_t(a_-)$ be the value of an unemployed worker with asset holdings a_- , and $W_{s,t}(a_-, \omega, \psi_-)$ be the value of an employed worker in sector s , with asset holdings a , match specific sharing rule ω , and productivity ψ . The value of an unemployed and employed worker is given by

$$U_t(a_-) = \max_{c,a} \left\{ u(c) + \beta(1 - \xi) \max_{\omega,s} [f(\theta_{s,t}(\omega))\mathbb{E}_t [W_{s,t+1}(a, \omega, e^{\sigma \psi, 0^\epsilon})] + (1 - f(\theta_{s,t}(\omega)))\mathbb{E}_t [U_{t+1}(a)]] \right\}$$

$$c + Qa = b + a_- \quad \text{and} \quad a \geq \underline{a} \quad (17)$$

$$W_{s,t}(a_-, \omega, \psi_-) = \max_{c,a} \left\{ u(c) + \beta(1 - \xi) \max_{\omega,s} [(1 - \delta)\mathbb{E}_t [W_{s,t+1}(a, \omega, \psi_- e^{\sigma \psi^\epsilon})] + \delta\mathbb{E}_t [U_{t+1}(a)]] \right\}$$

$$c + Qa = \omega y_s(q_t)\psi_- + a_- \quad \text{and} \quad a \geq \underline{a}. \quad (18)$$

Equilibrium definition. Given an exogenous process for the real exchange rate q_t , an equilibrium is defined by a set of stochastic processes for the value of worker $\{W_{s,t}(\cdot), U_t(\cdot)\}_{s,t}$, policy function for consumption and types of jobs to search for $\{c_t(\cdot)^*, \omega_{s^*,t}(\cdot), s_t^*(\cdot)\}$, value of firms $\{J_{s,t}(\cdot)\}$, and market tightness for each submarket $\{\theta_{s,t}(\omega)\}_{s,t}$ such that: (i) Given $\{W_{s,t+1}(\cdot), U_{t+1}(\cdot)\}_{s,t}$ and $\{\theta_{s,t}(\omega)\}_{s,t}$, the worker's policy functions $\{c_t(\cdot)^*, \omega_{s^*,t}(\cdot), s_t^*(\cdot)\}$ solve (17) and (18), (ii) Given $\{c_t(\cdot)^*, \omega_{s^*,t}(\cdot), s_t^*(\cdot)\}$ and $\{\theta_{s,t}(\omega)\}_{s,t}$, worker's values $\{W_{s,t}(\cdot), U_t(\cdot)\}_{s,t}$ satisfy (17) and (18), (iii) and firm's value $\{J_{s,t}(\cdot)\}$ satisfies (15), and (iv) market tightness $\{\theta_{s,t}(\omega)\}_{s,t}$ satisfies (16).

4.2 Calibration

The calibration strategy is to divide the set of parameters into three groups: (i) preferences and technology, (ii) stochastic process of match specific shocks, and (iii) stochastic process of the real exchange rate. Table III describes the parameters used to analyze the predictions of the model.

Table III – PARAMETERS VALUE AND TARGETS

Parameter	Value	Target
Preferences and technology		
ξ_{ez} : prob. of death	$1/(12 * (60 - 25))$	Entry and exit age of 25 and 60
β : discount factor	$0.95^{1/12}$	Standard in the literature
σ : risk aversion	2	Standard in the literature
Q : Price risk-free asset	$(1.04)^{-1/12}$	Risk-free rate 4%
\underline{a} : borrowing limit	0	Private net foreign position over GDP
Search and matching		
κ : cost of posting vacancies	5.2	Job finding rate of 40%
b : income unemployment	0.3	—
δ : separation rate	0.03	Separation rate of 0.03
γ : Matching function parameter	1.6	Schaal (2017)
Sectorial productivity and income risk		
$\sigma_{\psi,0}$: fixed match shock	(0.0372)	Moments income process
σ_{ψ} : persistent match shock	(0.0327)	Moments income process
(p_1, p_2) : elast. of output to exchange rate	(-0.4, -0.2)	Moments income process
Real exchange rate process		
ρ : autocorrelation	0.9844	Stoch. process of real exchange rate
$(\iota, \sigma_n, \zeta_1, \zeta_2, \zeta_3)$: innovations	(0.088, 0.0279, -0.053, 5.010, 0.874)	Stoch. process of real exchange rate

Notes: The table presents the parameters value assigned to the model.

Preferences and technology. We calibrate the model to a monthly frequency. In our data, we analyze workers between the ages of 25 to 60. Following this sample restriction, we calibrate the death probability to match an expected life of 35 years ($\xi = 1/(12*(60 - 25))$). We use a discount factor of $\beta = 0.95^{1/12}$ and $Q = R^{-1/12}$ where R is the international real interest rate of 4% per annum. Workers' utility function has constant relative risk aversion, $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ with $\sigma = 2$, a standard parameter in the literature.

We choose a borrowing limit to match the historical average private net asset position over GDP in Argentina. Argentina is a net debtor with respect to the rest of the world: average net foreign asset positions over GDP is equal to -18% of GDP during the time period 1970 to 2011—see [Lane and Milesi-Ferretti \(2007\)](#). Public net foreign positions is equal to -55% of GDP. Thus, the private sector is a net creditor with a net foreign position over GDP equal to 37%. In our model, a borrowing constraint of zero ($\underline{a} = 0$) generates an average asset to total labor income ratio—including home production—equal to 35%. Thus, we choose this value to calibrate the borrowing constraint.

The parameters for the labor market includes the level of home production whenever the worker is unemployed (b), the matching technology ($f(\theta)$), the separation rate (δ), and the cost of posting vacancies

κ . We follow [Menzio and Shi \(2010\)](#) and assume that the matching technology is given by

$$f(\theta) = \theta(1 + \theta^\gamma)^{-1/\gamma} \quad \text{and} \quad q(\theta) = (1 + \theta^\gamma)^{-1/\gamma}, \quad (19)$$

with $\gamma = 1.6$ as in [Schaal \(2017\)](#). We choose the level of home production to be 30% of income of the average employed worker. Finally, we choose κ and δ to generate an average monthly job finding probability of 40% and an average separation rate of 3%, as in our data.

Sectorial productivities and income risk. We use our data to calibrate $\sigma_{\psi,0}$, σ_ψ and $y_s(q_t)$. From [Section 3](#), we use $\sigma_{\psi,0} = 0.037$ and $\sigma_\psi = 0.032$. We assume that there are two sectors ($S = 2$) and parametrize $y_s(q) = e^{p_s q}$, where p_s is the elasticity of sectoral output to the real exchange rate. We calibrate p_1 and p_2 in two steps. First, for each ISIC industry we generate a measure of the exposure of labor income to international trade given by $\frac{X-M}{Y}$, where X are exports, M are imports and Y is gross output. We group industries in two groups, those above and below the median. Second, we choose p_1 and p_2 to match a regression coefficient of labor income on the real exchange rate obtained from the data.

Stochastic process for real exchange rate. To the best of our knowledge, there is no standard stochastic process to model real exchange rates. For this reason, we use the most parsimonious representation of this process. More specifically, we posit a first-order autoregressive process to model the real exchange rate, where the unique departure is on the distribution of the innovation. Thus, we model the real exchange rate as

$$q_t = \rho q_{t-1} + \eta_t, \quad \text{with} \quad \eta_t \sim i.i.d. \begin{cases} \mathcal{N}(0, \sigma_n) & \text{with probability } 1 - \iota \\ \mathcal{L}(\zeta_1, \zeta_2, \zeta_3) & \text{with probability } \iota, \end{cases} \quad (20)$$

here $\mathcal{N}(0, \sigma_n)$ denotes a normal random variable with zero mean and standard deviation σ_n , and $\mathcal{L}(\zeta_1, \zeta_2, \zeta_3)$ denotes a Laplace distribution with ζ_1 , ζ_2 , and ζ_3 describing the location, the scale and the asymmetry, respectively.⁵

We estimate the stochastic process with maximum likelihood and assume that $\mathbb{E}[\eta_t] = 0$. [Table IV](#) describes the moments of the real exchange rate in the data, and the model counterparts. As we can see, this stochastic process can approximately describe the normal distribution of the level of the exchange rate and the large skewness and kurtosis of the growth rates of exchange rates.

4.3 Putting the model to work: labor income risk during large devaluations

Can the model reproduce business cycle fluctuations regarding the stochastic process of labor income risk during the two devaluation episodes? What are the dynamics of the current account? To answer these questions, we simulate the model with the sequence of real exchange rates that we observe in the Argentine economy.

⁵A random variable has an asymmetric Laplace distribution $(\zeta_1, \zeta_2, \zeta_3)$ if its probability density function is $f(x; \zeta_1, \zeta_2, \zeta_3) = \frac{\zeta_2}{\zeta_3 + 1/\zeta_3} e^{-(x-\zeta_1)\zeta_2 \operatorname{sgn}(x-\zeta_1)\zeta_3^{\operatorname{sgn}(x-\zeta_1)}}$. This distribution can be rationalized in a model of fixed exchange rates in which the shadow real exchange rate is given by a Brownian motion with drift and an exponential date of adjustment of the nominal exchange rate.

Table IV – Business Cycle Moments Real Exchange Rate: Model and Data

	Level			Growth rate		
	Data	Model		Data	Model	
		Median	[5,95]		Median	[5,95]
mean	0.000	0.021	[-0.308,0.360]	0.000	-0.000	[-0.001,0.009]
Standard deviation	0.360	0.429	[0.293,,0.635]	0.089	0.078	[0.069,0.111]
Skewness	0.141	0.097	[-0.775,1.005]	5.381	1.275	[-2.918,5.463]
Kurtosis	2.730	2.916	[2.097,4.781]	60.351	42.154	[26.119,89.724]
Autocorrelation	0.969	0.977	[0.959,0.987]	-0.072	-0.072	[-0.067,0.051]

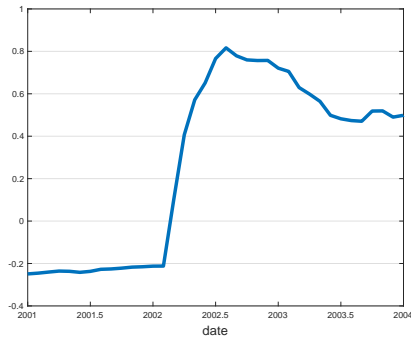
Notes: The table presents business cycle moments from the data and from the simulated series of the model. The real exchange rate in the data is computed as $\frac{E_t P_t^{US}}{P_t^{Arg}}$, where E is the nominal exchange rate of pesos per dollars, and (P_t^{US}, P_t^{Arg}) describe the CPI in the US and Argentina. The time period in the data is 1962:M1 to 2018:M8. The moments in the model are the median and the 95% confidence interval across simulations. The statistics in the model are computed over 5000 simulations with the same length as in the data.

Employment and labor income risk. Figure IV describes the real exchange rate, productivities in each sector and total employment. The real exchange sequence is chosen to match its empirical counterpart. In the case of sectoral productivity, we discipline them by matching average labor income across sectors. Employment is an outcome of the model and it decreases during the devaluation, followed by a recovery. From the calibration, we can see that the elasticity of output to exchange rates across sectors is negative (especially for sector $s = 1$). Thus, devaluations are associated with a lower present discounted value of output and a lower market tightness.

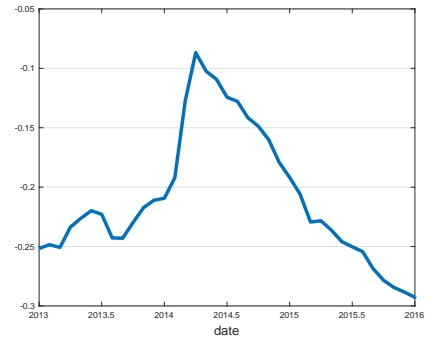
Figure V describes the first three moments of the log-income conditional on being employed. As we can see, there is a large decrease in mean income—this is a target in the calibration—, but also an increase in the cross-sectional dispersion and a decrease in the skewness of income in the first episode. To understand this result, note that searching for jobs is a risky enterprise affected by two effects. First, the distribution of sharing rules is heterogenous across workers. Workers with low wealth are willing to work for a lower share and this mechanism alone generates an increase in the standard deviation and a decrease in the skewness of the distribution of labor income. Second, the devaluation generates a reallocation of workers from Sector 1—with a lower productivity during the devaluation—to Sector 2. During this transition, there is an increase in the dispersion of income of workers across sectors.

Trade balance during a large devaluation. Why devaluations are associated with a reversion of the current account? This is difficult to rationalize since savings are decreasing during recessions. This model provides an answer to this question. Panel-a in Figure VI shows the evolution of income and consumption—their difference is the trade balance. Consumption falls with income in the model—even if the average worker’s level of assets is 40% of his monthly income. The intuition behind this result can be observed in Panel-b in Figure VI, which shows the distribution of assets one year before (blue) and one year after the devaluation (green). As long as a large fraction of unemployed workers are against the borrowing constraint, they will adjust consumption when income falls.

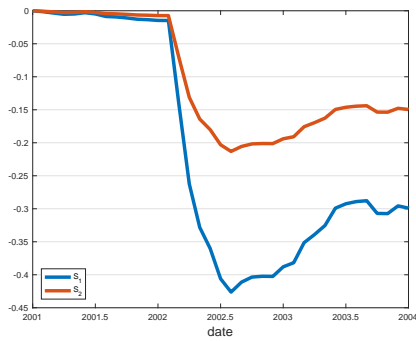
Figure IV – Aggregate Effect of a Devaluation



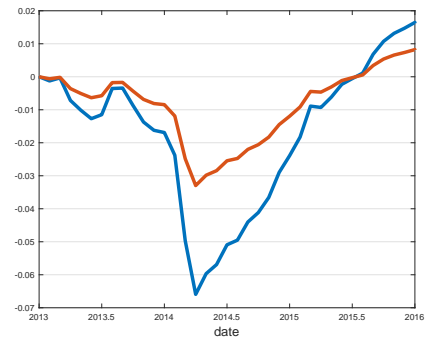
(a) Real exchange rate: Episode 1



(b) Real exchange rate: Episode 2



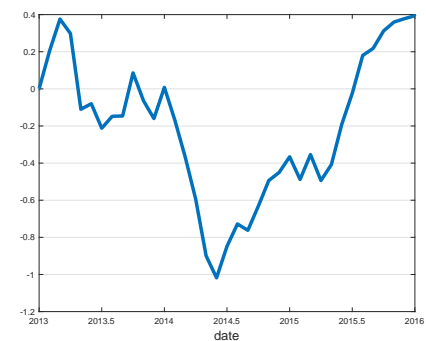
(c) Sectors productivity: Episode 1



(d) Sectors productivity: Episode 2



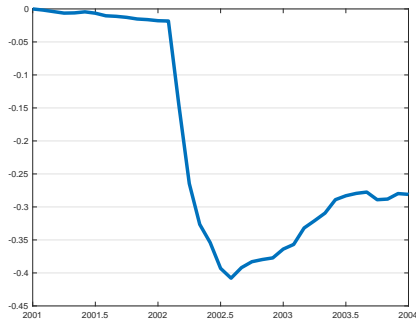
(e) Employment rate: Episode 1



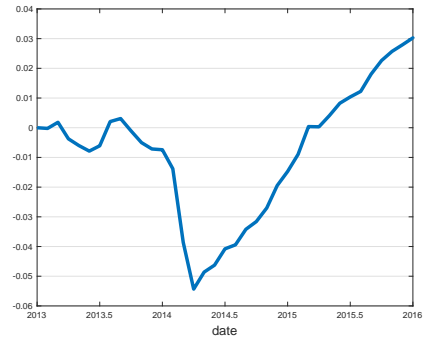
(f) Employment rate: Episode 2

Notes: These figures describe the real exchange rate, productivity by sector and employment rates across devaluation episodes. We normalize the value of productivity and employment to zero one year before the devaluation.

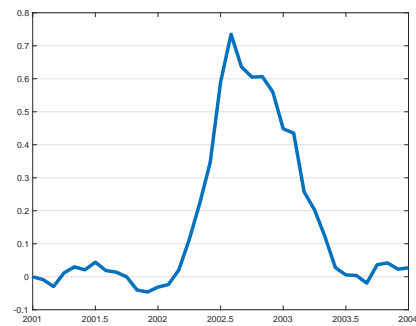
Figure V – Labor Income Moments



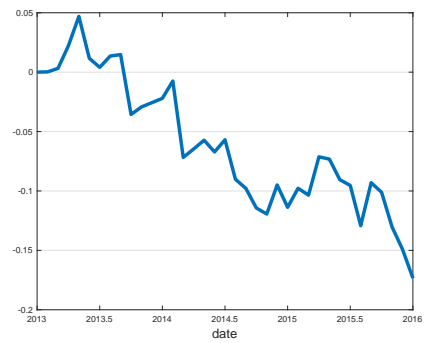
(a) Mean: Episode 1



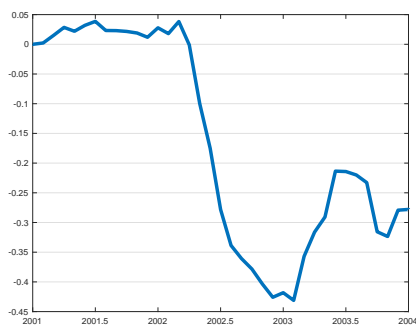
(b) Mean: Episode 2



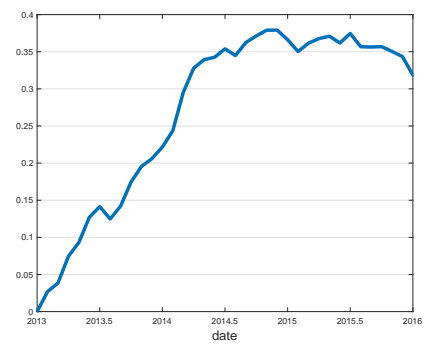
(c) Standard deviation: Episode 1



(d) Standard deviation: Episode 2



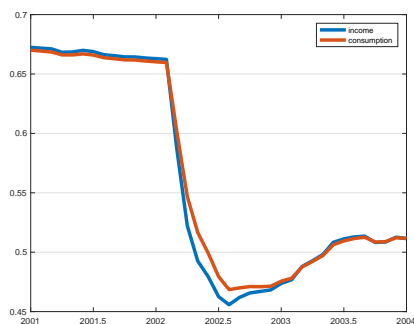
(e) Skewness: Episode 1



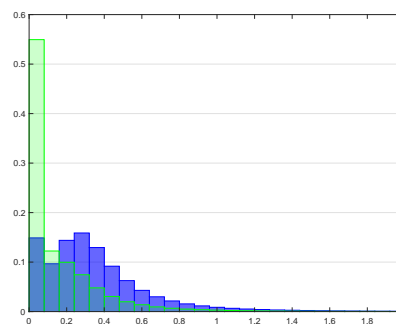
(f) Skewness: Episode 2

Notes: The figures describe the real exchange rate, productivity by sector and employment rates across devaluation episodes. We normalize the value of productivity and employment to zero one year before the devaluation.

Figure VI – Current account with heterogeneous workers



(a) Income and Consumption: Episode 1



(b) Distribution of asset: Episode 1

Notes: The first figure shows the evolution of aggregate income and consumption during a the first devaluation episode. The second figure shows the distribution of assets one year before (blue) and one year after the devaluation (green).

5 Conclusion [TBC]

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A Model moments

These are the theoretical counterparts to the moments used in the estimation of the income process based on estimated wage residuals $\tilde{\omega}_{i,a,t}$:

- Cross sectional variance of $\tilde{\omega}_{i,a,t}$ across a and t :

$$\mathbb{V}[\theta_{i,a,t}] = \begin{cases} \rho^{2a} \sigma_{\theta}^2 & \text{if } a = 0; \\ \rho^{2a} \sigma_{\theta}^2 + \sum_{h=1}^a \rho^{2(a-h)} \sigma_{\eta}^2 & \text{if } a > 0. \end{cases}$$

$$\mathbb{V}[f_{i,j(a_0),a,t}] = \begin{cases} \sigma_{\epsilon^F}^2 + \sigma_{\epsilon^T}^2 & \text{if } a_0 = a; \\ \sigma_{\epsilon^F}^2 + \sum_{h=1}^{a-a_0} \sigma_{\epsilon^P}^2 + \sigma_{\epsilon^T}^2 & \text{if } a > a_0. \end{cases}$$

Then,

$$\mathbb{V}[\tilde{\omega}_{i,j(a_0),a,t}] = \mathbb{V}[\theta_{i,a,t}] + \mathbb{V}[f_{i,j(a_0),a,t}]$$

- Autocovariance of $\tilde{\omega}_{i,a,t}$ and $\tilde{\omega}_{i,a-j,t-j}$ for stayers between $t-j$ and t :

$$\text{cov}[\theta_{i,a,t}, \theta_{i,a-j,t-j}] = \rho^a \rho^{(a-j)} \sigma_{\theta,t-a}^2 + \sum_{h=1}^{a-j} \rho^{(a-h)} \rho^{(a-h-j)} \sigma_{\eta,h,t-a+h}^2$$

$$\text{cov}[f_{i,j(a_0),a,t}, f_{i,j(a_0),a-j,t-j}] = \sigma_{\epsilon^F,t-(a-a_0)}^2 + \sum_{h=1}^j \sigma_{\epsilon^P,a_0+h,t-(a-a_0)+h}^2$$

Then,

$$\text{cov}[\tilde{\omega}_{i,j(a_0),a,t}, \tilde{\omega}_{i,j(a_0),a-j,t-j}] = \text{cov}[\theta_{i,a,t}, \theta_{i,a-j,t-j}] + \text{cov}[f_{i,j(a_0),a,t}, f_{i,j(a_0),a-j,t-j}]$$

- Autocovariance of $\tilde{\omega}_{i,a,t}$ and $\tilde{\omega}_{i,a-j,t-j}$ for switchers between $t-j$ and t :

$$\text{cov}[\tilde{\omega}_{i,j'(a'_0),a,t}, \tilde{\omega}_{i,j(a_0),a-j,t-j}] = \text{cov}[\theta_{i,a,t}, \theta_{i,a-j,t-j}]$$

Since some of these moments depend on workers' tenure in a job ($a - a_0$), we apply the conditional variance to obtain unconditional moments, which are the ones we compute from the data. Given that shocks have a mean equal to zero, this simply corresponds to the mean moment across the tenure distribution and we can compute, for example, the cross-sectional variance across groups with

$$\begin{aligned} \mathbb{V}[\tilde{\omega}_{i,a,t}] &= E[\mathbb{V}[\tilde{\omega}_{i,j(a_0),a,t}]] + V[\mathbb{E}[\tilde{\omega}_{i,j(a_0),a,t}]] \\ &= \sum_{a_0} \omega_{a_0,a,t} \mathbb{V}[\tilde{\omega}_{i,j(a_0),a,t}] \end{aligned}$$

where $\omega_{a_0,a,t}$ is the share of workers employed at period t , with age a and tenure a_0 (so that $\sum_{a_0} \omega_{j(a_0),a,t} = 1$).