An analysis of terms of trade shocks in Argentina

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Abstract

I analyze the effects of a terms of trade improvement over aggregate output and inflation in Argentina using a structural Vector Autoregression (VAR). I identify a terms of trade variation shock with a *sign restrictions* scheme conditional on a New Keynesian model estimated/calibrated for the country. I conclude that terms of trade improvements generates both output growth and inflation, though the effect is more statistically significant for the former than for the latter. These findings show the relevance of terms of trade as source of business cycles in Argentina during the last two decades.

Keywords: Terms of trade shocks; Structural VARs; Signs restrictions identification; Small open economy New Keynesian models; Argentina.

JEL Classification: C32; E12; F41

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1 Introduction

During the last twenty years there has been a substantial drop in macroeconomic volatility in developed countries: the so-called 'Great Moderation' period. However, developing countries in general have suffered from increasing instability during this period. For the case of Argentina, the country is more vulnerable now than it was before the financial globalization that took place during the 1990's. Theoretical explanations give two main reasons for this: an external one that says that developing countries are subject to more volatile shocks than developed nations are, or a local one that blames government policies as unable to tackle foreign disturbances.

One of the external sources of instability, if not the most important one, are the terms of trade variations. Being a small open economy, Argentina has always been affected by the oscillating prices of the commodities it exports. Since Prebisch [1959], it was proposed that terms of trade variations had important consequences over South American countries. The Singer-Prebisch hypothesis pointed out that deteriorating terms of trade were essential to explain underdevelopment in the region. This thesis was also called *structural* in opposition to an inquiry that allegedly leaves aside presumed relevant features when undertaking economic analysis. *Structuralism* is still very popular among economists in Latin America who rely on their premises to do policy recommendations. Nevertheless, there have not been many attempts to actually evaluate the impact of terms of trade shocks in the Argentinian economy.

In this work, I quantify the effects of an improvement in terms of trade over output and inflation. To perform such analysis, I use a Structural Vector Autoregression (SVAR) model identified with *sign restrictions* where the signs are formally imposed conditional on a New Keynesian Small Open Economy (NK SOE) model with estimated/calibrated parameters. I conclude that terms of trade improvements have an important effect fostering output growth and, though not as statistically significant, generating inflation. According to my results, an improvement of 1% in terms of trade increases output a maximum of 0.4% on the second quarter. This effect is significant for one year. The effect estimated on inflation is of the same magnitude, though not as persistent and statistically significant.

These findings can be explained by the fact that Argentina had a fixed exchange rate regime during the first half of the sampled years while it acquired a flexible one during the other half, when the volatility in the terms of trade increased. As noted by Friedman [1953], an advantage often attributed to flexible exchange rate regimes over fixed ones is their ability to insulate more effectively the economy against external shocks. Since then, a number of theories have confirmed this original intuition and it has become one of the least disputed arguments in favor of flexible exchange rate regimes[1]. As analyzed by Broda [2001], there are smoother real output paths after terms of trade shocks when exchange

[1]See for example Corsetti and Pesenti [2001].

rate is allow to float. At the same time, the author concludes that these disturbances are inflationary in flexible exchange rate regimes.

To my true knowledge, the present article is original as I am not aware of any similar work done to analyze terms of trade shocks in Argentina. The closer VAR analysis available is that of Broda [2004] who estimates terms of trade to have an effect weaker than the one I obtain for Argentina. This difference in magnitude can be explained by the fact that the author studies terms of trade shock effects for several developing countries using a panel VAR identified with *zero restrictions*. A main distinction with respect to Broda's paper is that here I use a SVAR identified with *sign restrictions* to derive quantitative conclusions about an improvement in terms of trade. This type of structural analysis is quite new and its use is beginning to extend in macroeconometric research. Its main advantage over *zero restrictions* is that it is more consistent with an underlying DSGE model structure. Or as Kilian [2011] put it, 'perhaps the best hope for matching structural VAR models and DSGE models is the use of *sign restrictions*'.

2 Data analysis

2.1 Recent economic events and data transformation

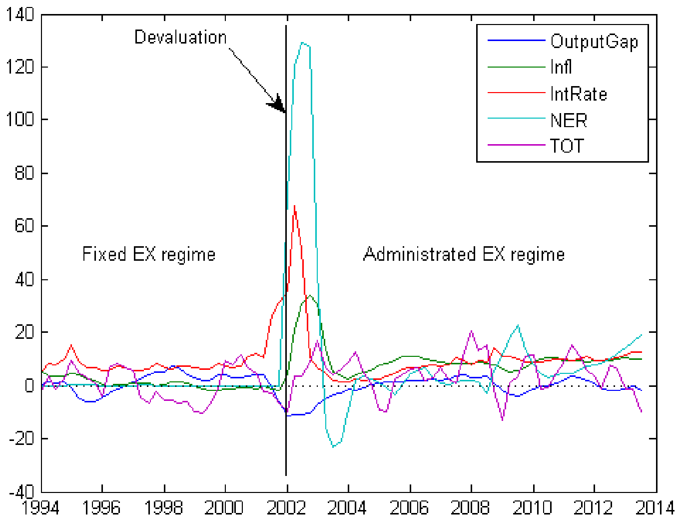
A widely known stylized fact is that emerging market economies are about twice as volatile as developed economies. Argentina is far from being the exception. During the last twenty years, the country has experienced important variability in its macroeconomic variables as shown in Figure 1. As presented in the figure, a first difficulty that arouses when analyzing Argentinian time series is the huge exchange rate devaluation that occurred at 2002 and that divides Argentinian recent economic history into two markedly different periods: the *fixed exchange rate regime* (also known as the *Convertibility model*) and the *administrated exchange rate regime* installed after the devaluation took place. Variability along the whole sample period is very high (around ±20%). But from 2001 to 2003, when the devaluation effects hit harder, macroeconomic volatility exploded beyond usual levels.

An analysis of Argentinian time series can be misleading if variability of the presented variables is not softened to lighten the effect of the violent devaluation episode of 2002. In order to do so, I follow Stock and Watson [2002] and get rid of outliers by applying the following criteria:

- Output gap: Outliers are identified as observations that differ from the sample median by more than two times the sample interquartile range. I replace these observations with the median of the eight adjacent values. As a result, four data values are transformed (from 2002:1 to 2002:4).

- Inflation: Outliers are identified as observations that differ from the sample median by more than two times the sample interquartile range. I replace these observations

Figure 1: Argentinian time series



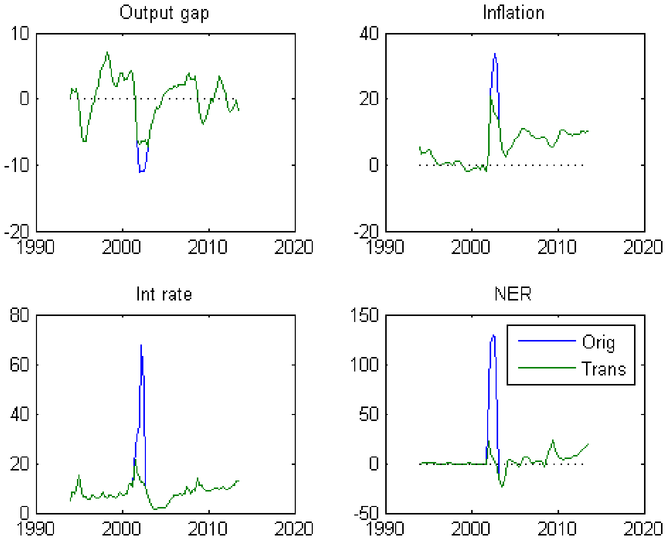
with the median of the six adjacent values. As a result, three data values are transformed (from 2002:3 to 2003:1).

- Nominal interest rate: Outliers are identified as observations that differ from the sample median by more than four times the sample interquartile range. I replace these observations with the median of the eight adjacent values. As a result, five data values are transformed (from 2001:3 to 2002:3).

- Nominal exchange rate (NER): Outliers are identified as observations that differ from the sample median by more than six times the sample interquartile range. I replace these observations with the median of the eight adjacent values. As a result, five data values are transformed (from 2002:1 to 2003:1).

As terms of trade do not present outliers, I keep original values. The data transformation detail can be seen in Figure 2. As a result of this data transformation, I obtain sample series that are still extremely volatile but benefit from the lack of outliers values occurred around the devaluation event. The transformed series are shown in Figure 3 from where some observations can be derived. However, before analyzing empirical regularities in Argentina, I will describe briefly major economic events that took place during the last twenty years.

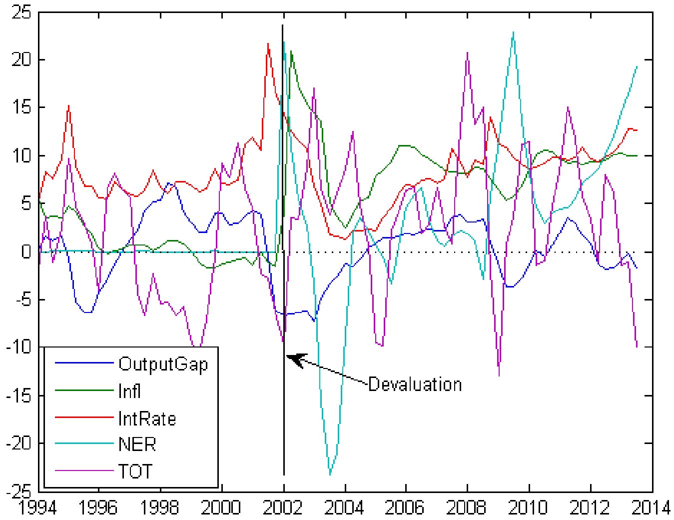
Figure 2: Argentinian time series original and transformed



In order to grasp recent economic history in the country, it is important to distinguish among both regimes that settled before and after the devaluation event of 2002. *Fixed* and *administrated exchange rate regimes* were completely different in nature and responded to the circumstances of their times. Fixed exchange rate was implemented on 1991 to face hyper-inflationary episodes that had been damaging Argentina since the late 1980's. It was very successful in halting inflation and fostering output during most of the 1990's, but it turned out to be ill suited to cope with economic downturns. The reason behind this was that the *fixed exchange rate* regime was mainly a capital-inflow led growth model: foreign reserves came mostly from the capital account, while the country frequently run current account deficits. Output growth during the first half of 1990's was sustained by FDI, which consisted basically on private investment in the privatization of services state own companies. But the second half was based mainly on portfolio investment, which was very volatile and highly influenced by other emerging markets outlooks. A first warning of the fragility of the *fixed exchange rate* regime was the impact of Mexican *peso* devaluation in 1995 (known as the *Tequila* effect). But it wasn't until Brazilian *real* devaluation in 1999 that the system started to crumble.

During 2001, Argentinian government aimed to save the *fixed exchange rate* system. The country borrowed two loans of 40 and 30 billion US$ (known as the *Blindaje* and

Figure 3: Argentinian time series (without outliers)



Megacanje loans, respectively), provided mostly by the IMF because private investors were reluctant to keep on lending to the country. A *zero deficit* policy, that inhibited fiscal deficits by law, was also implemented some months before the breakdown in an endeavor to regain private investors' confidence. However, all these attempts were fruitless. The main reason was that Argentina had become to expensive under the *fixed exchange rate* regime. The Central Bank was unable to devaluate the currency because it was forbidden by the *Convertibility* law, and the speed of deflation in internal prices, which was assumed to be the solution for the lack of competitiveness at the time, was just never fast enough.

Excluded from international financial markets, Argentina had no choice other than debt default and local currency devaluation on January 2002. This marked the end of the *fixed exchange rate* regime and the beginning of the *administrated* one. The immediate effect of the devaluation was an important gain in competitiveness of the country. Argentina had traditionally been considered one of the most advanced countries in the region, so it had both the industrial potential and a skillful workforce to undergo a fast recovery. Economic performance improved steadily since the devaluation episode: GDP growth has remain quite high during most of the *administrated exchange rate* regime. The difference with the previous regime, was that now it had become mainly an export led growth model: foreign reserves came mostly from the current account surplus. At the same time, terms of trade

Table 1: Sample moments

Statistic	Argentina Whole sample	Fixed EX	Adminstrated EX	US
σ_q	7.15	6.23	7.33	3.17
σ_y/σ_q	0.48	0.60	0.42	0.46
σ_π/σ_q	0.71	0.32	0.46	0.26
σ_r/σ_q	0.51	0.63	0.48	0.69
σ_e/σ_q	1.03	0.01	1.26	2.24
$\rho(q_t, q_{t-1})$	0.60	0.69	0.46	0.72
$\rho_{q,y}$	-0.06	-0.20	0.15	-0.41
$\rho_{q,\pi}$	0.29	0.12	0.10	-0.81
$\rho_{q,r}$	-0.08	0.05	-0.16	-0.06
$\rho_{q,e}$	-0.15	-0.01	-0.30	0.44

See Data Appendix on page 23 for details.

improved significantly for Argentina (as for many commodity exporting countries) during the past ten years driven mostly by China's increasing demand. Considering that since 2002 Argentina's GDP growth is mainly lead by exports, this fact has improved even more the country's performance.

Nevertheless, economic perspective for the country has worsen significantly during the last three years. Argentina has been unable to tackle inflationary pressure and it is now in danger of falling into stagnation. Local authorities have not only been powerless to reduce inflation, they have also been unwilling to recognize that rising prices were actually taking place at unusual speed[2]. In a country were inflation has been out of control several times in the recent past, government's attitude has eroded private sector trust regarding economic outlook, with a consequent drop in private investment. Additionally, high inflation has turned the country more expensive and less competitive. And, to get things worse, commodity exports prices have decreased in the last two years. Consequently, the export led growth model has been seriously weakened.

2.2 Empirical regularities

Looking at Figure 3, we can see there are some distinctions between the *fixed* and *administered exchange rate* regimes. More specifically, volatilities and TOT correlations with the rest of the variables seem to be different before and after devaluation. Table 1 presents relevant sample data moments for the whole sample as well as for both periods. The same moments are shown for US as a representation of a developed country.

The table shows that there are important differences both between Argentina's subsequent regimes and between this nation and US. A first salient feature is that terms of

[2]A brief description of this serious issue is given at page 8.

trade volatility (σ_q) in Argentina more than doubles that of the US. As most developing countries, Argentina is basically a commodity exporter and a capital goods importer. In 2013, commodities represented 66% of total exports and capital goods represented 74% of total imports for the country[3]. Consequently, terms of trade for the country are mainly driven by the prices of these products. Being an important player in world commodity market (specially for products like soya, wheat, corn, barley, leather, meat, fruits, vegetables, biodiesel, copper and gold), Argentina is a price taker for the goods she exports. It follows that the terms of trade can be regarded as an exogenous source of aggregate fluctuations for the country. Because primary commodities display large fluctuations over time, terms of trade have the potential of being an important source of business cycles in the country.

A second important observation is that terms of trade go from weakly counter-cyclical to weakly pro-cyclical with the subsequent exchange regimes in Argentina, while they are strongly counter-cyclical in US. Now, the counter-cyclicality in the US can be explained by the size of its economy, such that the high imports demand during booms can affect worldwide prices and deteriorate US terms of trade. But for Argentina, being a small world market player, this explanation is not satisfactory. Countercyclical terms of trade during the fixed *exchange rate regime* are hard to explain, while them being procyclical during *administrated exchange rate regime* can be due to the export led growth during that period.

Finally, correlation of terms of trade with both inflation and nominal exchange rate are qualitatively different between the countries. For Argentina, there seems to be a non-negligible impact of the improvement of terms of trade rising internal prices and appreciating the nominal exchange rate. These features are replicated successfully by the theoretical model as explained below.

2.3 Problems with Argentinian data

The credibility of macroeconomic series measurement has been seriously damaged during the last years in Argentina. It is known that the consumer price index (CPI) has been systematically underestimated since the national statistics institute's intervention in 2007. Since then, official inflation has been lower than the one estimated by private consultants. But it was not until the last three years that the gap between both estimations has widened. It is also suspected that GDP series have been overestimated lately. This is said to be taking place since 2007, according to a group of researchers of the University of Buenos Aires[4]. Finally, Argentinian government has tighten the control on foreign currency reserves since 2011 in an attempt to reduce capital outflow. Since then, official

[3]Source: Argentian statistic national institute (Indec).
[4]Refer to www.arklems.org for further information.

exchange rate has been lower than the market value. But it was not until 2012 that the gap between official and market currency values widened.

This being said, in the present work I use official data. I expect results presented here not to be qualitatively distinct from those obtained if national series would not have been arbitrarily modified, although quantitative differences might arise.

3 The theoretical model

The data description presented above might give us some clues of the dynamics of some variables of interest after a terms of trade innovation. However, the raw data is in principle driven by a multitude of shocks, of which the terms of trade is just one. So, as Ravn et al. [2007] put it, 'an important step in the process of isolating TOT shocks (or any kind of shock, for that matter) is identification. Data analysis based purely on statistical methods will in general not result in a successful identification of TOT shocks. Economic theory must be at center stage in the identification process.'

The model used here is taken from Lubik and Schorfheide [2007], which is a simplified version of Galí and Monacelli [2005]. It features the three key ingredients any New Keynesian (NK) model has: the existence of money, such that nominal prices are present; monopolistic competition, where firms have some market power to set the price of differentiated goods; and nominal rigidities in prices represented by the New Keynesian Phillips curve. At the same time, the model incorporates explicitly the exchange rate, the terms of trade, exports, imports and international financial markets. So it is a Small Open Economy (SOE) model. In this sense, the NK framework, which typically consists of a two-equation dynamical system with a NK Phillips curve and a dynamic IS-type equation plus the monetary rule, is augmented with the *law of one price* and a dynamic rule for the terms of trade.

Regarding household's behavior, consumption maximization leads to the Euler equation that can be expressed as an open economy dynamic IS-curve:

$$\begin{aligned} y_t =& E_t y_{t+1} - [\tau + \alpha(2-\alpha)(1-\tau)](R_t - E_t\pi_{t+1}) - \rho_z z_t \\ & - \alpha[\tau + \alpha(2-\alpha)(1-\tau)]E_t\Delta q_{t+1} + \alpha(2-\alpha)\frac{1-\tau}{\tau}E_t\Delta y^*_{t+1} \end{aligned} \tag{1}$$

where $0 < \alpha < 1$ is the import share and τ is the intertemporal substitution elasticity between home and foreign goods. Endogenous variables are aggregate output y_t and CPI inflation rate π_t. The terms of trade q_t, defined as the relative price of exports in terms of imports, enter in first differences (Δq_t) and will be alternatively assumed to be exogenous and endogenous, as described below. R_t is the nominal interest rate, y^*_t is exogenous world output and z_t is the growth rate of the technology process A_t with ρ_z as persistence parameter[5].

With respect to the producer side, domestic firm's maximization leads to the following open economy Phillips curve:

$$\pi_t = \beta E_t \pi_{t+1} + \alpha\beta E_t \Delta q_{t+1} - \alpha \Delta q_t + \frac{\kappa}{\tau + \alpha(2-\alpha)(1-\tau)}(y_t - \bar{y_t}) \tag{2}$$

where $0 < \beta < 1$ is the households discount factor, and $\kappa > 0$ is the Phillips curve slope that captures the degree of price stickiness. Additionally, potential output in the absence of nominal rigidities is defined as:

$$\bar{y_t} = \frac{-\alpha(2-\alpha)(1-\tau)}{\tau} y_t^* \tag{3}$$

The monetary authority is assumed to follow a policy rule where, besides CPI inflation and output, nominal exchange rate depreciation (Δe_t) is targeted:

$$R_t = \rho_R R_{t-1} + (1-\rho_R)[\phi_\pi \pi_t + \phi_y y_t + \phi_e \Delta e_t] + \varepsilon_{R_t} \qquad ; \qquad \varepsilon_{R_t} \sim \mathcal{N}(0, \sigma_R^2) \tag{4}$$

where e_t is the nominal exchange rate and policy coefficients are assumed to be $\phi_\pi, \phi_y, \phi_e \geq 0$. The persistence parameter is $0 < \rho_R < 1$ and ε_{R_t} is an exogenous policy shock which can be interpreted as the non-systematic component of the monetary policy.

Following the *law of one price*, it is assumed that relative PPP holds:

$$\pi_t = \Delta e_t + (1-\alpha)\Delta q_t + \pi_t^* \tag{5}$$

where π_t^* is a world inflation shock which is treated as unobservable[6].

Regarding terms of trade, they are treated subsequently as exogenous and endogenous. I use the latter specification to study the impact of productivity shocks on terms of trade and to optimize the function that minimizes the differences between theoretical and empirical sample moments when obtaining values for the parameters of the Phillips curve (κ) and the elasticity of substitution (τ). For the rest of the simulations, including the variance decomposition analysis, I treat terms of trade as exogenous. Whenever TOT are exogenous, they are assumed to follow an AR(1) process:

$$\Delta q_t = \rho_q \Delta q_{t-1} + \varepsilon_{q_t} \qquad ; \qquad \varepsilon_{q_t} \sim \mathcal{N}(0, \sigma_q^2) \tag{6}$$

where $0 < \rho_q < 1$ is the persistence parameter and ε_{q_t} is the TOT innovation. By the other hand, when TOT are endogenous, (6) is replaced by:

[5] In order to guarantee stationarity of the model, all real variables are expressed in terms of percentage deviations from A_t.

[6] Another interpretation for π_t^* is that it captures deviations from PPP.

$$[\tau + \alpha(2-\alpha)(1-\tau)]\Delta q_t = \Delta y_t^* - \Delta y_t \tag{7}$$

where

$$\Delta y_t^* = y_t^* - y_{t-1}^* \tag{8}$$
$$\Delta y_t = y_t - y_{t-1} \tag{9}$$

Endogenous terms of trade as defined by (7) imply that this is the relative price that clears world market. With this specification, an increase in world output will improve terms of trade, while a increase in domestic output will deteriorate them.

And, lastly, the rest of the exogenous shocks are assumed to follow AR(1) processes:

$$z_t = \rho_z z_{t-1} + \varepsilon_{z_t} \quad ; \quad \varepsilon_{z_t} \sim \mathcal{N}(0, \sigma_z^2) \tag{10}$$
$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_{\pi_t^*} \quad ; \quad \varepsilon_{\pi_t^*} \sim \mathcal{N}(0, \sigma_{\pi^*}^2) \tag{11}$$
$$y_t^* = \rho_{y^*} y_{t-1}^* + \varepsilon_{y_t^*} \quad ; \quad \varepsilon_{y_t^*} \sim \mathcal{N}(0, \sigma_{y^*}^2) \tag{12}$$

where $0 < \rho_i < 1$ and ε_i are the persistence parameters and innovations of the i_{th} variable, respectively.

As mentioned before, I use two different specifications of the model depending on whether terms of trade are treated exogenously or endogenously. When TOT are treated as exogenous, the system is represented by the 10 equations (1)-(6), (8) and (10)-(12) which has 10 variables: 2 control variables (π_t, y_t) and 8 state variables $(R_t, \Delta q_t, \pi_t^*, y_t^*, \Delta y_t^*, \Delta e_t, \bar{y}_t, z_t)$. There are five innovations that affect this system: $\varepsilon_{R_t}, \varepsilon_{q_t}, \varepsilon_{z_t}, \varepsilon_{\pi_t^*}$ and $\varepsilon_{y_t^*}$. By the other hand, when TOT are solved endogenously, the system is represented by the 11 equations (1)-(5) and (7)-(12) which has 11 variables: 3 control variables $(\pi_t, y_t, \Delta q_t)$ and 8 state variables $(R_t, \pi_t^*, y_t^*, \Delta y_t^*, \Delta e_t, \bar{y}_t, z_t, \Delta y_t)$. There are four innovations that affect this system: $\varepsilon_{R_t}, \varepsilon_{z_t}, \varepsilon_{\pi_t^*}$ and $\varepsilon_{y_t^*}$.

Both specifications of the model are linearized around the zero steady state and solved using Sims [2002] method[7]. Linearization, solution and simulation of both models are performed with Dynare software as referred to in Adjemian et al. [2011].

3.1 Empirical implementation

I follow a mixed strategy to obtain model's parameters values: some of them are calibrated while others are estimated using sample data from 1993:1 to 2013:3 of Argentina and US,

[7] It is questionable whether it makes sense to linearize around zero steady state a model that should accurately represent a country like Argentina, where (for example) inflation has been systematically high. A solution to this problem can be the modification of the typical NK model used here as proposed by Ascari and Ropele [2009]. This being said, I leave the implementation of the modified model for further work.

as it corresponds. Calibrated parameters are the discount factor $\beta = e^{-r_{ss}/400}$, where the real interest rate at steady state is $r_{ss} = 2.58$; Argentinian import share α, that comes from the ratio of average imports over output; TOT persistence ρ_q and volatility σ_q, which are set to match the serial correlation and standard deviation of terms of trade in Argentina; and world output and inflation persistences and volatilities ($\rho_{y^*}, \rho_{\pi^*}, \sigma_{y^*}$ and σ_{π^*}, respectively), which are set to match US serial correlations and standard deviations of output gap and inflation, correspondingly.

In order to calibrate the intertemporal substitution elasticity τ and the Phillips curve slope κ, I minimize the following loss function

$$F = \left(\sigma_q^m - \sigma_q^d\right)^2 + \left[\rho(q,y)^m - \rho(q,y)^d\right]^2 + \left[\rho(q,\pi)^m - \rho(q,\pi)^d\right]^2 + \left[\rho(q,e)^m - \rho(q,e)^d\right]^2 \tag{13}$$

where statistics with upperscript m refer to the model and those with upperscript d refer to sample data (just of the *administrated exchange rate* regime). The criteria to include these targeted sample moments, and not others, is that the these are the ones differ the most from those of the US, as can be seen on Table 1. So, it can be interpreted that these are the sample moments that best explain the special characteristics of Argentina, as a difference from US. I solve the model for determinancy taking terms of trade as endogenous and using the parameter values of Table 2. Initial values assigned for τ and κ are 0.30 for both, which is the estimation obtained for Canada in Lubik and Schorfheide [2007]. I perform 10,000 Monte Carlo simulations for the optimization of (13). Each simulation is of size 80, that matches 20 years of quarterly available sample data of Argentina, and get the median of the distributions of τ and κ, which are shown on Table 2.

Policy rule and productivity's parameters are estimated by OLS and Cochrane-Orcutt procedure, respectively. Regarding the former, the rule (4) can be expressed as:

$$R_t = \rho_R R_{t-1} + \beta_1 \pi_t + \beta_2 y_t + \beta_3 \Delta e_t + \varepsilon_{R_t} \tag{14}$$

where $\beta_i = (1-\rho_R)\phi_i$ for the i_{th} variable, respectively. The function (14) is estimated only with data of the *administrated exchange rate* period (2002:1-2013:3), as using the whole sample results in implausible values[8]. The estimation results in the following parameter's values:

$$\hat{R}_t = 0.82^{***} R_{t-1} + 0.13^{**} \pi_t + 0.26^{***} y_t + 0.07^{***} \Delta e_t \quad \text{with} \quad \sigma_R = 1.16$$

[8]The estimation of (14) using the whole sample data produced the following values: $\rho_R = 0.96, \phi_\pi = 0.63, \phi_y = 5.35$ and $\phi_e = 0.77$. As output parameter value is much higher than it usually is in the literature, these estimation is discarded. In any case, it makes sense to focus on the *administrated exchange rate* regime when fitting a Taylor rule to the monetary authority because during the *fixed exchange rate* regime the Central Bank of Argentina had limited power to set the nominal rate, as explained with the *trilemma* by Obstfeld et al. [2004].

Table 2: Parameter values

Name	Symbol	Value	Remarks
Discount factor	β	0.99	calibrated
Intertemporal substitution elasticity	τ	0.25	estimated
Import share	α	0.12	calibrated
Phillips curve slope	κ	0.56	estimated
Policy rule parameters			
Inflation parameter	ϕ_π	0.71**	estimated
Output parameter	ϕ_y	1.40***	estimated
Exchange rate parameter	ϕ_e	0.38***	estimated
Interest rate persistence	ρ_R	0.82***	estimated
Interest rate volatility	σ_R	1.16	estimated
Shocks' parameters			
Productivity persistence	ρ_z	0.87*	estimated
Productivity volatility	σ_z	1.34	estimated
TOT persistence	ρ_q	0.60	calibrated
TOT volatility	σ_q	7.14	calibrated
World output persistence	ρ_{y^*}	0.92	calibrated
World output volatility	σ_{y^*}	1.47	calibrated
World inflation persistence	ρ_{π^*}	0.73	calibrated
World inflation volatility	σ_{π^*}	0.83	calibrated

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$. See Data Appendix on page 23 for details.

where *** and ** denote 99% and 95% significance levels, respectively. It is straightforward to recuperate the monetary rule parameters considering $\beta_i = (1 - \rho_R)\phi_i$, which are presented in Table 2[9].

To estimate productivity parameters ρ_z and σ_z, I follow Galí and Monacelli [2005] and define the following production function:

$$Y_t = Z_t N_t \tag{15}$$

where N_t denotes employment and $z_t = \ln Z_t$ follows the AR(1) process (10). I apply logs to the cyclical components obtained by HP-filtering Y_t and N_t and estimate (15) together with (10) using the Cochrane-Orcutt procedure with whole sample data (1993:1 to 2013:3). Convergence of estimated parameters is achieved after 10 iterations[10]. A detail of calibrated and estimated parameters is present in Table 2.

[9]As mentioned by Lubik and Schorfheide [2007], OLS estimation of the policy rule is questionable because of endogeneity problems. Nevertheless, system based estimation methods, like Bayesian, are left for further work.

[10]See Appendix on page 24 for data details.

3.2 Simulation results

As mentioned above, there are two different specifications of the model depending on whether terms of trade are treated exogenously or endogenously. I use the former to analyze the responses to a TOT shock and to do a variance decomposition, and the latter to check the response of TOT to a productivity innovation as well as to get parameters κ and τ minimizing the function (13). Starting with the first specification, the model is simulated using TOT as exogenous. My intention is to replicate sample moments for the second part of the sample (for the administrated exchange rate regime). Except for the relative volatility of inflation and terms of trade (σ_π/σ_q), targeted moments are well replicated by the model, as shown in Table 3. Nevertheless, some non-targeted moments replication is quantitatively far from those of data and others are even qualitatively different. The worse performance of the model is in replicating output autocorrelation ($\rho(y_t, y_{t-1})$) and output correlation with inflation, nominal interest rate and nominal exchange rate ($\rho(y, \pi), \rho(y, r)$ and $\rho(y, e)$, respectively). Calibrating a lower value for the intertemporal substitution elasticity (τ) can improve the fit of the model to these non-targeted moments, but at the expense of generating implausible values for the targeted relative volatilities $\sigma_\pi/\sigma_q, \sigma_r/\sigma_q$ and , σ_e/σ_q.

The dynamics generated after a TOT shock are presented in Figure 3. An improvement in terms of trade is followed by a nominal exchange rate appreciation (which is a fall in Δe_t) because, as is clear from (5), relative PPP holds. The nominal exchange rate appreciation has a negative effect on nominal interest rate as the monetary authority reacts according to the rule (4). Now, using a NK model where rigidities in prices exist, a nominal variation will have real effects, at least in the short run. So, output rises according to (1). At the same time, there is an increase in inflation according to (2), which mitigates the real effect in the short horizon. The rise in prices is such that there is a rise in the real interest rate and the increase in output is rapidly muted.

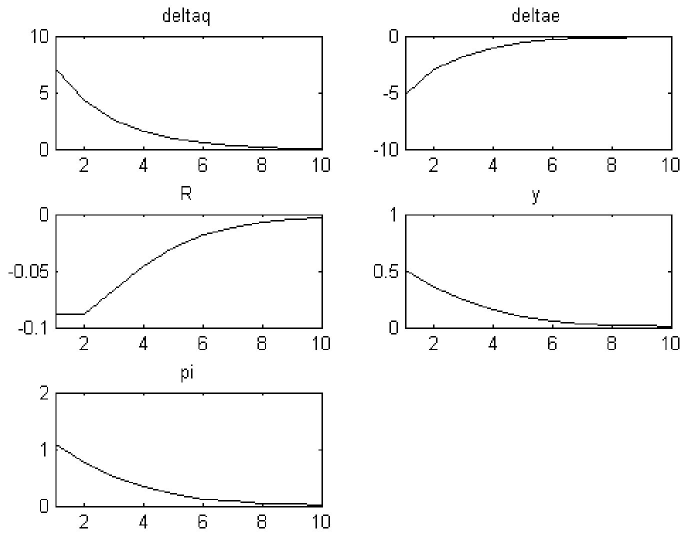
Calibrating the intertemporal substitution elasticity τ for a higher value and the Phillips curve slope κ for a lower one, decrease the impact that output increment, that follows an improvement of the terms of trade, has on inflation according to the NK Phillips curve (2). Intuitively, if local and foreign goods are perfectly substitutable, increment of local prices are moderated when there is an output rise. But still, exchange rate will appreciate as PPP holds and nominal interest rate will fall as is clear from the monetary rule. There is then more room for a persistent rise in output as the real nominal rate decreases.

Interestingly, terms of trade disturbances have a higher impact on inflation than they have on output. Again, the elasticity of substitution between home and foreign goods and the Phillips curve parameters are crucial for this result. If both of them were calibrated at higher values, then terms of trade would have a stronger impact on prices. Dynamics would follow the usual path: PPP implies that terms of trade improvement are counterbalanced

Table 3: Actual vs Simulated moments

Statistic	Actual data	Simulated data
Targeted moments:		
σ_q	7.33	8.93
σ_y/σ_q	0.42	0.41
σ_π/σ_q	0.46	1.25
σ_r/σ_q	0.48	0.86
σ_e/σ_q	1.26	1.43
$\rho_{g,y}$	0.15	0.19
$\rho_{g,\pi}$	0.10	0.13
$\rho_{g,r}$	-0.16	-0.02
$\rho_{g,e}$	-0.30	-0.50
Non-targeted moments:		
$\rho(y_t, y_{t-1})$	0.89	0.53
$\rho(\pi_t, \pi_{t-1})$	0.60	0.62
$\rho(r_t, r_{t-1})$	0.85	0.95
$\rho(e_t, e_{t-1})$	0.79	0.61
$\rho_{y,\pi}$	-0.25	0.45
$\rho_{y,r}$	-0.12	0.09
$\rho_{y,e}$	-0.10	0.28
$\rho_{\pi,r}$	0.38	0.71
$\rho_{\pi,e}$	0.09	0.79
$\rho_{r,e}$	0.71	0.63

Figure 4: NK IRFs to a TOT shock



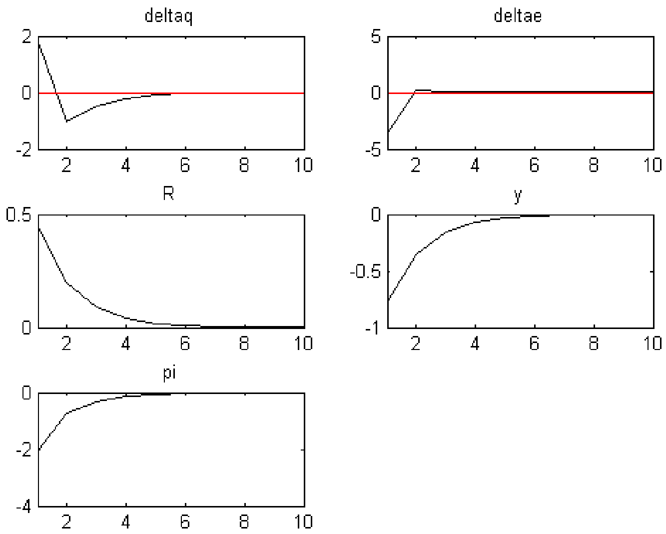
by a nominal exchange rate appreciation; then nominal interest rate falls as it is implied by the Taylor rule; and, as a consequence, output increases. But a high value for the substitution elasticity τ and, specially, for the Phillips curve parameter κ, will amplify the effect on inflation. So, real rate will rise and the initial increment in output will be muted soon.

I will use IRFs of subplots (1,1), (2,2) and (3,1) in Figures 4 and 5 to impose signs in the SVAR analysis of the following section. I will also need to do imposition of signs to another structural shocks, which I will identify as a cost-push and it is not modeled in the theoretical framework used here. So I will impose those signs informally. That is, not backed by the DSGE model of this paper. However, the signs imposed are in line with standard DGSE frameworks that do model this structural shocks.

4 The empirical model

In this section I use a Structural Vector Autoregression (SVAR) model to evaluate the impact of a positive terms of trade shock in Argentina. I interpret the shock as an unexpected increase in the relative price of exports over imports (P_x/P_m) and check which is the behavior of output and inflation by analyzing their IRFs. In order to perform such

Figure 5: NK IRFs to a Money shock



analysis, I first estimate a reduced form VAR composed of output growth, CPI inflation and terms of trade variations. Afterwards, I identify the structural shocks that affect endogenous variables by adopting a *sign restrictions* identification scheme. I identify three structural shocks: a terms of trade, a monetary and a cost-push shock. The first two ones are identified using the signs obtained after a terms of trade and money innovations shown in Figures 4. Regarding the responses to cost-push shock, it is set informally, though it is consistent with usual DSGE models dynamics.

4.1 The reduced form VAR

I use a fixed-coefficients VAR as an empirical model to analyze the effect of a fiscal shock. Its reduced form is represented as:

$$Y_t = B_0 + B_1 Y_{t-1} + B_2 Y_{t-2} + ... + B_p Y_{t-p} + \mu_t$$

where Y_t is a 3x1 vector of time series including output growth (y_t), CPI inflation (π) and terms of trade variations (Δq_t). The coefficients are represented by B_0, which is a $3x1$ constants' vector, and B_i, which are $3x3$ matrices of variables' coefficients. Lastly, μ_t is a $3xT$ Gaussian white noise process vector with zero mean and variance Σ.

Before estimating the VAR, I need to define its lag order, which I do by applying the Akaike information criterion (AIC). It results in a two-lag order, so that the VAR has the following reduced form:

$$Y_t = B_0 + B_1 Y_{t-1} + B_2 Y_{t-2} + \mu_t \tag{16}$$

I estimate the VAR using OLS[11]. I get as well the reduced-form residuals μ_t that have a zero mean and a variance-covariance matrix denoted as Σ.

4.2 The structural VAR identified with *sign restrictions*

In order to identify the VAR I follow a procedure that has two essential ingredients: on one hand, exact identification is achieved by doing a Cholesky decomposition of the reduced form variance covariance matrix. On the other hand, the desired pattern of signs is imposed using a rotation matrix that comes from an orthogonal decomposition of matrices randomly drawn from a normal distribution. At the end of the procedure, I am left with a large number of candidate impact matrices with the desired properties.

More precisely, the procedure is as follows:

1. I decompose the reduced form residuals variance-covariance matrix using Cholesky: $\Sigma = CC'$.
2. A sufficiently large amount of K_{3x3} matrices are drawn from a normal distribution.
3. I do the QR decomposition of K matrices using the algorithm by Rubio-Ramirez et al. [2010] to obtain rotation matrices Q such that $K = QR$ and $QQ' = I$. This is, Q is an orthogonal matrix.
4. I get the candidate impact matrix: $A_0 = C'Q'$ and keep only those matrices that have the desired pattern of signs shown below.
5. Use the A_0 matrices to plot IRFs and do forecast error variance decomposition analysis.

In the present case, once the algorithm presented on steps 1 to 5 is done, the reduced form model (16) turns into:

$$Y_t = \hat{B}_1 Y_{t-1} + \hat{B}_2 Y_{t-2} + A_0 e_t \tag{17}$$

where A_0 is a 3x3 matrix and e_t is a 3x1 vector of normally distributed structural shocks with unit variance by definition. The model is demeaned for convenience in its interpretation. The SVAR system relates observable VAR-based residuals to unobserved structural shocks. In other words, it is the link between data and theory. Additionally,

[11] See Appendix on page 24 for estimation results details.

as noted in Canova and Pina [2005], general equilibrium logic implies that impact of all shocks at the initial period should be, in general, non-zero. Indeed, this is exactly what DSGE models, as the one presented previously in this work, reproduce: all the responses of the variables are non-zero at $t = 0$, as shown in Figures 4 and 5. This fact implies that the elements of the A_0 matrix should typically be non-zero as is the case with the *signs restrictions* approach. By using this identification scheme, I assign the signs conditional on the RBC model to the elements of A_0 matrix:

$$\begin{bmatrix} y_t \\ \pi_t \\ \Delta q_t \end{bmatrix} = \hat{B}_0 + \hat{B}_1 Y_{t-1} + \hat{B}_2 Y_{t-2} + \underbrace{\begin{bmatrix} - & - & + \\ - & + & + \\ + & ? & + \end{bmatrix}}_{A_0} \begin{bmatrix} e_t^M \\ e_t^S \\ e_t^q \end{bmatrix} \tag{18}$$

where e_t^M, e_t^S and e_t^q are interpreted as a monetary, cost-push (or negative supply disturbance) and a terms of trade shocks, respectively. The signs of the first and third columns of the A_0 matrix at (18) are based on the responses generated by the NK model shown in Figure 5 and 4, respectively. As it stands, the pattern of signs that have been imposed imply that a terms of trade improvement increases all variables.

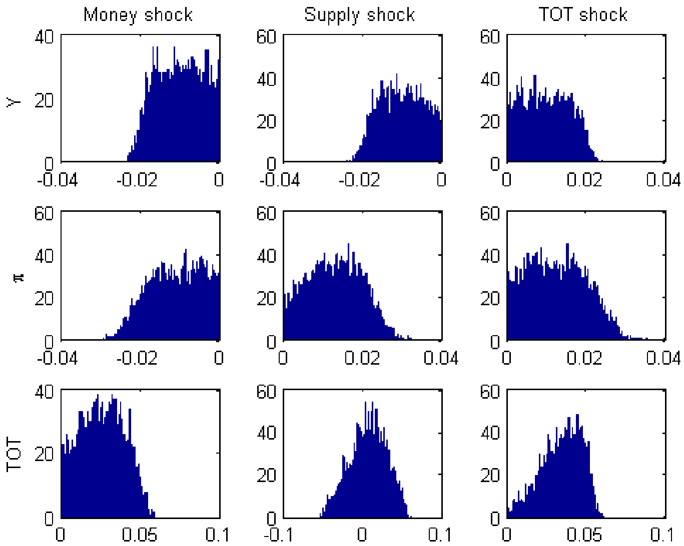
Regarding cost-push shock signs, they are imposed informally. The reason for this resides in that, given the specification of the theoretical model used here, a supply shock affects output gap and, as a consequence, does not generate the usual response observed for supply innovations. Additionally, the response of terms of trade to these disturbances is not so straightforward, as explained by Gauthier and Thessier [2002]. Here, I leave unrestricted the sign of this response.

Now, following the steps described above, my goal is to achieve 5000 A_0 matrices that satisfy the two aforementioned characteristics: that they are all exactly identified (which is ensured by the Cholesky decomposition of the first step) and that they have the desired pattern of signs. The distribution of the A_0 matrices obtained is presented in Figure 6. It is important to notice that the pattern of signs imposed on impact produces distributions of elements in the A_0 matrices that are mostly either positive or negative. What is relevant for my analysis is that the signs imposed are not contradicting the information contained in the data. Another good sign is that the distributions look pretty centered around one mode. A bimodal distribution would tell us that some of the signs imposed are not coherent with data information.

4.3 Variance decomposition analysis

To do a forecast error variance decomposition analysis, I use the 5000 A_0 matrices obtained in the previous section and I build a distribution of variance decomposition matrices using the variance of the first step forecast error. Table 4 presents the mean of this

Figure 6: Distribution of A_0 matrix' elements



distribution. According to it, all three shocks are equally important to explain output volatility. Regarding inflation is indeed importantly affected by terms of trade shocks, that explain around a third of its total variability.

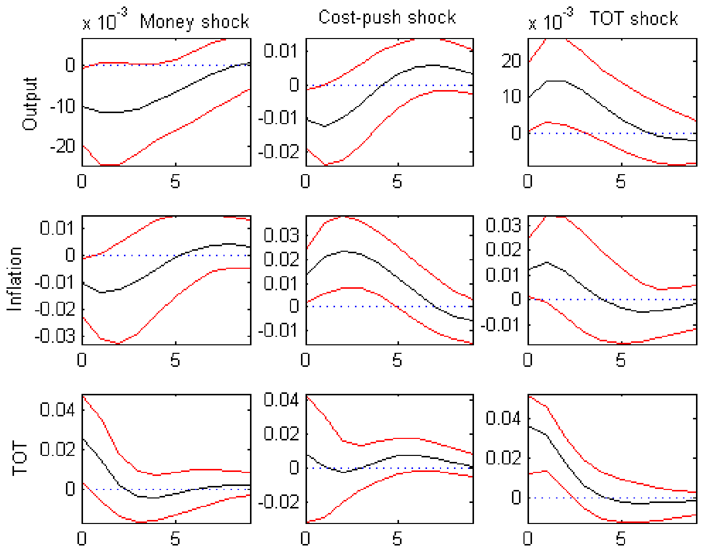
Results obtained here are in line with those of Mendoza [1995] and Kose [2002] who assign much importance to terms of trade shocks explaining output variability. These authors calibrate RBC models for developing countries and find that terms of trade shocks account for 35% and 90% of total output variability, respectively. By the other hand, Lubik and Teo [2005] and Lubik and Schorfheide [2007] perform a Bayesian estimation of an RBC and a NK model, respectively, and find evidence of an explanatory power of terms of trade

Table 4: Variance decomposition

Variables:	Output	Inflation	TOT
Shock:			
Money	0.34	0.28	0.31
Cost-push	0.34	0.36	0.20
TOT	0.33	0.35	0.49

Means and 90% intervals (in brackets)

Figure 7: SVAR IRFs



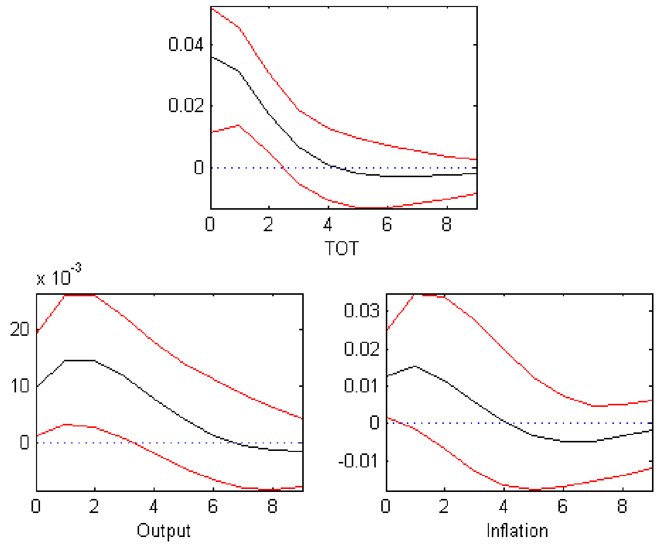
below 10%, which is lower than the results obtained here. My results are also higher then those of Broda [2004].

4.4 Impulse-Response Functions Analysis

Using the 5000 A_0 matrices obtained when applying the *sign restrictions* algorithm, I built a distribution of IRFs and calculate with it the responses of endogenous variables to structural shocks. A plot of the median and the 90% confidence interval of each IRF distribution is shown in Figure 7. At the same time, Figures 8 and 9 present the IRFs of just the terms of trade disturbance with and without confidence bands, respectively. These graphs show that an improvement in terms of trade fosters output and inflation around 40% the size of the shock, being the peak effect around the second and first quarter, respectively. The influence of the innovation is not as persistent and statistically significant for inflation as it is for output. According to my findings, terms of trade fluctuations can be held responsible as a relevant driver of output in Argentina, and they also cause non negligible movements on prices.

Secondary results are the effects of money and cost-push shocks as shown in the first and second columns of Figure 7, respectively.

Figure 8: SVAR IRFs to TOT shock

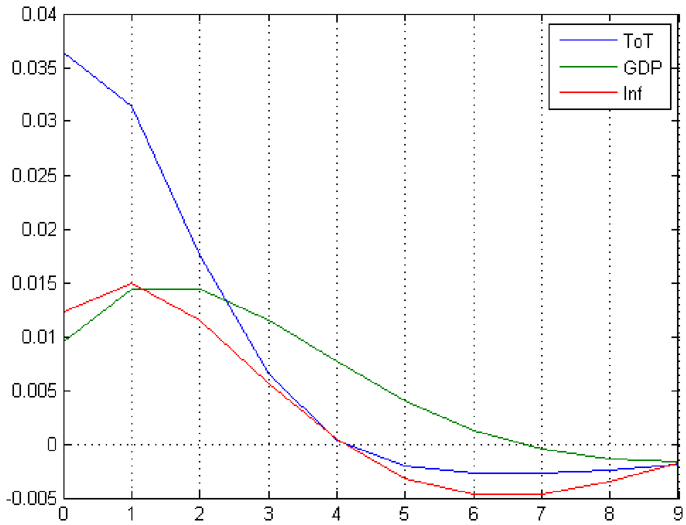


5 Conclusions

In this work, I analyze the effects of a terms of trade improvement over output and inflation in Argentina using a Structural Vector Autoregression identified with *sign restrictions*. The identification is conditional on the IRFs generated by a New Keynesian Small Open Economy model with estimated/calibrated parameters that replicates fairly well some target moments of the country under study.

My main finding is that terms of trade improvements generate both output growth and inflation, though the effects differ for each variable. While the impact on output is persistent and statistically significant, inflation increases mainly on impact. These findings can be explained by the fact that Argentina faced lower volatility in its terms of trade during the fixed exchange rate regime than during the flexible one. In any case, results presented here shed light over a widely discussed but rarely studied phenomenon in the country: the quantitative measurement of terms of trade disturbances and its effects over local activity and prices' dynamics.

Figure 9: SVAR IRFs to Money shock



6 Appendix

6.1 Data

Figure 1, Table 1 & actual data of Table 3: The variables used are y (GDP), q (terms of trade), π (CPI inflation), r (nominal interest rate) and e (nominal exchange rate). Argentinian data comes from the Economic Ministry (MECON) while US data was taken from the US Bureau of Economic Analysis (BEU).
Argentina:

- GDP original series is at constant prices, quarterly frequency and seasonally adjusted. Source is Mecon. I transform original series into Output Gap by applying an HP filter with smoothing parameter $\lambda = 1600$.

- Terms of trade original series is defined as the ratio of export unit value index over import unit value index ($TOT = 100 * X$average price$/M$average price). The terms of trade fluctuate in line with changes in export and import prices. Clearly the exchange rate and the rate of inflation can both influence the direction of any change in the terms of trade. Quarterly frequency, non seasonally adjusted. Source: Indec. I transform original series by applying interanual Quarter-to-Quarter log differences.

- CPI original series is not seasonally adjusted with base year 2008:M4 and monthly frequency. Source: Indec. To obtain quarterly frequency I use just the second month of each quarter. In order to obtain CPI inflation, I transform original series by applying interanual Quarter-to-Quarter log differences.

- Nominal exchange rate original series are AR$ to US$ at monthly frequency. Source: BCRA. To obtain quarterly frequency I use just the second month of each quarter. I transform original series by applying interanual Quarter-to-Quarter log differences.

- Nominal interest rate is interbank rate up to 15 days at monthly frequency. Source: BCRA.

Technology: Labor series corresponds to number of urban workers. They are taken from the Encuesta Permanente de Hogares (EPH) of the Argentinian Economic Ministry (MECON). From 1993 until 2002 they are bianual, and quarterly from then on. In order to transform bianual into quarterly data I apply the following procedure:

$$\Delta L_t = \alpha + \sum_{j=1}^{20} \beta_j D_{j,t} + e_t \tag{19}$$

where ΔL_t are labor series expressed in difference and $D_{j,t}$ are 20 dummy variables I use to fill missing values, which are the 2nd and 4th quarters from 1993 until 2002 (inclusive). Each dummy variable is a $(1xT)$ zero vector (where T is the number of observations), which has a 1 in the row corresponding to each specific missing quarter. As a result of the application of (19), original values are kept and missing values are created. I then transform the series back into levels in order to estimate productivity parameters.

The data is expressed at constant prices and at quarterly frequency from 1993:Q1 to 2013:Q1. All series used are seasonally adjusted. Net exports is trade balance over output. All series but net exports are taken in logs. All series are Hodrick-Prescott filtered with a smoothing parameter of 1,600.

6.2 VAR estimation results

Table 5 presents the detail of the reduced form estimation of the empirical model (16). Significant variables for all variables are their own lags. Additionally, for terms of trade output lags are also significantly.

Table 6 presents the F-statistics for the Granger casualty test. It shows that just the past of all variables are important to predict them.

Table 5: VAR estimation results

Variables	y_t	π_t	Δq_t
y_{t-1}	1.27***	-0.20	0.50*
y_{t-2}	-0.48***	0.10	-0.46*
π_{t-1}	0.03	1.44***	-0.01
π_{t-2}	0.04	-0.60***	0.09
Δq_{t-1}	0.05	-0.02	0.75***
Δq_{t-2}	-0.05	-0.01	-0.28**
constant	0.00	0.01	0.01
Observations	82	82	82
R^2	0.84	0.88	0.48

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Table 6: Granger casualty test (F-statistics)

Variables	y	π	Δq
y	144.33***	1.98	1.76
π	1.43	225.97***	0.37
Δq	0.96	0.19	23.80***

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

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