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Estimating an Equilibrium Exchange Rate for the Argentine Peso

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Abstract

This paper assesses the equilibrium value of the Argentine peso exchange rate based on the country's economic fundamentals and compares it with the official exchange rate value. The paper estimates a behavioral equilibrium exchange rate model that allows for movements in the equilibrium real effective exchange rate based on changing economic fundamentals, using monthly data from 1980 to 2015. The analysis identifies four key fundamentals driving the equilibrium exchange rate in Argentina: terms of trade, productivity differentials, foreign currency reserves, and trade openness. Based on these fundamentals, before the exchange rate reunification that took place at the end of 2015, the Argentine peso was overvalued by 39 percent. The results are robust to alternative estimation approaches.

Estimating an Equilibrium Exchange Rate for the Argentine Peso

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1. Introduction: Argentina's dual exchange rate regime

The current section motivates the study of Argentina's equilibrium exchange rate. It presents the country context and Argentina's de-facto dual exchange rate regime.

A de-facto dual exchange rate regime emerged in Argentina when, faced with a shortage of dollars in 2011, the government introduced a series of capital controls. Formal and informal currency restrictions were put in place to limit capital flight and exchange rate depreciation and protect reserve levels. The government effectively controlled the formal exchange rate by limiting the amount of foreign currency that Argentines could legally purchase for imports, travel, and savings.[2] This situation lasted until December 2015, when the government lifted controls and allowed the exchange rate to depreciate.

While the controls were in place, the lack of convertibility of the currency led to the emergence of various parallel exchange rates, which authorities had little control over. Moreover, concerns about the sustainability of this policy and speculation over eventual devaluation, mirrored in widening spreads of parallel rates, triggered a run to U.S. dollars in parallel markets. Two widely used rates, which became reference points for pricing transactions in the economy, were the blue dollar rate–based on tracking average stock prices of eight major companies quoted on both the Argentine and US exchanges–and the blue chip swap rate–the implied rate derived when businesses were buying dollar-denominated bonds or shares in pesos and then selling them on international stock exchanges for dollars. Argentines could purchase US dollars onshore at the blue rate and receive dollars in an offshore account at the blue chip swap rate.

Figure 1: Evolution of the official vs. blue and blue chip swap rates
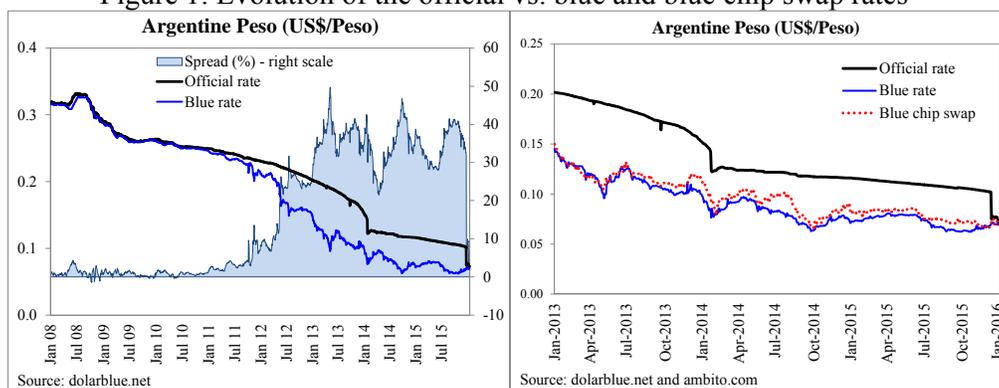
The existence of multiple exchange rates led to distortions and costs that raised concerns over allocative efficiency. Importers who could not access US dollars at the official exchange rate, and instead resorted to the illegal market, were at a clear disadvantage unrelated to productivity. Moreover, exchange rate spreads created arbitrage opportunities that resulted in the widespread selling of dollars in the informal

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[2] Importers are required to obtain government authorization before purchasing U.S. dollars. The central bank must approve dividend and profit remittances overseas, which have been subject to delays. Foreign-currency purchases for Argentines traveling abroad require an extensive list of documents, foreign purchases are subject to credit card taxes, and online spending has become limited. Government quotas for Argentines seeking to purchase dollars for savings have been limited and this transaction became virtually banned in mid-2012. All in all, these restrictions have made it very difficult for Argentine citizens to obtain dollars to save or invest abroad.

market, shifting resources from the productive sector to the informal financial sector. Finally, a widening gap between official and parallel market rates added pressure to the legal economy by generating expectations of another devaluation, since it signaled the possibility that the government could not support the exchange rate with its stock of international reserves.

On December 16, 2015, the government announced its decision to remove the capital controls and currency restriction and let the peso float within certain limits. As a result, the currency immediately depreciated by 30 percent and the gap with parallel rates virtually closed. The removal of the *cepo* boosted the debate on the exchange rate equilibrium levels. What is the exchange rate equilibrium level based on the fundamentals of the Argentine economy? What could be the equilibrium level going forward, in a context where economic fundamentals are expected to evolve?

To address these questions, this paper uses a model-based approach known as the behavioral equilibrium exchange rate (BEER), which allows the equilibrium exchange rate to vary over time according to fundamentals in the economy. A reduced-form single-equation vector error correction model is estimated by employing Johansen's (1995) approach using monthly data spanning from 1980 to 2015. The analysis identifies fundamental factors driving Argentina's real exchange rate to be: the terms of trade, productivity differentials, trade openness, and reserves. While doing so, the analysis takes into account important features specific to Argentina in constructing adjusted measures of the REER and productivity differentials, such as: potentially underestimated inflation, potentially overestimated output, and a large share of agriculture in exports. Based on this approach, estimation results suggest that, as of October 2015, the peso was overvalued by 39%.

As a robustness check, the estimates of exchange rate misalignment are compared to alternative estimation-based methods, which signal that the peso was overvalued by approximately 34–46%, as of October 2015. Premia on parallel exchange markets are indicative of the magnitude of overvaluation, and had been widening since 2011 and reached about 34–36 percent in December 2015, before the removal of capital and currency controls. Arbitrage conditions in goods markets also provide measures of currency overvaluation, but need to be interpreted with caution. Indicators relying on the law of one price (LOP), such as the Big Mac and iPad indices, equate goods prices across countries once converted in a common currency, assuming the absence of trade barriers and price controls, and price discrimination. Purchasing power parity (PPP), which implies the real effective exchange rate should be constant (normalized to a year in which it is assumed to be in equilibrium), suggests the peso is undervalued. Artificially low prices in recent years caused these indicators to be misleading. Upon correcting the REER for discrepancies in inflation statistics reported by official vis-à-vis alternative private sector sources, PPP signaled the peso to be overvalued in October 2015 by approximately 46 percent.

The remainder of the paper is structured as follows. Section 2 provides a literature review on the estimation of equilibrium exchange rates, its different approaches and empirical findings. Section 3 explains the methodology and data employed in the BEER analysis. Section 4 presents a range of estimates of the peso's misalignment using the BEER approach, conducts a series of robustness checks, and contrasts findings to estimation-based approaches using parallel rate premia, LOP, and PPP. Finally, Section 5 summarizes the findings and concludes.

2. Literature Review

This section offers a literature review of the array of existing definitions of equilibrium exchange rate, which vary according to the time horizon (short, medium, and long-term) as well as the choice of theoretical framework. It discusses different approaches to estimating equilibrium exchange rates, 'direct estimation' versus 'model-based'. Finally, it provides a review of empirical applications and recent estimations of equilibrium exchange rates using the BEER approach.

The empirical literature emphasizes two main approaches to equilibrium exchange rates: (i) direct estimation-based using measures of the black-market premium or PPP, and (ii) model-based using economic fundamentals or analysis of current account sustainability.

The direct estimation-based approach involves estimating a model for exchange rates explicitly. One branch measures misalignment using the black market exchange rate premium (Quirk et al., 1987). Onour and Cameron (1997) find that "a change in the parallel market premium is an appropriate indicator of change in the real official rate misalignment". However, empirical evidence regarding the black rate premium as a predictor of misalignment is mixed. Montiel and Ostry (1993) caution in "drawing inferences about the sign and magnitude of real exchange misalignment from the parallel market premium" arguing that "the informational content of the parallel rate is limited, since its deviation from the official rate could be positive or negative in response to a shock at various times along the adjustment path".

The main branch of the estimation-based approach measures misalignment as deviations of the actual real exchange rate from some base year in which it is believed to be in equilibrium (Balassa, 1990; Chinn, 1998). Based on purchasing power parity,[3] this approach assumes a constant (stationary) equilibrium real exchange rate equal to unity. As a result, it does not take into account changes in the equilibrium real exchange rate caused by fundamentals.

Empirical evidence supporting PPP tends to be based on long horizon samples, periods with substantial price variation such as periods of hyperinflation, or papers using non-stationary panel techniques.[4] However, real exchange rates exhibit high volatility and very slow rates of mean reversion, with a "remarkable consensus" of 3 to 5 year half-lives of PPP deviations, known as the PPP puzzle (Rogoff, 1996 and Murray and Papell, 2002). Moreover, a large strand of literature finds empirical evidence of real exchange rates being non-stationary I(1), suggesting the existence of real fundamentals that drive a time-varying equilibrium exchange rate.

In line with these conclusions, the model-based approach involves a formal model for determining the equilibrium real exchange rate, which is allowed to vary over time according to fundamentals. Real exchange rate misalignment is then the difference between the actual and the estimated equilibrium real exchange rate.

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[3] PPP is a no-arbitrage condition in markets for goods, which predicts that in the long-run (tradable or output) price levels will be equalized across countries when measured in common currency. The real exchange rate is defined as the product between the foreign-to-domestic currency exchange rate and domestic-to-foreign relative price levels. A value of the real exchange rate above (below) unity implies that the country's currency is overvalued (undervalued).

[4] For references see Frankel and Rose (1996), MacDonald (1996), Oh (1996), Papell (1997) and Coakley and Fuertes (1997).

Real exchange rates are essentially relative prices that can vary because of differences in consumer preferences, differentiated products, imperfect competition, the existence of nontradable goods, and productivity differentials, among other factors. These factors call for a model of equilibrium that can potentially deal with variations across all these dimensions and involve assumptions about the transmission mechanism of real exchange rates within the economy. Model-based simulation approaches tend to have much stronger predictions for medium to long-run equilibrium measures but are less effective to explain short-term movements (Edwards, 1988; Elbadawi, 1994; Baffes et al., 1999).

A multitude of measures and methods for calculating equilibrium exchange rates have emerged in the empirical literature.[5] The theoretical framework determines the choice of fundamentals whereas the equilibrium time horizon determines their values. In the short-run, fundamentals are their current actual values after abstracting from random effects, such as asset market bubbles, and equilibrium has a transitory component. In the medium-run, fundamentals are defined as being at their trend values (no transitory component), but these may still be adjusting towards some longer-run steady state. In the long-run, equilibrium is defined as the point when stock-flow equilibrium is achieved at all levels of the economy including net foreign assets, which remain constant as a percentage of GDP. Fundamentals are their long-run values and there is no endogenous tendency to change.

One widely used model-based approach is the fundamental equilibrium exchange rate (FEER)[6] popularized by Williamson (1985, 1994). The FEER is defined as the rate consistent with the economy being at internal and external balance, simultaneously. Internal balance concerns demand meeting supply potential and the economy running at normal capacity; the output gap is zero and unemployment is the non-accelerating inflation rate of unemployment (NAIRU). External balance is defined in terms of a 'sustainable' current account balance, consistent with eventual convergence to the stock-flow equilibrium (domestic real interest rates will still be in the process of converging to world levels). This approach requires an econometric model for the trade sector that captures the relationships among output, current account, demand, and competitiveness. It also requires defining current account sustainability. Two conceptually close methodologies that differ in this definition are the "macroeconomic balance" (MB) approach and the "external sustainability" (ES) approach.[7]

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[5] These can be classified into short, medium, and long-term equilibrium concepts. For a detailed literature review on equilibrium exchange rates, see Driver and Westaway (2004). In general, the monetary models, BEERs, ITMEERs and CHEERs are more closely related to short-run equilibrium, FEERs and DEERs provide measures of medium-run equilibrium, while AREERs, PEERs, and NATREX models aim to capture some concept of long-run equilibrium. Alternative methods such as SVARs and DSGE models provide information on the likely response of the exchange rate in the face of shocks but do not provide any information on the level of the real exchange rate.

[6] Black (1994) summarizes this approach.

[7] The external sustainability approach focuses on the relationship between the sustainability of a country's external stock position and its flow current account balance, trade balance, and real exchange rate. It involves determining the trade or current account balance to GDP ratios that would stabilize the foreign asset position at given "benchmark" values, comparing these with the balances expected to prevail over the medium term. This approach does not require econometric estimation but rather a few assumptions about the economy's potential growth rate, inflation rate, and rates of return on external assets and liabilities. This provides a simple and transparent structure, making it a useful reference point for comparison against more sophisticated econometric approaches.

Another well-known model-based approach, which is the one we adopt, is known as the behavioral equilibrium exchange rate.[8] This methodology, proposed by MacDonald (1997), is based on reduced form estimation of a long-run equilibrium relationship between the real exchange rate and a set of fundamentals, using Johansen's (1995) cointegration techniques. The current value of fundamentals can be used to determine equilibrium exchange rates, and the difference with the actual exchange rate defines the magnitude of the misalignment.

The major advantage of these equilibrium exchange rate models, over the simple PPP framework, is that they relax the assumption of the equilibrium being static and allow for it to vary according to changes in fundamentals. However, they also have their caveats. For example, the FEER approach removes speculative capital flows from the medium-term capital account, making it difficult to account for short-term changes in the UIP condition that affect the dynamic adjustment path of the exchange rate. Moreover, the FEER approach is critically sensitive to trade elasticity estimates. Unlike the FEER, the BEER considers how changes in fundamentals affecting the capital account may impact the "behavior" of the exchange rate. This is critical for "countries that are experiencing substantial variation in short-term fundamentals (for relatively stable economies operating in the neighborhood of internal and external balance, the BEER would converge to the FEER)" (IMF 2007). However, the BEER approach relies on appropriate historical data availability, and is therefore difficult to implement in countries that have undergone substantial structural change or for which longer-term data are scarce. Sustained misalignment may also lead to misinforming results.[9] Another drawback is that very little economic theory guides the choice of economic fundamentals considered in the econometric analysis.

Table 1: Equilibrium Exchange Rate: Alternative Concepts

Definition of equilibrium exchange rate	
Estimation-based approach	
Black market exchange rate premium	Black market exchange rate.
Law of One Price (LOP)	Rate that equalizes prices of goods across countries, when converted in the same currency.
Purchasing Power Parity (PPP)	Rate that equalizes the real exchange rate to its level in a base year.
Model-based approach	
Behavioral Equilibrium Exchange Rate (BEER) - Clark and MacDonald (1997, 1999)	The BEER is based on reduced-form estimation of a long-run relationship between the real exchange rate and economic fundamentals. Actual or medium-term fundamental values are then used to obtain predicted values of the real exchange rate, and an HP filter is applied, to obtain the BEER.
Fundamental Equilibrium Exchange Rate (FEER) - Williamson (1983, 1994)	The FEER is the exchange rate consistent with simultaneous internal (zero output gap) and external (sustainable current account) balance. It requires estimation of an econometric model for the trade sector (trade elasticities) and selection of the (sustainable) current account norm that is either estimated empirically (MB approach) or derived as the level that stabilizes the net foreign asset position (ES approach).

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[8] Égert (2003) provides a comprehensive survey of the literature.
[9] Several papers have dealt with this by adopting a cross-country panel framework to incorporate a wider range of country experiences (for example, Maeso-Fernandez et al, 2004, MacDonald and Dias, 2007, Ricci et. Al, 2008, and Bénassy-Quéré et al., 2009).

There is a vast empirical literature evaluating the determinants of real exchange rates using the BEER approach, proposing a range of important fundamentals (see Table 2). Economic fundamentals can impact the equilibrium exchange rate in the long run (terms of trade, productivity differentials, net foreign assets) or in the short run (monetary, fiscal, and trade policy instruments). The key variables considered by the literature and their theoretical impact on the equilibrium exchange rate are discussed below:

- **Real interest rate differential:** according to the uncovered interest rate parity (UIP) condition, which equates the rate of return on domestic and foreign currency assets (adjusted for foreign exchange risk), a rise in domestic (real) interest rates relative to foreign rates is associated with an expected depreciation of the exchange rate.[10] The nominal exchange rate (and in the presence of real rigidities also the real exchange rate) would appreciate beyond its long-run value (i.e. overshoot) so as to allow the expected depreciation to occur after the monetary policy shock disappears (Dornbusch, 1976 and Obstfeld and Roggoff 1996). A persistent monetary shock (rise in real interest rates) would be captured as part of the long-run relation in cointegration analysis. The expected sign is positive for the real interest rate differential (negative for the foreign real interest rate).[11]

- **Productivity differential:** according to the Balassa-Samuelson effect,[12] growth in the productivity of tradables relative to nontradables causes higher wages in the tradables sector to spill over to nontradables, thereby raising prices of nontradables resulting in a real appreciation. Most papers capture this effect via cross-country GDP per capita or per worker differentials. Given that productivity growth may arise in the nontradable sector, these measures of productivity differentials may suffer from coefficients being underestimated or

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[10] The UIP condition provides the basic theoretical underpinning of the reduced form BEER econometric model. The UIP condition is also the basis of what has been named the monetary model of exchange rate determination. In this approach, the nominal exchange rate equilibrium is determined by monetary fundamentals such as money supply, output, interest rate, and price differentials compared to other countries.

[11] MacDonald and Ricci (2003) suggest two additional reasons why we expect a positive relationship with the real exchange rate: rather than representing persistent monetary policy, a real interest rate differential could also represent aggregate demand or productivity. An increase in aggregate demand (increase in absorption relative to savings), in the context of imperfect capital mobility, would put upward pressure on the real interest rate, which in turn would raise the demand for tradables and nontradables, thereby increasing the price of nontradables, which would appreciate the exchange rate. An increase in productivity differentials, to the extent that the measure used to proxy for the Balassa-Samuelson effect is imperfect, could also show up in real interest rate differentials. If the productivity of capital rises, capital will flow in and result in an appreciation of the exchange rate.

[12] The Balassa-Samuelson model assumes the arbitrage condition underlying PPP affects only traded goods, causing productivity differentials between traded and non-traded sectors to influence real exchange rates based on CPI, as CPI also incorporates non-traded goods. The real exchange rate becomes a combination of the real exchange rate for traded goods and the non-tradables/tradables price ratio in the two economies. As the former is predicted to be stationary, the real exchange rate should appreciate/cointegrate with relative prices of non-tradables to tradables and hence also with productivity growth in the tradables sector. Empirically, there is a large body of evidence supporting Balassa-Samuelson effects. Movements in relative productivity can explain changes in relative non-tradables to tradables prices in the long-run. However, movements in relative prices are not of sufficient magnitude to explain large movements in real exchange rates. Furthermore, there is little evidence that the real exchange rate for tradables is stationary.

even reversed (Schnatz et al., 2003). Chinn (1997) finds that relative prices lead to more reliable results than relative productivity measures. Alberola et al. (1999, 2002) suggests proxying by the CPI-to-PPI ratio. Ricci et al. (2008) use a finer measure of the difference in output per worker in tradables and nontradables production relative to trading partners. The expected sign is positive.

- **Terms of trade:** a higher ratio of export-to-import prices generates positive wealth effects, putting upward pressure on the real exchange rate. For commodity exporters, commodity terms of trade is usually used, defined as the weighted average of main commodity export prices divided by main commodity import prices, where all commodity prices are calculated relative to the price of manufacturing exports of advanced economies. Alternatively, trade balance or net exports (% of annualized GDP) can be used as a proxy for terms of trade. The expected sign is positive.
- **Net foreign assets** (% of GDP or trade): debtor countries need a more depreciated REER to generate trade surpluses necessary to service their external liabilities (debt service and profit remittances). Conversely, creditor nations can afford to have trade deficits. The expected sign is positive for net foreign assets (negative for external debt).
- **Government spending or fiscal balance** (% of GDP): higher government consumption, to the extent that it raises consumption of nontradables more than tradables, will raise the relative price of nontradables and therefore appreciate the exchange rate. The expected sign is positive for government spending (negative for fiscal balance).
- **Ratio of foreign-to-domestic government debt:** captures a risk premium (in the UIP condition).
- **Trade openness:** trade restrictions raise domestic prices and thus the real exchange rate. Trade openness measured as exports plus imports as a % of GDP is often used as a proxy for commercial policy. The expected sign is negative.
- **Price controls:** are associated with an undervalued real exchange rate, which is expected to appreciate as price controls are removed. This effect can be captured using the share of administered prices in the CPI basket. Expected sign is negative.
- **Money supply:** an increase in the money supply would cause the exchange rate to depreciate. The log-change of money supply is typically used. The expected sign is negative.
- **International reserves:** an increase in foreign reserve holdings by the central bank typically implies the demand for home currency is high, resulting in an appreciation of the real exchange rate. This variable is used as a proxy for foreign exchange intervention in estimations for China (Yajie et al., 2007; and Cui, 2013) and Peru (Tashu, 2015). The expected sign is positive.

Whereas a vast empirical literature attempts to estimate the equilibrium exchange rate for China and EMU accession countries, no existing studies appear to focus on Argentina.[13] Cline (2015) estimates the FEER and currency misalignments for 34 economies and finds that the Argentine peso is at equilibrium (given its current

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[13] Uz and Bildir (2009) test whether the monetary model of exchange rate determination holds for Argentina and find weak supportive evidence. Using cointegration analysis they find that the nominal exchange rate is positively related to interest rate differentials, but obtain a negative relationship with price differentials (inconsistent with theoretical predictions).

account forecast and target at -2.6% of GDP), requiring no change in the REER. Bénassy-Quéré et al. (2009) estimate the BEER for a panel of G20 countries including Argentina, and estimated an undervaluation of the peso against the U.S. dollar in the range of 36.5–60.3 in 2005.

Our paper contributes to the literature by being the first, to the best of our knowledge, to identify the long-run drivers of Argentina's exchange rate and estimate the extent of the peso's exchange rate misalignment over time. We employ the BEER approach, which is well suited to developing countries with fluctuating fundamentals. We tailor our analysis to the Argentine economy, taking into account its structure (heavy reliance on the agricultural sector and soybean exports) and domestic policies observed during the period considered for the analysis (active exchange rate intervention using reserves as well as restrictive trade and capital control policies). We also take into account potential data mismeasurement and compute a range of plausible estimates of exchange rate misalignment. Finally, we contrast our findings to direct estimation-based measures, based on parallel exchange rate premia, law of one price, and purchasing power parity.

Table 2: Summary of Empirical Findings using the BEER Approach

Paper	Country	Time	Conditioning variables and cointegrating coefficients
Feyzioğlu (1997)	Finland	1975–1995	world real interest rates (0.03), productivity differential (0.85), terms of trade (0.37), devaluation dummy (-0.14).
Zhang (2001)	China	1952–1997	investment at constant prices as proxy for technological progress (0.37), exports growth rate as proxy for terms of trade (-3.4), government consumption in current prices (-0.32), total trade as % of GDP as proxy for commercial policy (0.88).
MacDonald and Ricci (2003)	South Africa	1970:Q1–2002:Q1	real interest rate differential (0.03), GDP per capita differential (0.13), real commodity prices (0.45), trade openness (-0.01), fiscal balance (-0.02), net foreign asset position (0.01).
Maeso-Fernandez et al. (2004)	CEE acceding countries	1975–2002	income per capita as a proxy for productivity (0.40), trade openness (-0.17), government spending (0.31).
Nilsson (2004)	Sweden	1982:Q1–2000:Q4	real interest rate djfferential (exogenous, stationary), relative price of tradables to nontradables (-0.46), terms of trade (0.65), net foreign debt as % of GDP (-0.10).
Babetskii and Égert (2005)	Czech Republic	1993:M1–2004:M9	average labour productivity differential [0.7, 2.2], net foreign assets position [0.04, 0.60].
Iimi (2006)	Botswana	1985–2004	real interest rate differential (0.024), relative prices of nontradables to tradables (1.35), terms of trade (0.29), net foreign asset position (-0.003, unexpected sign).
Iossifov and Loukoianova (2007)	Ghana	1984:Q2–2006:Q3	real interest rate differential (1.1), real GDP per capita growth differential (4.7), real world prices of Ghana's four main export commodities (0.35).
MacDonald and Dias (2007)	Canada, China, Japan, Germany, Norway, Singapore, Sweden, Switzerland, U.K and U.S.	1988:Q1–2006:Q1	real interest differential [-0.09, 0.06], net exports as a proportion of GDP [-178, -1.34], terms of trade differential [-4.1, 2.4], GDP per capita differential [-1.5, 1.5].
Yajie et al. (2007)	China	1980–2004	interest rate differential (not included due to capital controls), relative price of tradables to nontradables as a proxy for productivity divergence (1.25), terms of trade (not signif.), money supply (-1.18), central bank foreign reserve holdings (0.86).
Ricci et al. (2008)	panel of 48 countries using DOLS	1980–2004	productivity based on sectoral breakdown for tradables (0.17) and nontradables (-0.21), commodity terms of trade (0.56), net foreign assets as % of trade (0.04), government consumption as % of GDP (2.84), trade restrictions dummy (0.13), and price controls based on share of administered prices in the CPI basket (-0.04).
Bénassy-Quéré et al. (2009)	panel of G20 countries	1980–2005	real interest rate differential (excl. due to stationarity), alternative measures of productivity differentials such as CPI-to-PPI ratio (0.88), services to agriculture and industry deflators (0.91), GDP per capita (0.04), and GDP per employed worker (0.07), terms of trade [0.33, 1.04], net foreign assets [0.28, 0.47].
Cui (2013)	China	1997:M1–2012:M12	relative prices of nontradables to tradables measured as CPI-to-PPI (-1.14), terms of trade (0.39), openness (6.76), reserves as % of GDP (insig.), FDI as % of GDP (41.3).
Gan et al (2013)	China	1999:Q1–2007:Q4	productivity (0.51), terms of trade (not signif.), trade openness (-0.41), government expenditure (0.75), money supply M2 (-0.97).
Tashu (2015)	Peru	1992:Q1–2013:Q1	relative labor productivity (0.36), real price of export commodities (0.03), net foreign liabilities as % of trade (-0.06), primary current public sector consumption as % of GDP (0.37), profit repatriation (-0.16), net international reserves as % of GDP as proxy for forex intervention (-0.56).

Note: A positive (negative) coefficient denotes REER appreciation (depreciation) pressure.

3. Methodology and Data

This section discusses the methodology and data we use in producing estimates of the equilibrium peso exchange rate using the BEER approach.

We employ a model-based approach known as the behavioral equilibrium exchange rate to compute estimates of the equilibrium exchange rate for Argentina. This methodology (MacDonald, 1997) identifies the main determinants of the equilibrium real exchange rate and assesses exchange rate misalignment taking into account Argentina's fundamentals. A reduced-form vector error correction model is estimated using Johansen's (1995) cointegration procedure, from which the equilibrium real exchange rate is inferred as a function of macroeconomic fundamentals.

The equilibrium real exchange rate depends on a vector of fundamental variables, x_t, as follows:

$$RER_t^* = \alpha + \beta' x_t + \varepsilon_t$$

Changes in the actual real exchange rate can be expressed in the following form, where θ denotes the adjustment coefficient:

$$\Delta RER_t = \theta(RER_t^* - RER_{t-1}) + u_t$$

Combining these two equations we obtain:

$$RER_t = (1 - \theta)RER_{t-1} + \theta\alpha + \theta\beta' x_t + \theta\varepsilon_t + u_t$$

The equilibrium exchange rate can therefore be measured as a function of macroeconomic fundamentals via reduced form model estimation of a vector error correction model. Predicted values of the real exchange rate (smoothed using an HP filter) constitute the so-called behavioral equilibrium exchange rate, which can be expressed compactly as:

$$BEER_t = f(x_t)$$

We explore the long-run relationship between the real exchange rate and fundamentals found to be important in the literature (see Table 2). We consider a large selection of fundamental indicators representing terms of trade, productivity differentials, net foreign assets, trade openness, government consumption, active foreign exchange interventions, and money supply. Real interest rate differentials are not used because they are found to be stationary I(0). We use monthly data for the period 1980:m1 to 2015:m5 and all variables are expressed in natural logarithms. A detailed description of the data is provided in Appendix Table A.1.

We employ Johansen's (1995) cointegration approach to estimate the BEER as follows. First, we test for stationarity and confirm I(1) processes for all series we consider as fundamentals driving the long-term REER. Second, we choose the number of lags to include based on various information criteria. Third, we use trace and maximum eigenvalue tests for the number of cointegration relations between the REER and fundamentals (Johansen, 1991). This three-step procedure is repeated for different combinations of fundamentals and only those yielding a single cointegrating relation are retained. Finally, we estimate the cointegration relation using a vector error-correction (VEC) model with an unrestricted constant, which allows for a linear trend in the data and a cointegrating equation that is stationary around a nonzero mean. The VEC model is equivalent to a restricted VAR designed for use with non-stationary

series that are known to be cointegrated. We then ensure that signs are consistent with theoretical predictions.

The set of fundamentals found to be driving the long-run exchange rate for Argentina includes: the terms of trade, productivity differential, trade openness, and foreign exchange reserves. The indicators are defined as follows:

- **REER:** data for the REER (*reer*) is taken from the BIS (1994-2015) and appended using data from the IMF (1980-1993), where both series are based on a trade-weighted nominal effective exchange rate (foreign currency units per unit of domestic currency) and relative CPI price indices. For the period December 2007-October 2015, we adjust the REER (*reer_adj*) to correct the domestic price level for cumulative inflation discrepancies between (lower) official statistics and (higher) inflation figures produced by PriceStats.
- **Terms of trade:** in the monthly analysis, IFS data on the world price of soybeans deflated by CPI in advanced economies (*psoy*)[14] is used as a proxy for terms of trade, stipulating a 'commodity currency' property of the peso based on soybean exports. In our annual analysis, we use a terms of trade index (*tot*) that measures the ratio of export-to-import prices obtained from the WDI database. [15]
- **Productivity differential:** this variable captures the Balassa-Samuelson effect based on the divergence of productivity levels in the country's non-tradable and tradable goods sectors. In the monthly analysis we two simplistic measures: the ratio of consumer-to-producer prices relative to main trade partners[16] (*cpi/ppi*, potentially underestimated) and industrial production relative to Brazil (*ip_rel*, potentially overestimated), Argentina's main trade partner.[17] To correct for potential mismeasurement, we also make adjustments that increase CPI/PPI (increasing the ratio by 30% over 2008-2015)[18] and decrease industrial production (using OJF estimated growth rates). In the annual analysis we use trade-weighted measures[19] of: (i) GDP per capita (*ypc* and *ypc_adj*, adjusted for mismeasurement by applying PriceStats CPI index as a deflator) and (ii) a more refined measure of tradables-to-nontradables labor productivity differentials (*tnt*) along the lines of Ricci et al. (2008).

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[14] This is also used in Tashu (2015) and MacDonald and Ricci (2003). We alternatively use world CPI as a deflator.

[15] An export-to-import price index is not available at monthly frequency for the length of our sample.

[16] The main trade partners considered are Brazil, the United States, and Germany, where weights are computed using time-varying trade shares.

[17] We consider the internal price ratio as a measure of the relative price of tradables-to-nontradables, defined as the ratio of the consumer price index to domestic wholesale or producer price index (as suggested in the literature by Alberola et al., 1999). Other studies, as a rough measure in the presence of widespread price controls, have used either GDP per capita (Wang et al., 2007) or real GDP per capita at PPP (MacDonald and Ricci, 2003) relative to main trading-partner countries. At monthly frequency, industrial production is a good proxy for GDP per capita.

[18] To the extent that CPI figures are underreported by more than PPI, we adjust the CPI/PPI ratio upwards over 2008-201, in line with an estimated long-run relationship between the two price indices.

[19] Trade-weighted measures consider the trade share represented by Argentina's five main trade partners over 1980-2014: averaging 19% for Brazil, 13% for the United States, 5% for Germany, 5% for China (5%), 4% for Chile. Whereas Brazil and China grew in terms of trade importance over the period, we see a decline in the trade share of the US and Germany. See Appendix Figure 1.

- **International reserves:** in the monthly analysis, the stock of foreign exchange reserves held by the Central Bank of Argentina in US dollars is deflated by US CPI (*res*).[20] In the annual analysis, international reserves are expressed as a percentage of GDP (*resY*).
- **Trade openness:** in the monthly analysis, total trade (exports plus imports) in US dollars is deflated by US CPI (*trade*). In the annual analysis, trade is expressed as a percentage of GDP (*tradeY*).

We also considered a range of other variables that are not in our preferred specification, namely: real interest rate differentials,[21] net foreign assets deflated by US CPI (nfa), government spending deflated by CPI (gov), money supply defined as broad money in circulation deflated by CPI as a measure of monetary policy (m2).[22] The full list of variables considered in our analysis is found in Appendix Table A.1.

Data Adjustments

Our analysis deals with potential data mismeasurement, whereby official and private sector inflation and output estimates differed substantially in recent years. Alleged manipulations of depressed inflation and inflated growth figures have undermined the credibility of official statistics and led to widespread reliance on private sector parallel estimates of the inflation rate and output growth. To deal with this, we construct adjusted measures of the REER and productivity differentials.

If domestic prices are indeed underestimated, as is possibly the case for Argentina,[23] the REER would also be underestimated. We therefore complement the analysis by considering a measure of the REER that corrects for this. Data for the monthly real effective exchange rate, starting in 1994, is obtained from the BIS. We adjust this measure for cumulative monthly discrepancies between official (INDEC) and private sector inflation estimates since November 2007 from PriceStats, thereby constructing an adjusted measure of the REER (see Figure 3).

We furthermore consider the case where CPI is possibly underestimated relative to PPI and adjust the CPI/PPI ratio upward by a cumulative 30% over 2008-2015, consistent with an estimated long-run relationship between the two price indices (average CPI inflation being higher than PPI inflation by 0.5%).[24] We also conduct a

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[20] We find other measures used in the literature, such as reserves as a percent of imports, to be I(0).

[21] Real interest rate differentials between Argentina and countries such as Brazil and the US are found to be I(0), and therefore excluded from the cointegration estimation. Moreover, the presence of capital controls in Argentina is expected to mitigate the effects of this variable, as it violates the UIP condition that otherwise equalizes real interest rates.

[22] Other papers have used this variable in log-differences but we find this measure to be I(0).

[23] The official national and urban consumer price index (IPCNu) by INDEC, measured an annual inflation rate of 24% in 2014, lower than the implicit GDP deflator and much lower than inflation figures estimated by the private sector reaching close to 40% (see Figure 2). PriceStats−a specialist provider of inflation rates published by State Street, a financial services firm−estimates that since November 2007, cumulative inflation has reached 484% compared to 141% according to official estimates. "Congress" CPI inflation, which is calculated by averaging the measurements of eight independent consultants starting in 2011, estimates figures close to PriceStats and suggests that inflation averaged approximately 25% over the years 2011-2013.

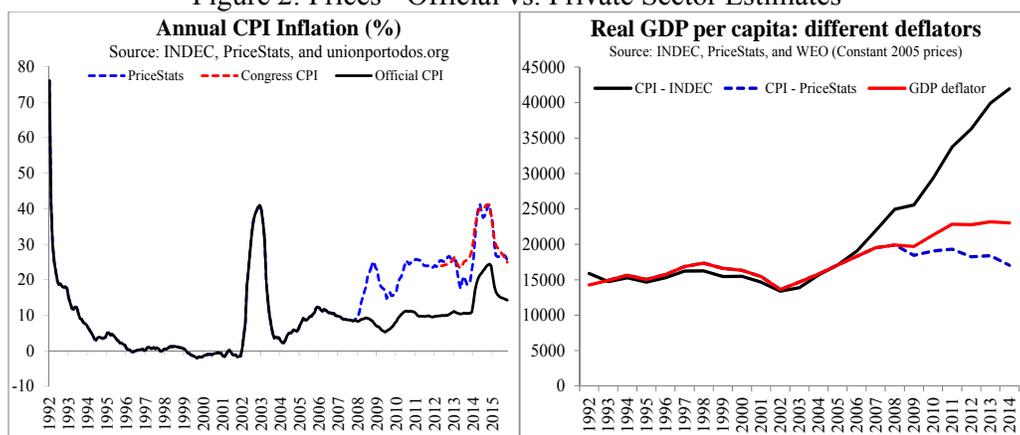[24] On average, PPI historically tracks CPI closely in Argentina, with CPI inflation averaging 0.5% higher than PPI inflation over the period 1993-2007 (where average annual inflation is measured excluding the years 2002-03, due to large price adjustments following the devaluation, and the period before 1993 due to hyperinflation episodes). By contrast, the CPI/PPI ratio has been falling since 2008 since reported

scenario for a large increase in the CPI/PPI ratio that uses private sector CPI inflation estimates, consistent with adjustments made to the REER. This implies a cumulative 70% increase in the CPI/PPI ratio over 2008-2015, such that average annual CPI inflation is underestimated by 5% relative to PPI during the period (see Figure 3).

Figures for domestic output suffer from similar measurement discrepancies (see Figure 4).[25] Inflated official growth estimates would be reflected in monthly industrial production and annual GDP per capita differentials. We compute two alternative measures of output that adjust for this: (i) industrial production corrected for growth rates estimated by Orlando J. Ferreres & Asociados since 2007, and (ii) GDP per capita deflated by PriceStats CPI inflation starting in 2009, when the GDP deflator and PriceStats inflation began to diverge substantially. The latter measure implies GDP in 2014 was overstated by 26 percent.

Finally, an improved measure of productivity differentials is constructed using annual data following Ricci et al. (2008), measuring the ratio of real value added per worker in the agricultural sector vis-à-vis the nontradable sector in Argentina, relative to its main trade-weighted partners, excluding China.[26] We obtain data on value added and employment for 10-sectors from the Groningen Growth and Development Centre (GGDC) and classify sectors into tradables versus nontradables using three alternative definitions.[27]

Figure 2: Prices - Official vs. Private Sector Estimates

Figure 3: Adjusted Statistics: REER and CPI/PPI

REER (2005 = 100)
Source: BIS, INDEC, PriceStats, and authors' calculations

·········· Inflation-adjusted REER   ── REER

CPI / PPI Ratio in Logs

── Large Adj. CPI / PPI
── Adjusted CPI / PPI
── CPI / PPI
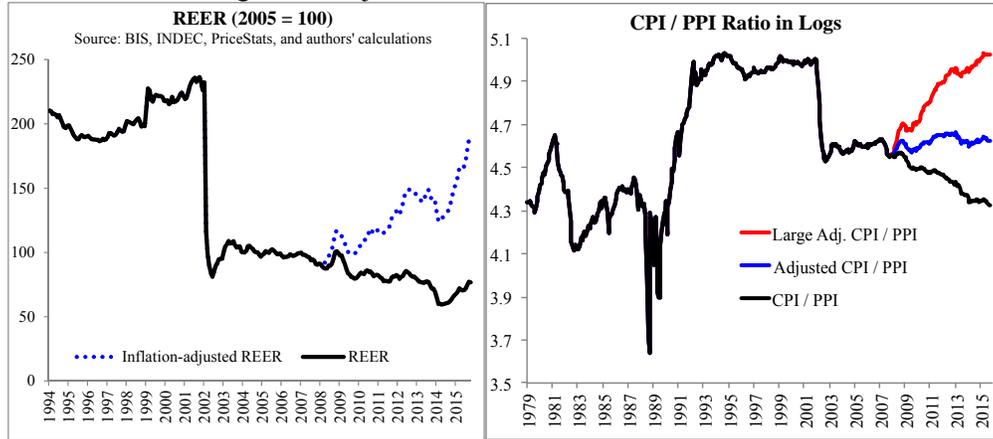
Figure 4: Output - Official vs. Private Sector Estimates

Economic Activity Index (2007m1 = 100)
Source: INDEC, Elypsis, Orlando J. Ferreres & Asociados

── EMAE
---- ICAE
---- IGA

Industrial Production Index (2007m1 = 100)
Source: INDEC, Orlando J. Ferreres & Asociados

── INDEC
---- OJF
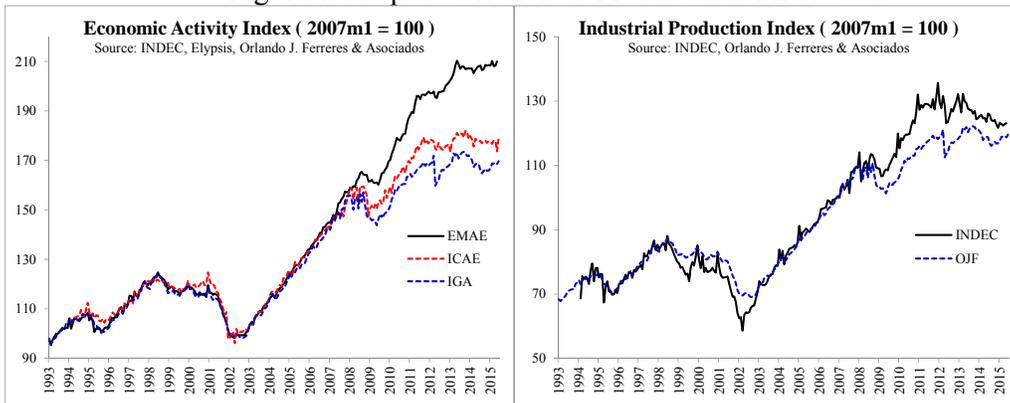
Figure 5: Agriculture-Nontradables Labor Productivity Differentials

Agriculture/Nontradables Labor Productivity

── Excl. utilities & transport
── Excl. utilities
── Baseline

15
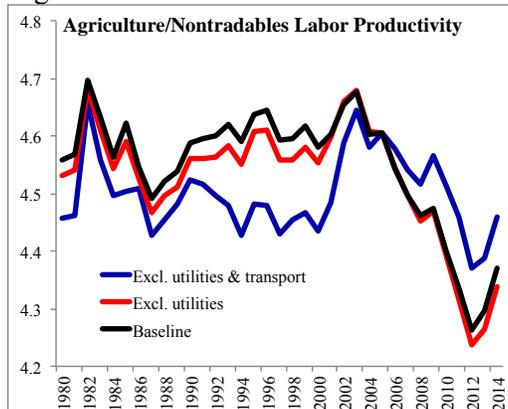
4. Estimation Results and Robustness

This section produces a range of estimates for the equilibrium exchange rate based on the estimated BEER. It also reports a series of robustness checks conducted to the main analysis and compares results to misalignments measured via direct estimation-based approaches. It discusses the caveats of each of the approaches and the plausibility of the estimations.

4.1. Behavioral Equilibrium Exchange Rate (BEER)

To allow the equilibrium real exchange rate to depend on fundamentals, we employ Johansen's (1995) cointegration approach to estimate the BEER as follows. First, we test for stationarity and confirm I(1) processes for all series we consider as fundamentals driving the long-term REER. Second, we choose the number of lags to include based on various information criteria. Third, we test for the number of cointegration relations between the REER and fundamentals using Johansen's (1991) procedure. Finally, we estimate the cointegration relation using a vector error-correction (VEC) model, which is equivalent to a restricted VAR designed for use with nonstationary series that are known to be cointegrated. We employ a VEC model with an unrestricted constant, which allows for a linear trend in the data and a cointegrating equation that is stationary around a nonzero mean.

Before cointegration analysis, all variables are tested for unit roots and the VAR lag order is selected. ADF tests confirm that our variables are integrated of order 1 and thus are valid for cointegration analysis (see Appendix Table A.2). The test accepts the null hypothesis that there is a unit root at the 5% level for all variables expressed in levels, while rejecting this hypothesis for variables in first-differences. We select the optimal lag length according to the Bayesian Information Criterion (BIC), which suggests the inclusion of two monthly lags for most specifications (out of a maximum of 13).

Johansen's (1991) cointegration trace and maximum eigenvalue statistics are used to determine the rank of the coefficient matrix in the VAR model, indicating the number of cointegrating relationships among variables. The cointegration rank is equal to 1 if according to the trace and/or eigenvalue test statistic, we reject the null of no cointegration but fail to reject the null that the rank is maximum 1 at the 5% significance level. We then conclude that there exists one single cointegrating relation among the variables. Having established cointegration between the set of fundamentals and the real effective exchange rate, we estimate the cointegrating vector.

In our baseline specification,[28] we identify the set of fundamentals that determine the long-run value of the REER to consist of: the commodity terms of trade (real soybean prices), productivity differentials (defined as the consumer-to-producer price ratio), real international reserves, and trade openness (real total trade).[29] We

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[28]For this specification, optimal lag length criteria prescribe the inclusion of one lag according to the BIC, 2 months according to HQ, and 13 months according to AIC. We follow the BIC. However, signs and significance are preserved when using 2 and 13 months.

[29] We arrive at this specification after discarding specifications in which: the order of cointegration is different from one (in line with the literature, see Iimi 2006; Iossifov and Loukoianova, 2007; Baffes et

estimate the VEC model using data only up to 2007, to ensure that the fundamental relationship is robust to potential data mismeasurement in recent years. The coefficients of the cointegrating vector are statistically significant and have the expected signs, conforming to economic theory. The following cointegrating relation is obtained:

$$reer_t = 0.64 psoy_t + 1.46 \frac{cpi}{ppi_t} + 0.31 res_t - 0.63 trade_t - 2.72$$

Besides being used to estimate the equilibrium exchange rate, based on the actual values of macroeconomic fundamentals, the coefficients of the cointegrating relation are useful to discuss what the equilibrium exchange rate level could be going forward, in a context where economic fundamentals are expected to evolve. Based on the estimates presented above, for every 1% increase in real soybean prices, representing an improvement in the terms of trade, the real exchange rate appreciates by 0.64% in the long run. A 1% increase in the ratio of CPI-to-PPI relative to trade partners, a proxy for tradables-nontradables productivity differentials, results in a 1.46% appreciation of the real exchange rate. A 1% increase in the level of real reserves implies a 0.31% appreciation of the exchange rate. Finally, a 1% increase in trade openness, measured as real total trade, depresses the real exchange rate by 0.63% in the long-run. A growth decomposition of the adjusted-REER for this baseline case shows the contributions of the various fundamentals in explaining movements in the REER (see Appendix Figure A.6).

The error correction coefficient is -0.031, meaning that if the real exchange rate revalues it will be adjusted downward, and vice versa, converging towards the long-run equilibrium. This adjustment speed translates to a half-life estimated at approximately 1.8 years, in line with findings in the empirical literature.

Finally, the equilibrium peso exchange rate (BEER) is estimated by applying the long-run elasticities to the actual values of the macroeconomic fundamentals. The Hodrick-Prescott (HP) filter[30] is applied to the predicted values of the estimated equation in order to abstract from short-term random disturbances. The (smoothed) fitted values of the REER are measures of real exchange rate equilibrium.

The log-deviation of the actual REER from the estimated BEER measures the degree of overvaluation. According to the baseline specification, the peso is overvalued by 25% (21% applying the HP filter). A much larger overvaluation of approximately 114% (110% applying the HP filter) is obtained using the inflation-adjusted REER measure. Robustness checks suggest that the former underestimates the exchange rate misalignment whereas the latter largely overestimates it. This large discrepancy in measuring exchange rate misalignment highlights sensitivity of results to the mismeasurement of the REER. Contrasting results across the two measures, we detect a substantial decoupling of the misalignment according to the adjusted and unadjusted REER. Whereas relatively little misalignment is evidenced by the unadjusted REER, the adjusted-REER measure points to substantial overvaluation of the peso.

Additionally considering the adjusted measures that correct for potential mismeasurement (underestimation) of the CPI-PPI ratio reduces estimates of overvaluation substantially. A smaller overvaluation is estimated according to the adjusted REER towards more plausible values (e.g., compared to parallel exchange rate

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al, 1997, among others), where the fundamentals are insignificant (we eliminate one by one those that are least significant), or where coefficient signs are inconsistent with theoretical predictions.

[30] We use a smoothing parameter of 129,600 consistent with monthly data.

premia, see section 4.2). This suggests that adjustments applied to both the REER and CPI-PPI ratio are justified.

Upon estimating the cointegrating relation coefficients using the whole sample of data, estimates of misalignment converge (see Table 3, columns 2-5). According to the unadjusted REER, the peso's overvaluation is estimated at 27% (31% without the HP filter). If instead we use the adjusted-REER measure, the peso becomes overvalued at an estimated 46% (62% without the HP filter).[31] This is an upper bound if we consider that the CPI-to-PPI ratio is underestimated.[32] In fact, when we use our upward-adjusted CPI/PPI ratio, misalignment estimates converge further: overvaluation becomes 39% (49% without the HP filter) for the adjusted-REER. Finally, in a scenario of large CPI/PPI adjustment, estimates of currency misalignment converge to 21% (26% without the HP filter), considered to be a lower bound.

This analysis reveals that, considering our adjusted measures for REER and CPI/PPI, the peso is overvalued by approximately 39%, with a range of 21–46% when we correct the REER and CPI/PPI ratio for underestimated CPI.

Table 3: VEC Cointegration Relation

| | REER | | Adj-REER | | |
| | Pre-2008 | Full sample | Full sample | | |
	(1)	(2)	(3)	(4)	(5)
Terms of trade	0.642***	0.586***	0.402**	0.537***	0.567***
Productivity differentials (CPI/PPI)	1.456***	1.673***	1.828***		
Reserves	0.312***	0.128*	-0.700***	-0.139	0.359***
Trade openess	-0.634***	-0.489***	0.840***	-0.055	-0.880***
Constant	-2.717	-2.910	-5.791	-3.963	-1.377***
Prod. diff. (Adj. CPI/PPI)				1.730***	
Prod. diff. (Large Adj. CPI/PPI)					1.584***
Error correction	-0.031	-0.032	-0.010	-0.026	-0.031
Half life (years)	1.8	1.8	5.6	2.2	1.8
Cointegrating rank	1	1	1	1	1
Lags in VAR	1	2	2	2	2
Overvaluation as of October 2015					
No HP filter	-	31%	62%	49%	26%
HP filter	-	27%	46%	39%	21%
Overval. using coefficients in column (1)					
No HP filter		25%	114%	70%	12%
HP filter		21%	110%	64%	4%

[31] In Table 3 column 3, coefficients for reserves and trade openness are significant with opposite signs to theoretical predictions. We believe this is because after 2008: (i) the REER appreciation arose due to inflationary pressures rather than higher demand for pesos (explaining the negative sign on reserves), and (ii) there was a rise in prices of traded goods (in part due to the commodity boom raising export prices) rather than a rise in trade volumes. For the next version of the paper, we could consider using data on trade volumes rather than values to test this hypothesis, although such data is only available from INDEC since 1986.

[32] In the robustness section, we provide evidence supporting our claim that the CPI-to-PPI ratio is under-reported, making 62% an upper bound using our adjusted-REER measure.
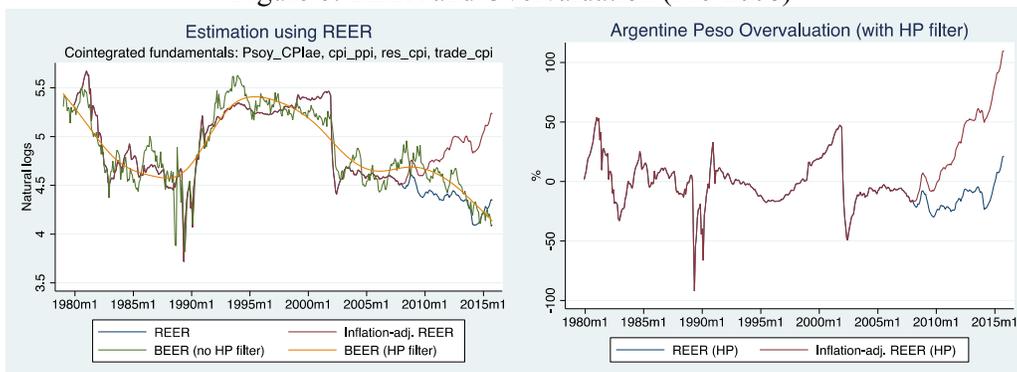
Figure 6: BEER and Overvaluation (Pre-2008)

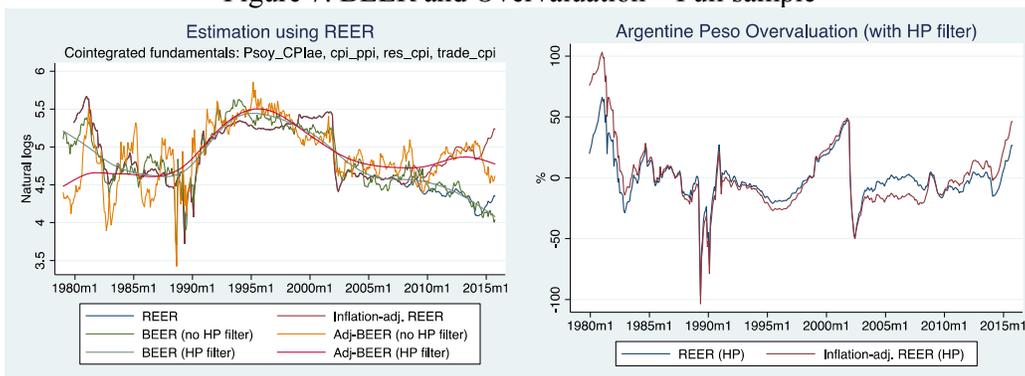Figure 7: BEER and Overvaluation – Full sample

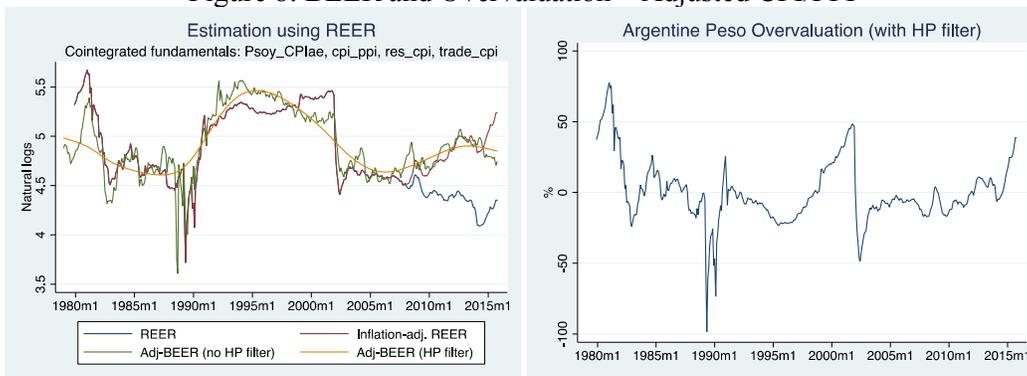Figure 8: BEER and Overvaluation – Adjusted CPI/PPI

Figure 9: BEER and Overvaluation – Large Adj. CPI/PPI

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Robustness Checks

To test the sensitivity of our results, we conduct a series of robustness checks. First, we control for shocks/outliers in our sample that could bias our estimates. Specifically, we include as exogenous variables dummies for large devaluations/revaluations of the peso (more than 15% of the NEER as well as a separate dummy for the devaluation in 2002m1) and episodes of volatility due to hyperinflation (in order to smooth large swings in the REER and CPI/PPI ratio in 1988-89).[33] Coefficients keep their signs, magnitudes, and significance (see Table A.4).[34] Moreover, the eigenvalue stability condition (4 unit moduli plus 1 root less than unity) is satisfied for the estimated VEC model. We conclude that the cointegrating relationship estimated between the REER and our set of fundamentals is stable.

Second, the choice of the number of lags is also important. The risk of including too few lags is that results could suffer from size distortions and fail specification tests (e.g., the Portmanteau test for autocorrelation). On the other hand, inclusion of too many lags reduces the power in cointegration rank tests. Coefficient signs and significance remain robust to the inclusion of two lags as prescribed by the HQ criterion, and thirteen lags as suggested by the AIC (with the exception of significance of trade).

The third robustness check involves the inspection of residuals. In order to assess model misspecification, residuals in the VEC model require diagnostic tests that check for non-normality and serial correlation. The LM test rejects the null hypothesis of no residual serial correlation. Furthermore, the Jarque Bera test rejects the hypothesis that residuals are normality distributed (an indicator of possible model misspecificiation) due to excess kurtosis, under the specification including dummies for hyperinflation and devaluation episodes (see Table A.5). However, Paruolo (1997) demonstrated that when normality is rejected due to kurtosis rather than skewness, the Johansen coefficients are not affected.

In the presence of residual non-normality and serial correlation, we contrast results with estimates of the cointegrating relation using fully-modified OLS (FMOLS[35]) and dynamic OLS (DOLS[36]) with corrected standard errors. The basic idea behind both the FMOLS and DOLS estimators is to correct for endogeneity bias and serial correlation and thereby allow for standard normal inference by using corrected standard errors that are asymptotically valid. Coefficient signs, magnitudes, and

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[33] During 1975-1990, Argentina experienced hyperinflation, poor growth, and capital flight that culminated in a balance of payments crisis with severe stagflation in 1988-90. This was also a period of large fiscal deficits and unsustainable growth of money supply.

[34] Note, however, that critical values may not be valid with exogenous variables.

[35] The FMOLS estimator, proposed by Phillips and Hansen (1990), employs semi-parametric correction for endogeneity and serial correlation that is due to the existence of a cointegrating relationship. In this way, it modifies least squares to eliminate the problems caused by the long-run correlation between the cointegrating equation and stochastic regressors innovations. It is asymptotically unbiased and has fully efficient mixture normal asymptotics allowing for standard Wald tests using asymptotic Chi-square statistical inference. The standard error, t-statistic, and p-value for the constant is, strictly speaking, not valid.

[36] The DOLS estimator, proposed by Stock and Watson (1993), augments the cointegrating regression with leads and lags of the explanatory variables in first differences, thus making the error term orthogonal to the history of stochastic regressor innovations. Assuming that the number of leads and lags included soaks up the long-run correlation of residuals, this estimator has fully efficient mixture normal asymptotics. Standard errors are corrected by applying the long-run variance of the residuals (rescaled OLS), White, or a robust HAC - Newey West estimator of the coefficient covariance matrix.

significance remain robust to both estimators. The peso's overvaluation is estimated at 49% according to the adjusted measure of CPI/PPI (baseline), with an upper bound of 69% (unadjusted CPI-PPI) and lower bound of 20% (large adj. CPI-PPI). The FMOLS and DOLS estimators support our assessment that the peso is strongly overvalued. We note that the upper bound obtained using the DOLS/FMOLS approach is higher than the 46% obtained using the VEC approach. (See Table A.6.)

We study whether the estimated cointegrating relation is robust to: (i) alternative measures of the variables, and (ii) the inclusion of new variables. Table A.7 reports the cointegration relation estimated using alternative measures of the variables in our specification. Coefficient sign and significance is generally robust to: the real price of soybeans deflated by world CPI (as a measure of terms of trade), consumer-to-wholesale price ratio (as a measure of relative productivity), and imports deflated by CPI (as a measure of trade openness).

When additional variables are added to the model one at a time the cointegrating rank increases. The added explanatory variables enter insignificantly in the model (net foreign assets and real interest rate differential) or with coefficient signs that contradict theoretical predictions (money supply and government spending). Moreover, other fundamentals lose significance and change signs (reserves and terms of trade). Thus, we conclude that our specification is preferred to all these alternatives.

As a last exercise in the monthly analysis, we estimate an alternative specification, where we change our measure of productivity differentials to industrial production relative to Brazil (rather than the CPI/PPI ratio). We also include, as an exogenous variable, a dummy equal to one for the interval 1991-2001 when Argentina had a currency board that established a 1-to-1 peg with the US dollar, with full convertibility (every peso in circulation was backed by a dollar in reserves), which caused a rise in reserves and a sustained period of exchange rate overvaluation.[37] Though coefficients have the predicted signs, a cointegration rank of order 2 is detected,[38] with reserves and trade coefficients insignificant when we include the same other fundamentals as before (for the adjusted-REER specification). Results are robust to dropping these two fundamentals (see Table A.8).

Exchange rate misalignment would be underestimated, provided that industrial production is overstated. To deal with this, we also consider a downward-adjusted measure of industrial production measured by the private sector. According to VEC estimates using the adjusted-REER, overvaluation is approximately 11-26% (see Table A.8). Given evidence of possible misspecification (residual serial correlation and non-normality), we estimate the cointegrating relation using DOLS and FMOLS methods. Coefficients again have the theoretically predicted signs and are statistically significant. The DOLS and FMOLS approaches with industrial production estimate a 40–54% overvaluation of the peso (see Table A.9). However, we note that industrial production

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[37] Between 1995 and 2001, Argentina struggled to maintain its overvalued fixed exchange rate and entered an economic downturn that became the Argentine Great Depression. During the second half of 2001, pressure mounted on the currency board to abandon the peg. In January 2002, the convertibility law was repealed and the peso depreciated 75% after being devalued and floated. In 2003, expansionary policy and commodity exports helped GDP rebound.

[38] This result is borderline significant as the trace and maximum eigenvalue tests for cointegration rank suggest the rank has order 2 at the 5% level but order 1 at the 1% level. We choose to focus on single cointegrating relationships since multiple cointegrating vectors complicate the economic interpretation of estimated relationships (see Johansen and Juselius, 1992; Dibooglu and Enders, 1995; Wickens, 1996; MacDonald and Nagayasu, 1998; Clark and MacDonald, 1999).

relative to Brazil may be a weak proxy for tradables-to-nontradables productivity and thus poorly capture the Balassa-Samuelson effect.

To test the robustness of the set of fundamentals identified as driving the peso's equilibrium exchange rate, we repeat the analysis using annual data for 1980-2014, in which we include alternative measures of our fundamental variables (see detailed description in Appendix Table A.1). In particular, we use Argentina's terms of trade[39] index (exports-to-imports price ratio available quarterly), improved measures of productivity differentials to better capture the Balassa Samuelson effect, and reserves and trade openness measured as a percent of GDP. We find that our choice of fundamentals is robust to estimation at annual frequency. We obtain a single cointegrating relation in which coefficients are significant and have the predicted signs (Table A.10 columns 1 and 3). The estimated cointegration equation for our new preferred specification can be written as:

$$reer\_adj_t = 1.68tot_t + 0.64tnt_t + 0.64resY_t - 2.02tradeY_t - 13.66$$

$$reer_t = 0.81tot_t + 1.09tnt_t + 0.81resY_t - 2.06tradeY_t - 11.88$$

Terms of trade improvements (wealth effect), increases in labor productivity of agriculture relative to the service sector vis-à-vis main trading partners excluding China (Balassa-Samuelson effect), rising reserves, and decreased trade (e.g., tighter trade restrictions), all appreciate the real exchange rate. The speed of adjustment coefficients (error correction) yield half-lives of approximately 2 and 5 years in the specifications using the REER and inflation-adjusted REER, respectively, in line with the empirical literature.

According to the estimated long-run relationship using the inflation-adjusted REER, the peso was overvalued from the mid-90s until the devaluation in 2002, and undervalued thereafter until 2010, after which an overvaluation has re-emerged. In 2014, the estimated cointegration relations suggest the peso was overvalued by 15% according to inflation-adjusted REER, contrasting the 7% undervaluation measured according to the unadjusted REER. Thus, we find a large discrepancy between the two measures of the REER.

Residual testing shows signs of possible misspecification: we fail to reject zero autocorrelation of residuals but find evidence of non-normality[40] and heteroskedasticity for some specifications. As a result, we employ alternative methodologies such as dynamic OLS (DOLS[41]) and fully modified OLS (FMOLS), which confirm our results. Both DOLS and FMOLS suggest the existence of a cointegrating relation by failing to reject the Hansen test for parameter instability. Both methodologies also fail to reject

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[39] As stressed by MacDonald and Ricci (2003), many studies find the real exchange rate of commodity exports to be strongly correlated with commodity prices though weakly correlated with terms of trade. This can be rationalized by: (i) the inclusion of goods with sluggish price adjustments and incomplete pass-through in aggregate terms of trade indices, (ii) the higher relative accuracy of commodity prices compared to export and import deflators, and (iii) the higher frequency of commodity price data that may influence financial decisions regarding currencies of commodity exporters. In contrast to these studies, we find that real soybean prices decrease the significance of productivity differentials between agriculture and services (tradables vs nontradables).

[40] We fail to reject skewness in all specifications upon inclusion of two dummy variables taking value 1 in 1982 and 2002, respectively, and value 0 in all other years. Results are robust to this specification.

[41] The DOLS estimators use HAC standard error correction and contain leads and lags of order 0 and 1, respectively.

residual normality. Finally, coefficient signs, significance, and size are robust (see Table A.11).

Lastly, we consider alternative measures of terms of trade and productivity differentials (see Table A.12). Real soybean prices are correctly signed and significant at the 10% level; however, no cointegrating relation is detected and moreover agriculture-to-nontradables productivity differentials loses significance (column 2). Aggregate productivity differentials, as measured by real GDP per capita vis-à-vis main trade partners, yields no cointegrating relation and takes the wrong sign (column 3). Sectoral productivity differentials perform better, once we exclude China (columns 1, 6-8).[42] We obtain the best specification to capture the Balassa-Samuelson effect uses agriculture relative to nontradables labor productivity. This reflects the importance of the agricultural sector as the main source of exports in Argentina. Results are robust to all three measures of the nontradables sector (columns 1, 7-8).

The annual analysis suggests the peso was overvalued by 15% on average in 2014 (see Appendix Figure A.5). The monthly analysis allows to shed light on the appreciation experienced by the peso during 2014, following the nominal devaluation that occurred at the beginning of the year. According to all specifications, the overvaluation in December 2014 exceeded the year average. This appreciation continued in 2015, leading to increased measures of overvaluation as of October.

The series of robustness checks support our assessment that the peso is strongly overvalued, as of October 2015.

Table 4: Adj-REER Overvaluation in 2014 – Monthly Analysis[43]

Adj-REER	Average 2014			December 2014			October 2015		
Overvaluation (%)	VEC	DOLS	FMOLS	VEC	DOLS	FMOLS	VEC	DOLS	FMOLS
	No HP filter								
CPI/PPI									
Official CPI/PPI (upper bound)	-3	24	23	36	46	45	62	78	76
Adjusted CPI/PPI	0	12	11	22	28	28	49	58	57
Large adj. CPI/PPI (lower bound)	-4	-6	-6	0	0	0	26	25	25
IP-differential									
Official IP	-	13	16	-	24	21	-	49	40
Adjusted IP	-	14	18	-	26	24	-	54	49
	HP filter								
CPI/PPI									
Official CPI/PPI (upper bound)	6	22	21	20	39	38	46	69	67
Adjusted CPI/PPI	1	9	8	14	23	23	39	49	49
Large adj. CPI/PPI (lower bound)	-11	-12	-11	1	0	1	21	20	21
IP-differential									
Official IP	-	8	9	-	23	22	-	48	46
Adjusted IP	-	10	12	-	24	25	-	49	49

[42] Including China, agriculture-nontradables productivity differentials is insignificant but correctly signed (column 4), whereas the sum of agriculture and industry (tradables) relative to nontradables is incorrectly signed (column 5). Moreover, both affect the terms of trade significance.

[43] Estimated overvaluation for the VEC specifications using industrial production is not reported due to aforementioned evidence of model misspecification.

4.2. Direct estimation-based measures

Finally, we contrast results obtained using the model-based BEER approach against three commonly used direct estimation-based measures of exchange rate misalignment: parallel exchange rate premia, the law of one price condition, and purchasing power parity.

We stress that it is important to consider their assumptions and caveats in evaluating their relevance. For the case of Argentina, where price statistics were allegedly manipulated (under reported), the law of one price and purchasing power parity may considerably underestimate exchange rate overvaluation. Moreover, in the presence of trade restrictions, the law of one price may have the opposite effect of considerably overestimating the degree of overvaluation.

An additional caveat is that direct estimations derived from the LOP and PPP conditions assume that the real exchange rate should be constant and equal to unity in equilibrium, and deviations from unity should eventually die out, exhibiting a stationary or mean-reverting property in the long-run. Empirically, however, the real exchange rate has been found to exhibit persistent deviations and a unit root process, providing weak empirical support for the PPP hypothesis. This speaks in favor of using a model-based approach such as the BEER, in which we estimate a time-varying equilibrium real exchange rate that allows deviations from PPP to be accounted for by real factors, reconciling the high volatility of the real exchange rate with very slow adjustment of shocks to PPP.

Parallel exchange market premia

Parallel exchange rate premia implied by the blue dollar rate and blue chip swap rate (percentage deviations from the official exchange rate) provided two measures of the implied overvaluation of the peso, using data obtained from dolarblue.net and ambito.com.

The published blue dollar rate, or '*paralelo*', has been for a long time the best-known alternative to the official exchange rate and was based on tracking average stock prices of eight major companies quoted on both the Argentine and US exchanges. The blue dollar to official exchange rate spread fluctuated with capital controls, market forces in response to the economy (e.g., demand), and other market information (e.g., expectations), but also affected economic activity. Argentine citizens turned to the blue market for dollars required for personal needs – it was more expensive but easier to obtain given restricted currency availability through official channels. Fear of inflation and of further depreciation of the peso kept demand for dollars high. The blue rate signaled an overvaluation of the US$/Peso exchange rate averaging at 35% over 2013-2015.

The blue chip swap rate, or '*contado con liqui*', also known as the capital flight dollar ('*dolar fuga*') or grey rate, is less well known than the blue, but it was critical to the financial market. This was the implied rate derived when businesses were buying dollar-denominated bonds or shares in pesos and then selling them on international stock exchanges for dollars. Typically the securities involved were Argentine government bonds denominated in dollars or American Depositary Receipts (ADRs)

listed in New York.[44] These transactions constituted a legal way of circumventing currency limits and converting pesos to dollars, which were deposited in offshore accounts. Many of these dollars returned to Argentina off the books (and into the blue market) or as payment for imports. The blue chip swap signaled the risk of a roughly 36% overvaluation of the US$/peso exchange rate as of December 14, 2015, ahead of the reunification of the exchange rate.

In addition to the blue and grey rates, a multitude of other exchange rates emerged in Argentina and were described by color (green, light-blue), by city (Miami, Colonia), a rate for individual savers, and another just for soy exporters (see Table 5). Foreign transactions and soy exports were essentially 'taxed' by a fixed spread over the official rate. We restrict our definition of parallel exchange rates to refer to the blue and blue chip swap rates.

Table 5: Argentina's multiple exchange rates and premia w.r.t. official rate

Exchange rate	Description	Legal status	Dec. 4, 2015 US$/Peso	Premia (%) US$/Peso
Source: www.dolarblue.net				
White	Official exchange rate.	Yes	0.10	0.0
Blue	Parallel market rate tracking stock market prices in Argentina and the US.	No	0.07	34.1
Blue chip swap / grey	Capital flight dollar using financial arbitrage.	Yes	0.07	35.7
MEP / bolsa	'Liqui casero' - arbitrage for sovereign bond, ex: Bonar 2017 and Boden 2015.	Yes	0.07	33.8
Light blue / celest	Real estate rate. Average of white and blue.	No	0.08	20.5
Savings	Dollars for personal use (max. monthly purchase = $2,000). Official rate + 20%.	Yes	0.09	16.7
Foreign credit/debit card	Card transaction rate for tourists in Argentina. Official rate + 35%.	Yes	0.08	25.9
Miami	Purchases abroad over $300. Foreign credit/debit card rate + offirical rate/2.	Yes	0.06	45.9
Colonia	Uruguay ATM advance withdrawals. Foreign card rate + 3% p.m + operating fees.	Yes	0.08	20.7
Airport	Buying rate.	Yes	0.10	0.1
Mayoristas bancos	Firms transfering/remitting money abroad.	Yes	0.10	0.0
Reference BCRA	Central Bank of Argentina reference (buying) rate.	Yes	0.10	0.0
Soy	Agricultural export retention. Official - 35%	Yes	0.16	-53.8
Dollar convertibility	Implicit theoretical shadow rate based on the monetary base, reserves excluding foreign liabilities or short-term debt, and adjusted dollar deposits.	No	0.05	55.7

Law of One Price (LOP)

The law of one price has been used to construct several measures of currency over and undervaluation. We consider the overvaluation implied by The Economist's Big Mac and Commsec's iPad price indices, under the assumption that the law of one price holds. This hinges on the restrictive (and implausible) assumptions regarding the absence of: barriers to trade (e.g., tariffs), transport costs, adjustment costs (causing price differentials to respond with a lag), and market power (which leads firms to price to market). We calculate the implied exchange rate as the local price of the good in pesos relative to its price in US dollars abroad and measure the percentage misalignment.

The Economist's Big Mac index computes the exchange rate that would equalize prices of a Big Mac burger in MacDonald's across countries, while an adjusted index attempts to correct for country differences in labor costs and GDP per capita. The adjusted index suggests the overvaluation of the peso has fallen from 50% in July 2011 to -5% in July 2015 (see Figure 10).[45] Yet we caution against this indicator of exchange rate overvaluation for Argentina as a result of market-diverging burger prices. Big Mac prices for Argentina have been subject to large controversy since 2011,[46] when the Big

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[44] However, costs of doing business by using this exchange rate are high as securities priced in US dollars must be purchased and exchanged to obtain scarce foreign currency.

[45] In January 2016, the Big Mac index implied the peso is undervalued by an even larger 33% (106% according to the unadjusted index).

[46] The Big Mac index for Argentina provides suggestive evidence of official inflation statistics being misreported. According to the Economist in January 2011, statistics support "claims that Argentina's

Mac became priced lower than other value meals and temporarily stopped being advertised for sale, raising speculation over artificial distortions leading to underpricing.[47] Moreover, findings by Portes and Atal (2014) suggest the Big Mac index is at most a qualitative indicator of the direction of movements in the nominal exchange rate in rich and economically stable economies, while being less effective in forecasting movements in emerging markets.[48]

In a similar spirit, CommSec, a unit of Australia's commonwealth bank, constructs an iPad index in which price differences derive from currency misalignments but are also largely attributed to transportation costs, taxes, and to some extent price discrimination (due to Apple's large market share). By this measure, Argentina ranks the most expensive place to buy an iPad as of September 2015, costing almost triple that in the US, suggesting an overvaluation of the peso of approximately 64% without adjusting for transport costs and tariffs (see Figure 11). Argentina has high trade barriers, such as tariffs and currency controls, which prevent iPad price adjustment in line with the world market. Therefore, we expect this estimate to overestimate the peso's overvaluation, such that controlling for these market imperfections, would suggest a lower overvaluation. The caveat of Apple's potential price discrimination, however, remains.

Rather than comparing prices of single commodities across countries, other measures of PPP equate consumption baskets. This is the spirit of the OECD measure of different price levels by calculating the PPP ratio for private final consumption expenditure.[49]

Purchasing Power Parity (PPP)

Lastly, we calculate the peso's misalignment according to the theory of purchasing power parity, which equates price levels across countries and implies that the real effective exchange rate–measured as the nominal effective exchange rate adjusted for relative consumer price indices–should be constant. If the real exchange rate is below (above) its equilibrium value, it is expected to rise (fall) back towards its fundamental value. This provides a simple tool to back out the misalignment of the peso.

If LOP holds for all commodities then PPP must also hold apart from under certain conditions: when nontradables exist, consumers' preferences differ, or countries specialize in different goods. We measure the percentage deviation of the real effective exchange rate from its value at a year in which it is considered to be at equilibrium. The adjusted measure of the REER that uses private sector inflation figures yields an alternative measurement of the peso's misalignment implied by the PPP condition.

In this analysis, we normalize the constant equilibrium value of the real effective exchange rate (REER) to 100 in 2005, considered to be a year of

government is cooking the books… the gap between its average annual rate of burger inflation (19%) and its official rate (10%) is far bigger than in any other country". To the extent that Big Mac inflation tracks CPI closely, a big gap is a sign that prices are being managed/misreported due to government intervention. In fact, in 2010, Big Mac inflation was closer to unofficial statistics (25% according to PriceStats) than to official CPI.

[47] This is supported by *The New York Times* among many other press releases.

[48] Portes and Atal (2014) find that Big Mac prices tend to lag overall inflation rates (revealing high price stickiness), using data spanning 1986–2012 for 54 countries.

[49] Unfortunately, figures are not available for Argentina.

macroeconomic stability and robust growth for the Argentine economy. The declining real effective exchange rate since 2005 suggests an undervalued exchange rate of approximately 30%, as of October 2015. Depressed price statistics decrease the REER and lessen the peso's implied overvaluation. On the other hand, our inflation-adjusted REER,[50] exhibits an increasing trend and signals an overvalued US$/Peso exchange rate of 46% in 2015 relative to the base year 2005[51] (see Figure 10). Yet, the caveat of a assuming a constant real exchange rate remains.

Figure 10: Overvaluation Implied by the Big Mac Index and PPP
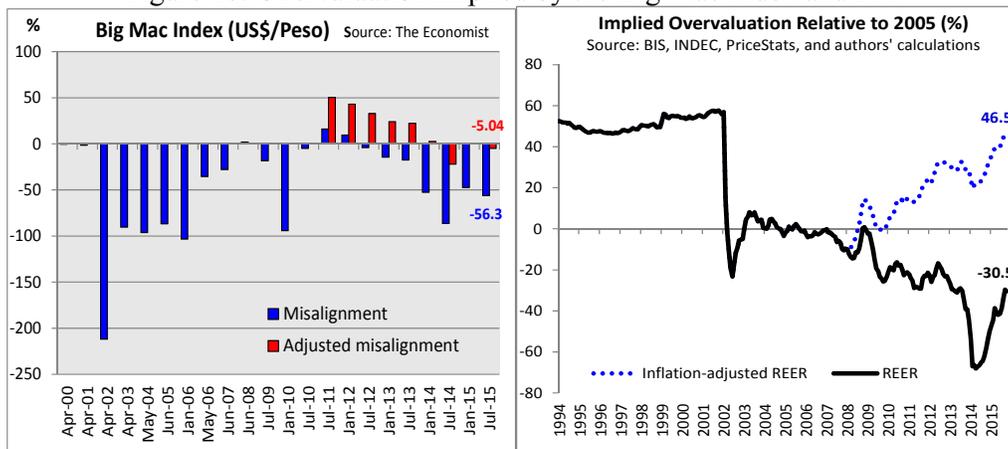
Figure 11: Overvaluation Implied by the iPad index in US$/LCU

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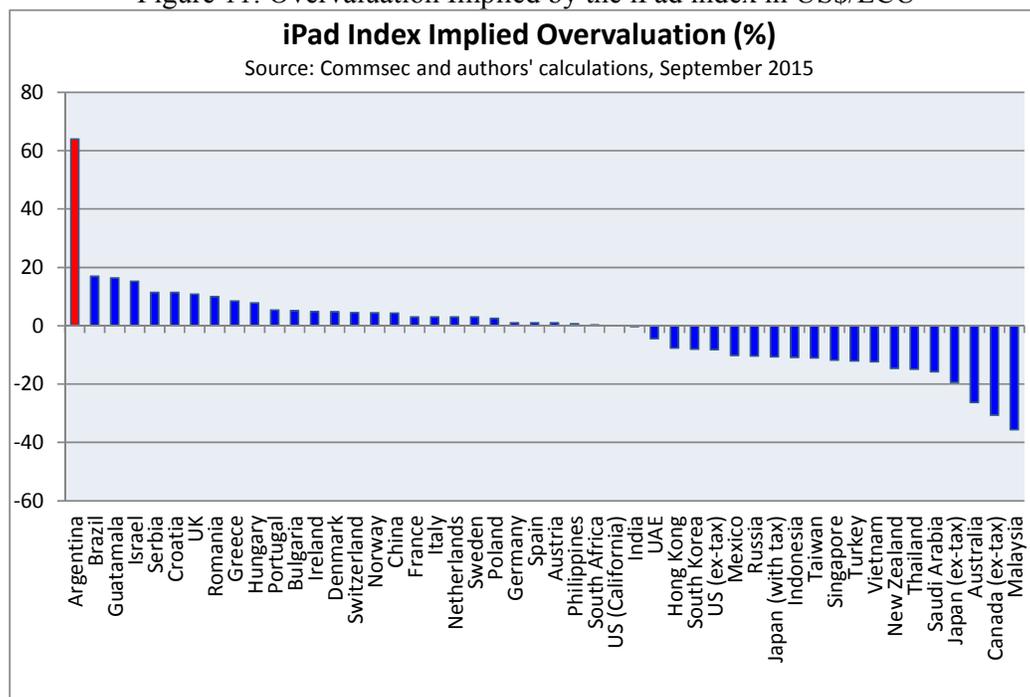
[50] The adjusted REER is estimated by inflating domestic prices by the cumulative difference in monthly inflation estimates produced by PriceStats compared to INDEC.

[51] 2005 is considered to be a year of macroeconomic stability and therefore assumed to reflect equilibrium. Argentina's economy had recovered from the 2001 crisis but not yet suffered from the global financial crisis nor the external (balance of payments) instability that has since prevailed.

5. Conclusion

Until the end of 2015, currency controls in Argentina led to a widening spread between the official exchange rate and parallel market rates. On December 16, 2015, the government announced its decision to remove the currency and capital controls and currency restriction and let the peso to float within certain limits. As a result, the currency immediately depreciated by about 30 percent and the gap with parallel rates virtually closed.

The removal of the controls boosted the debate on exchange rate equilibrium levels for Argentina. This study aims at contributing to this debate by: (a) identifying which are the macroeconomic fundamentals affecting the exchange rate equilibrium level in Argentina; and (b) estimating an equilibrium exchange rate, based on these fundamentals.

With this objective, the study adopts the behavioral equilibrium exchange rate (BEER) approach using monthly data for the period 1980-2015 and takes into account important features specific to the Argentine economy during the period considered, such as the relevance of agriculture exports and the potential underestimation and overestimation of inflation and economic activity figures, respectively.

According to the analysis, the set of fundamental factors driving Argentina's real exchange rate are identified as: the terms of trade, productivity differentials with trade partners, US real exchange rate, trade openness, and reserves. Based on the data available for these fundamentals, the peso was overvalued by 39%, as of October 2015. To ensure robustness of results, the analysis is repeated using different specifications, frequencies, and estimation approaches.

Moreover, estimation results shed light on the long-run impact of economic fundamentals on the equilibrium exchange rate in the context of Argentina. The analysis suggests that, for every 1% increase in real commodity (soybean) prices, the real exchange rate appreciates by approximately 0.6% in the long run. A 1% increase in the ratio of CPI-to-PPI relative to trade partners results in nearly a 1.5% appreciation. A 1% increase in the level of real reserves implies a 0.3% appreciation. Finally, a 1% increase in trade openness, measured as real total trade, depresses the real exchange rate by 0.6% in the long-run. The speed of adjustment coefficients (error correction) yield half-lives between 2 and 5 years, in line with the empirical literature.

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7. Appendix

Table A.1: Data Description

Variable	Monthly indicators	Additional yearly indicators.
Real effective exchange rate (REER)	**reer:** REER from BIS (1994:m1 onwards), appended with INS data (1979:m12-1993:m12). Both use CPI-adjusted nominal effective exchange rate. Source: BIS, INS. **reer_adj:** REER as above, adjusted by cummulated difference between official and unofficial CPI inflation for 2007:m12 onwards. Source: BIS, INS, IFS, INDEC, PriceStats, and own calculations.	
Terms of trade	**psoy_cpiae:** soybean price deflated by advanced economy CPI. Source: IFS. **psoy_cpiw:** soybean price deflated by world CPI. Source: IFS.	**tot:** terms of trade index. Source: WDI. **tbY:** trade balance as % of GDP.Source: WDI.
Productivity differential	**cpi_ppi:** ratio of consumer price index to producer price index relative to main trade partners. Source: INDEC. **cpi_ppi_adj:** ratio of consumer price index to producer price index, relative to main trade partners, adjusted upward by a cummulative 30% over 2008-2015. Source: INDEC and own calculations. **cpi_ppi_adj_large:** ratio of consumer to producer price index, relative to main trade partners, adjusted upward by a cummulative 70% over 2008-2015. Source: INDEC and own calculations. **cpi_wpi:** ratio of consumer price index to wholesale price index. Source: INDEC. **ip_rel**: industrial production rel. to Brazil. Source: INDEC. **ip_rel_adj:** industrial production (adjusted by OJF industrial production growth since 2008) rel. to Brazil. Source: INDEC, OJF, and own calculations.	**tw_gdppc** GDP per capita rel. to trade partners. Source: WEO, DOTS. **tw_gdppc_adj:** GDP per worker rel. to trade partners (adjusted for Argentina by Pricestats deflator from 2008 onwards). Source: WEO, DOTS, PriceStats. **agr_tw:** agriculture value added per worker (constant US$) relative to trade partners.(**agr_tw_xchn** excludes China.) Source: WDI, DOTS, GGDC, OECD. **tnt_ag_ind:** ratio of tradables (agric + other) value added (constant domestic prices) per worker to nontradables value added per worker, rel. to trade partners. Source: GGDC, WDI, DG ECFIN AMECO, OECD, DOTS. (**tnt_ag_ind_xchn** excludes China from trade partners.) **tnt_ag:** ratio of agiculture value added (constant domestic prices) per worker to nontradables value added per worker, rel. to trade partners. Source: GGDC, WDI, DG ECFIN AMECO, OECD, DOTS. (**tnt_ag_xchn** excludes China from trade partners.) **tnt_ag_xchn2** and **tnt_ag_xchn3**: use different classifications of nontradables sectors.
International reserves	**res_cpi:** reserves in US$ deflated by US CPI. Source: IFS. **res_imp:** reserves as % of imports. Source: IFS, INDEC.	**res_extdebt:** reserves as % of external debt. Source: WDI. **resY:** reserves as % of GDP. Source: WDI. **res_imp**: reserves as % of imports. Source: WDI, INDEC.
Trade openness	**trade_cpi:** total trade (exports plus imports) in US$, deflated by US CPI. Source: INDEC, IFS. **imp_cpi:** total imports in US$, deflated by US CPI. Source: INDEC, IFS.	**tradeY:** total trade (exports plus imports) as % of GDP. Source: WDI. **impY:** total imports as % of GDP. **imp_vol:** total volume of imports. Source: WDI.
Money supply	**m2_cpi:** M2 deflated by official CPI. Source: IFS, INDEC. **m2_cpi_adj:** M2 deflated by unofficial CPI. Source: IFS, INDEC, PriceStats, and own calculations.	**m2Y:** M2 as % of GDP. Source: WDI. **m2_res:** M2 as % of reserves. Source: WDI.
Net foreign assets	**nfa_cpi:** net foreign asset position in pesos deflated by official CPI. Source: IFS Banking and Monetary surveys, INDEC, IFS, and own calculations. Starts in 1990. **nfa_cpi_adj:** net foreign asset position in pesos deflated by unofficial CPI. Source: IFS Banking and Monetary surveys, INDEC, IFS, PriceStats, and own calculations. Starts in 1990.	**cab_cpi, cabY:** current account balance in US$ deflated by US CPI; current account balance as % of GDP. **xdebt_cpi, xdebtY, xdebt_exp:** stock of external debt in US$ deflated by US CPI, as % of GDP, and as % of exports. **nfaY:** net foreign assets as % of GDP.
Government spending	**ggcons_cpi:** nonfinancial public sector primary expenditure in pesos, deflated by CPI. Source: MECON. Starts in 1993. **ggcons_cpi_adj:** nonfinancial public sector primary expenditure in pesos, deflated by unofficial CPI. Source: MECON, PriceStats, and own calculations. Starts in 1993.	**ggconsY:** government consumption as % of GDP. Source: Oxford Economics. **ggcons_cpi:** real government consumption. Source: Oxford Economics.
Real interest rate differential	**r_rel: n**ominal interest rate minus official CPI inflation rel. to Brazil. Source: IFS, INDEC. **r_rel_usa:** nominal interest rate minus official CPI inflation rel. to US. Source: IFS, INDEC. **r_rel_adj:** nominal interest rate minus unofficial CPI inflation rel. to Brazil. Source: IFS, INDEC, PriceStats. **r_rel_adj_usa:** nominal interest rate minus unofficial CPI inflation rel. to US. Source: IFS, INDEC, Pricestats. **usa_r:** US nominal interest rate minus CPI inflation. Source: IFS.	

Table A.2: Augmented Dickey-Fuller (ADF) Unit Root Test – Monthly Data

Fundamental	Variable	Level			1st Difference			Stationarity
		None	Constant	Constant and Trend	None	Constant	Constant and Trend	
REER	reer	-0.91	-1.61	-1.83	-18.24	-18.25	-18.23	I(1)
	reer_adj	-0.29	-2.11	-2.03	-18.19	-18.17	-18.17	I(1)
Terms of trade	psoy_cpiae	-0.95	-2.50	-2.27	-15.32	-15.32	-15.34	I(1)
	psoy_cpiw	-2.91	-2.30	-1.36	-15.03	-15.19	-15.29	I(1)
Productivity differential	cpi_ppi	-0.10	-1.81	-1.68	-19.66	-19.64	-19.65	I(1)
	cpi_ppi_adj	0.10	-1.99	-1.92	-19.67	-19.65	-19.64	I(1)
	cpi_ppi_adj_large	0.47	-1.47	-1.34	-16.67	-16.66	-16.65	I(1)
	cpi_wpi	-0.13	-1.68	-1.55	-19.44	-19.42	-19.42	I(1)
	ip_rel	0.33	-1.93	-3.09	-33.55	-33.55	-33.57	I(1)
	ip_rel_adj	0.16	-2.63	-3.46	-30.16	-30.15	-30.17	I(0) / I(1)
International reserves	res_cpi	0.11	-1.26	-2.32	-19.70	-19.68	-19.67	I(1)
	res_imp	-1.63	-4.48	-4.57	-24.01	-23.98	-23.96	I(0)
Trade openness	trade_cpi	0.55	-1.18	-2.74	-27.24	-27.26	-27.24	I(1)
	imp_cpi	0.36	-1.31	2.41	-27.66	-27.65	-27.63	I(1)
Money supply	m2_cpi	1.34	0.10	-1.93	-18.86	-18.90	-18.96	I(1)
	m2_cpi_adj	0.67	-1.00	-2.33	-18.92	-18.91	-18.90	I(1)
Net foreign assets	nfa_cpi	-0.77	-1.76	-1.96	-29.00	-29.48	-29.82	I(1)
	nfa_cpi_adj	-1.50	-2.25	-2.00	-29.34	-29.61	-30.25	I(1)
Government spending	ggcons_cpi	2.13	0.47	-1.54	-23.94	-24.10	-24.07	I(1)
	ggcons_cpi_adj	1.17	-1.07	-3.50	-25.02	-25.22	-25.19	I(1)
Real interest rate differential	r_rel	-12.30	-12.34	-12.36	-21.77	-21.75	-21.72	I(0)
	r_rel_usa	-12.46	-12.49	-12.50	-22.05	-22.02	-22.00	I(0)
	r_rel_adj	-12.30	-12.34	-12.36	-21.77	-21.75	-21.72	I(0)
	r_rel_adj_usa	-12.46	-12.49	-12.50	-22.05	-22.02	-22.00	I(0)
	usa_r	-2.16	-2.56	-4.26	-14.00	-13.98	-13.97	I(0) / I(1)
	Critical values:							
	1%	-2.58	-3.46	-4.00	-2.58	-3.46	-4.00	
	5%	-1.94	-2.87	-3.43	-1.94	-2.87	-3.43	
	10%	-1.62	-2.57	-3.14	-1.62	-2.57	-3.14	

Table A.3: Augmented Dickey-Fuller (ADF) Unit Root Test – Annual data

Fundamental	Variable	Level			1st Difference			Stationarity
		None	Constant	Constant and Trend	None	Constant	Constant and Trend	
REER	reer	-1.22	-1.52	-1.68	-5.00	-5.07	-4.98	I(1)
	reer_adj	-0.63	-2.36	-2.23	-5.06	-5.00	4.98	I(1)
Terms of trade	tot	0.29	-1.17	-4.01	-5.94	-5.94	-5.85	I(1)
	tbY	-2.16	-2.59	-2.47	-5.18	-5.10	-5.05	I(1)
Productivity differential	tw_gdppc	-1.10	-2.53	-2.60	-5.05	-5.06	-5.03	I(1)
	tw_gdppc_adj	-1.88	-0.72	-1.79	-4.47	-4.73	-4.69	I(1)
	agr_tw	-0.47	-2.75	-2.70	-6.43	-6.33	-6.23	I(1)
	agr_tw_xchn	-0.31	-2.79	-2.73	-6.19	-6.08	-5.99	I(1)
	tnt_ag_ind	-0.91	-0.32	-1.46	-5.34	-5.40	-5.63	I(1)
	tnt_ag_ind_xchn	-0.65	-0.91	-1.81	-5.39	-5.37	-5.42	I(1)
	tnt_ag	-1.38	-0.93	0.05	-4.22	-4.16	-4.16	I(1)
	tnt_ag_xchn	-0.17	-1.15	-1.06	-3.83	-3.77	-3.70	I(1)
	tnt_ag_xchn (2)	-0.16	-1.16	-1.03	-3.80	-3.74	-3.67	I(1)
	tnt_ag_xchn (3)	0.70	1.43	-1.11	-3.93	-3.87	-3.80	I(1)
International reserves	resY	0.16	-1.61	-2.80	-7.91	-7.84	-7.84	I(1)
	res_extdebt	-0.60	-1.88	-3.67	-5.32	-5.24	-5.02	I(1)
	res_imp	0.48	-1.00	-2.93	-6.47	-6.51	-6.38	I(1)
Trade openness	tradeY	0.73	-1.73	-2.67	-7.06	-7.12	-7.04	I(1)
	impY	0.71	-1.14	-2.67	-6.42	-6.46	-6.35	I(1)
	imp_vol	0.68	-0.50	-2.94	-4.27	-4.31	-4.29	I(1)
Money supply	m2Y	-0.05	-2.04	-2.48	-4.41	-4.34	-4.36	I(1)
	m2_res	-0.17	-2.32	-2.94	-5.92	-5.82	-5.72	I(1)
Net foreign assets	nfaY	-3.38	-3.37	-4.42	-9.06	-8.92	-8.78	I(0)
	xdebtY	0.11	-3.06	-2.85	-5.49	-5.40	-5.48	I(0)
	xdebt_cpi	0.84	-2.27	-1.59	-4.67	-4.64	-4.69	I(1)
	xdebt_exp	-0.35	-0.92	-2.40	-4.47	-4.41	-4.59	I(1)
	cabY	-2.43	-2.46	-2.65	-5.36	-5.28	-5.21	I(1)
	cab_cpi	-1.78	-1.97	-1.95	-4.89	-4.81	-4.76	I(1)
Government spending	ggconsY	1.03	-0.03	-1.33	-4.58	-4.62	-4.91	I(1)
	ggcons_cpi	2.06	0.43	-2.15	-4.85	-5.37	-5.46	I(1)
Critical values:								
	1%	-2.58	-3.46	-4.00	-2.58	-3.46	-4.00	
	5%	-1.94	-2.87	-3.43	-1.94	-2.87	-3.43	
	10%	-1.62	-2.57	-3.14	-1.62	-2.57	-3.14	

Figure A.1: Trade Shares
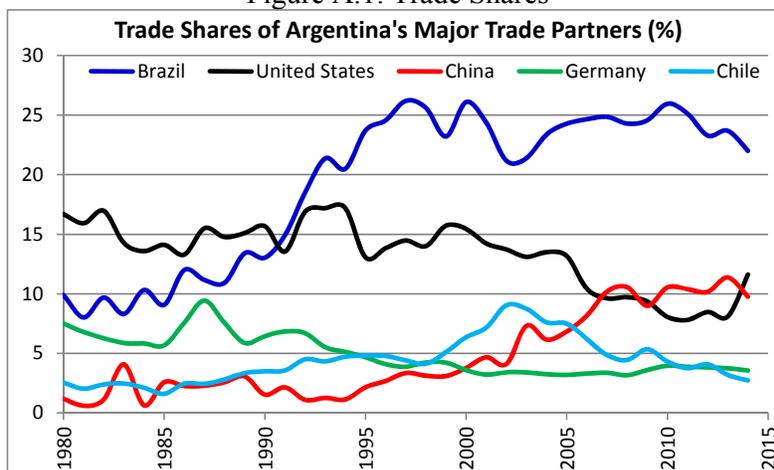
Source: IMF DOTS

Figure A.2: Data and Outliers
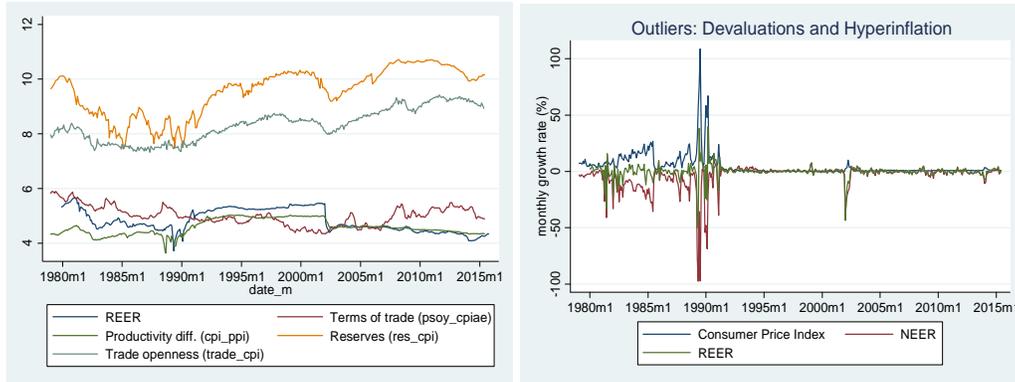
Table A.4: Robustness to Outliers and Lags

	Baseline (1)	Dummies (2)	2 Lags (3)	13 Lags (4)
Terms of trade	0.642***	0.863***	0.645***	0.688***
Productivity differential	1.456***	0.903**	1.530***	0.476***
Reserves	0.312***	1.880***	0.123*	1.688***
Trade openness	-0.634***	-3.237***	-0.336***	-2.442***
Constant	-2.720	5.290	-3.733	3.486

Table A.5: Test for Residual Normality

Component	Statistic	Prob.
Joint Skewness Chi-sq	10.0	0.076
Joint Kurtosis Chi-sq	280.7	0.000
Joint Jarque-Bera (Normality)	290.7	0.000

Table A.6: Robustness to DOLS and FMOLS

	Pre-2008		Full sample							
			REER		Adj - REER					
	DOLS	FMOLS	DOLS	FMOLS	DOLS			FMOLS		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Terms of trade	0.649***	0.642***	0.573***	0.567***	0.564***	0.590***	0.508***	0.548***	0.580***	0.504***
Productivity diff. (CPI/PPI)	1.380***	1.375***	1.513***	1.512***	1.253***			1.253***		
Reserves	0.215***	0.223***	0.217***	0.223***	0.039	0.109*	0.289***	0.028	0.102*	0.298***
Trade openess	-0.425***	-0.431***	-0.591***	-0.598***	-0.089	-0.333***	-0.733***	-0.068	-0.322***	-0.748***
Constant	-3.200***	-3.155***	-2.122***	-2.082***	-3.279***	-3.033***	-0.924*	-3.256***	-3.023***	-0.877*
Prod. diff (Adj CPI/PPI)						1.460***			1.465***	
Prod. diff. (Large Adj. CPI/PPI)							1.428***			1.429***
Jarque-Bera	7.3	11.2	3.4	22.0	74	20	1	47.5	37	8.3
P-value	0.026	0.004	0.182	0.000	0.000	0.000	0.634	0.000	0.000	0.016
Hansen instability	0.015	3.422	0.003	2.599	0.002	0.003	0.003	3.990	3.706	2.689
P-value	> 0.2	< 0.01	> 0.2	< 0.01	> 0.2	> 0.2	> 0.2	< 0.01	< 0.01	< 0.01
Overvaluation as of Oct 2015										
No HP filter	-	-	31%	31%	78%	58%	25%	76%	57%	25%
HP filter	-	-	27%	28%	69%	49%	20%	67%	49%	21%
Overvaluation using coefficients pre-2008										
No HP filter	-	-	31%	11%	101%	59%	4%	76%	57%	25%
HP filter	-	-	27%	5%	94%	50%	-7%	94%	50%	-7%

Table A.7: Robustness to Alternative and New Variables

Sample 1980-2007 REER	Baseline	Robustness to Alternative Measures:			Robustness to Additional Variables:			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Terms of trade (psoy_cpiae)	0.642***		0.670***	0.860***	1.012***	-0.020	-0.081**	0.627***
Productivity diff. (cpi_ppi)	1.456***	1.460***		1.768***	2.456***	1.533***	1.659***	1.448***
Reserves (res_cpi)	0.312***	0.161*	0.357***	0.294***	-0.130	0.231***	0.172***	0.332***
Trade openness (trade_cpi)	-0.634***	-0.164*	-0.697***		-1.047***	-0.337***	-0.141**	-0.662***
Constant	-2.720	-3.556	-0.392	-6.500	-12.964	-1.674	-0.776	-2.574
Alternative measures:								
Terms of trade (psoy_cpiw)		0.278***						
Productivity diff. (cpi_wpi)			1.336***					
Productivity diff (ip_rel)						-0.059		
Trade openness (imp_cpi)				-0.512***				
Additional variables:								
Money supply (m2_cpi)					0.964***			
Net foreign assets (nfa_cpi)						5.5e-5		
Government spending (ggcons_cpi)							-0.250***	
Real interest rate differential (usa_r)								0.005
Lags in VAR	1	1	1	1	1	1	1	1
Johansen coint. rank	1	2	1	1	3	2	3	2

Figure A.3: Robustness to Adj. CPI/PPI, Sample, and Methodology
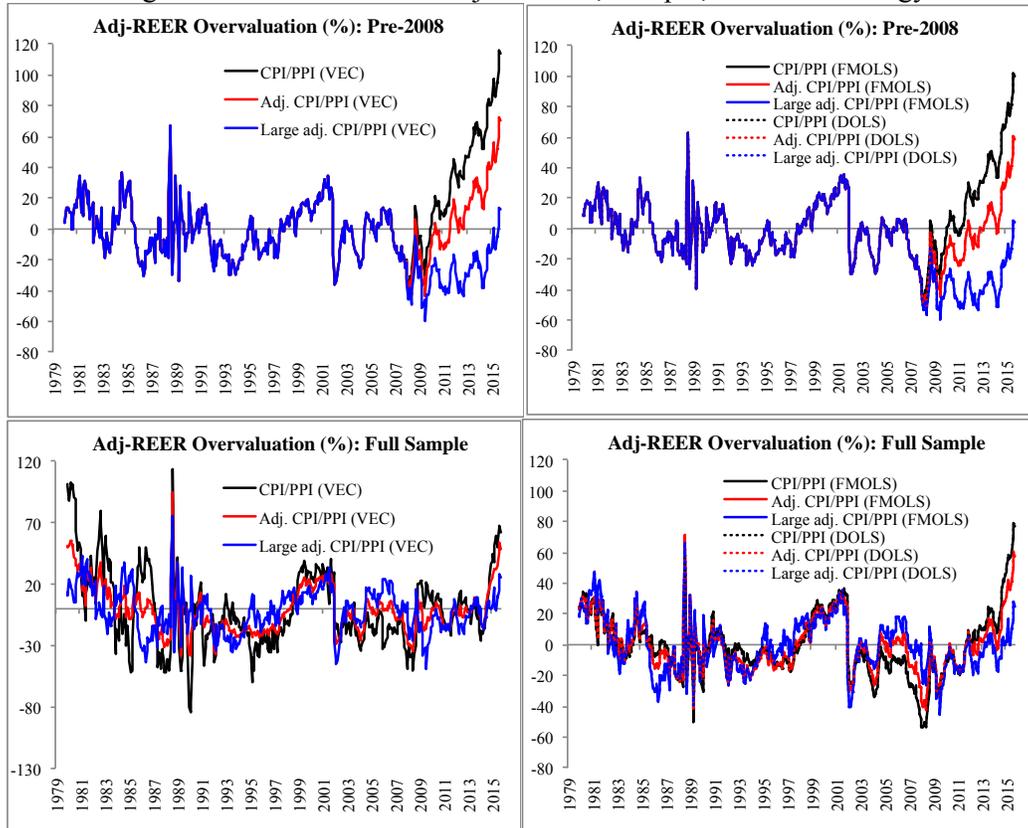
Table A.8: Robustness to Industrial Production Differential (VEC)

	Full specification				Restricted specification			
	REER		Adj - REER		REER		Adj - REER	
	Pre-2008	Full sample	Full sample		Pre-2008	Full sample	Full sample	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Terms of trade	0.325***	0.420**	0.205*	0.207*	0.499***	0.609***	0.502***	0.518***
Productivity diff. (IP)	0.808*	1.168*	0.876*		0.494	-0.667*	0.666**	
Reserves	0.036	0.953***	-0.082	-0.118				
Trade openness	-0.045	-1.693***	0.009	0.075				
Constant	-0.355	2.297	0.517	-0.332	0.205	4.900	-0.690	-1.488
Productivity diff. (Adj-IP)				1.018**				0.824**
Dummy for 1991-2001	YES	YES	YES	YES	YES	YES	YES	YES
Error correction	-0.079	-0.029	-0.062	-0.059	-0.084	-0.053	-0.072	-0.071
Half life (years)	0.7	1.9	0.9	0.9	0.7	1.1	0.8	0.8
Lags in VAR	2	2	2	2	2	2	2	2
Johansen coint. rank	2	2	2	2	1	1	1	1
Overvaluation as of Oct 2015								
No HP filter	-	-7%	11%	18%	-	-17%	20%	26%
HP filter	-	9%	11%	13%	-	-32%	13%	16%

Table A.9: Robustness to Industrial Production Differential (DOLS and FMOLS)

	REER				Adj - REER			
	Pre-2008		Full sample		Full sample		Full sample	
	DOLS	FMOLS	DOLS	FMOLS	DOLS		FMOLS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Terms of trade	0.434***	0.430***	0.338***	0.409***	0.344***	0.354***	0.284**	0.313**
Productivity diff. (IP)	0.235	0.489	-0.312	0.050	0.461		1.125**	
Reserves	0.329***	0.461***	0.424***	0.658***	0.213***	0.204***	0.310***	0.287**
Trade openness	-0.349***	-0.527**	-0.636***	-1.045***	-0.289**	-0.256**	-0.573***	-0.512***
Constant	1.293**	0.390	5.635***	4.786***	1.268	1.023	-0.063	-1.183
Dummy 1991-2001	0.532***	0.469***	0.698***	0.690***	0.547***	0.54***	0.516***	0.490***
Productivity diff. (Adj-IP)						0.464		1.281**
Dummy for 1991-2001	YES	YES	YES	YES	YES	YES	YES	YES
Jarque-Bera	56	24	100	41	90	74	56	28
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hansen instability	0.018	12.831	0.003	7.833	0.003	0.003	11.853	11.094
P-value	> 0.2	< 0.01	> 0.2	< 0.01	> 0.2	> 0.2	< 0.01	< 0.01
Overvaluation as of Oct 2015								
No HP filter	-	-	12%	17%	49%	54%	40%	49%
HP filter	-	-	11%	21%	48%	49%	46%	49%

Figure A.4: Robustness to Adj. IP, Sample, and Methodology
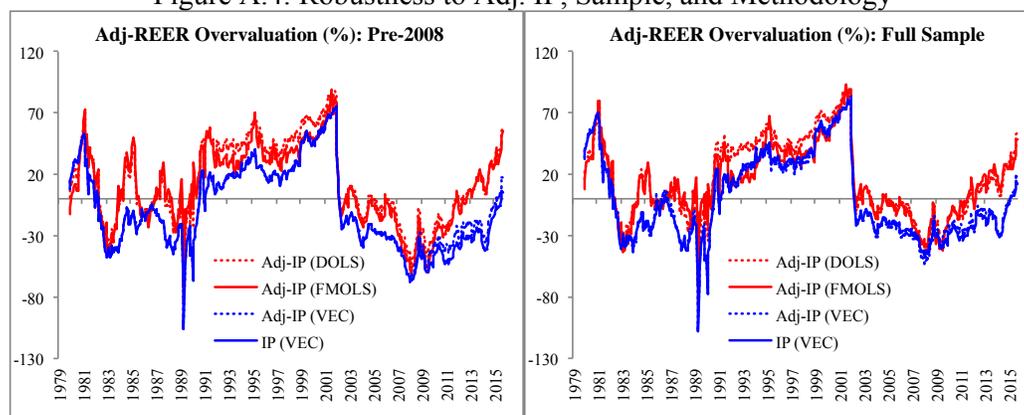
Table A.10: Robustness to Annual Data (VEC)

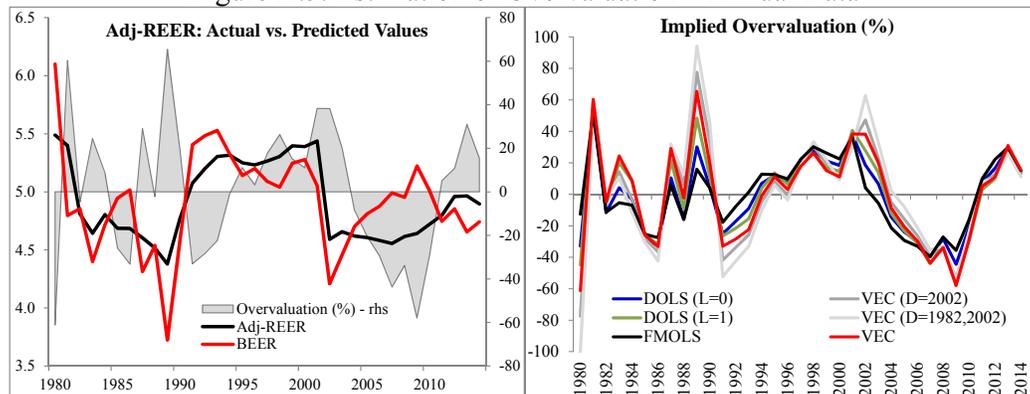| Cointegration relation	REER		Adj-REER	
	(1)	(2)	(3)	(4)
Terms of trade (tot)	0.081	0.362	1.681***	2.042***
Productivity diff (tnt_ag_xchn)	1.086***	1.154***	0.642**	0.768**
Reserves (resY)	0.809***	0.726***	0.644***	0.475***
Trade openness (tradeY)	-2.057***	-1.904***	-2.025***	-1.638***
Constant	-11.881***	-12.169***	-13.661***	-13.518***
Real interest rate differentials (usa_r)		0.018		0.042
Error correction coeff.	-0.256	-0.262	-0.121	-0.107
Half-life in years	2.344	2.286	5.363	6.110
Lags in VAR	1	1	1	1
Johansen's cointegration rank	1	1	1	1
Residual Normality Test				
Joint Skewness	8.123	9.221	18.096***	19.069***
Joint Kurtosis	43.901***	46.507***	56.859***	56.309***
Joint Jarque-Bera	52.024***	55.728***	74.955***	75.377***
Residual Autocorrelation Tests (lags 1-4)				
Portmanteau Test (null: no autocorrelation)	Don't reject	Don't reject	Don't reject	Don't reject
LM Test (null: no autocorrelation)	Don't reject	Don't reject	Don't reject	Don't reject
White Heteroskedasticity Test				
Joint Chi-squared statistic	40.932	51.259	53.089	47.437
Probability	0.088	0.155	0.117	0.023

Figure A.5: Estimation of Overvaluation – Annual Data

Table A.11: Robustness to Annual Data (DOLS and FMOLS)

	VEC	OLS	DOLS-1 (HAC)	DOLS-2 (HAC)	FMOLS
Cointegration relation					
Terms of trade (tot)	1.681***	1.001**	1.174***	1.360**	0.996***
Productivity diff (tnt_ag_xchn)	0.642**	0.729**	0.607**	0.513*	0.721*
Reserves (resY)	0.644***	0.246**	0.457***	0.591***	0.335**
Trade openness (tradeY)	-2.025***	-1.158***	-1.531***	-1.766***	-1.213***
Constant	-13.661***	-4.736**	-8.537***	-11.239***	-6.474**
Lag Specification					
Lags	1	0	-	-	-
Leads and lags	-	-	0	1	-
Cointegration Test					
Johansen's cointegration rank	1	-	-	-	-
Hansen Parameter Instability 1/	-	-	0.131	0.145	0.512
(Probability)	-	-	(> 0.2)	(> 0.2)	(> 0.2)
Single cointegration relation?	Yes	-	Yes	Yes	Yes
Residual Tests					
Jarque-Bera test for normality 2/	74.955***	2.244	1.396	0.596	0.988
Probability	*0.000*	*0.326*	*0.498*	*0.742*	*0.610*
LM test for autocorrelation					
Reject null for lags 1-4?	*No*	*Yes*	-	-	-

1/ Fails to reject the null hypothesis that series are cointegrated.
2/ Rejects the null hypothesis of residual normality only for the VEC specification.

Table A.12: Robustness to Annual Data (Alternative Indicators)

	Baseline	Alternative TOT and Productivity diff.					TNT robust.	
Adj. REER	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Reserves (resY)	0.644***	1.299***	1.428***	0.707***	1.586***	0.952***	0.631***	0.666***
Trade openness (tradeY)	-2.025***	-2.390***	-3.649***	-2.105***	-3.286***	-2.231***	-2.010***	-2.182***
Constant	-13.661***	-19.620***	-10.419***	-13.616***	-8.593***	-15.612***	-13.465***	-13.915***
Terms of trade								
tot	1.681***		0.934	1.624***	-0.607	0.899	1.699***	1.734***
psoy_cpiae		0.552*						
Productivity differential								
tnt_ag_xchn	0.642**	0.074						
tw_gdppc			-2.022*					
tnt_ag				0.424				
tnt_ag_ind					-1.944*			
tnt_ag_ind_xchn						0.464		
tnt_ag_xchn (2)							0.636**	
tnt_ag_xchn (3)								0.649*
Error correction coeff.	-0.121	-0.145	-0.081	-0.122	-0.097	-0.150	-0.121	-0.106
Half-life in years	5.4	4.4	8.2	5.3	6.8	4.3	5.4	6.2
Johansen cointegration rank	1	0	0	1	1	1	1	1

Figure A.6 Adj-REER Decomposition (Baseline) – Fundamentals vs. Overvaluation

%Δ REER Decomposition (monthly average)