# THE RANDOM FOREST PATH OF REAL EXCHANGE RATE MISALIGNMENTS : The Argentinean case*

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**Abstract**

This research develops a theoretical model that determines the influence on the dynamics of real exchange rate misalignments of the market turbulence index (or its components, the nominal exchange rate, the domestic interest rate and the international reserves), the monetary base, the international inflation, the VIX volatility index, the current and saving deposits (net of commercial banks' reserves held in the central bank) and the commercial bank money. The theoretical relationships are featured by a Random Forest model for, Argentina, the period January 1995 - November 2020. Up to now, nor a theoretical neither and empirical model has analyzed these relationships.

This paper finds evidence that top ranked variables that feature real exchange rate misalignments are their two period lagged variables and the market turbulence index, with an aggregate influence of both variables larger than the 60%. When the market turbulence index is disaggregated, the nominal exchange rate arises as the second top ranked variable featuring real exchange rate misalignments. The high power money aggregate importance does not exceed, in general, the 8%.

**JEL Codes**: C13, F31, F41.
**Keyword**: Real exchange rate, Hodrick and Prescott filter misalignment, Christiano-Fitzgerald misalignment, Random Forest, Market turbulence index, volatility VIX index.

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# 1 Introduction

Real exchange rates are misaligned when the equilibrium real exchange rate differs from its observed values, but the life of such misalignments are of short-term nature because it is a non-equilibrium position. Real exchange rate misalignments are, however, perceived to be the "causes of the loss of a competitiveness, growth slowdowns and currency crises (in cases of overvaluation), overheating and inflation in cases of undervaluation, sectoral misallocations of resources and global economic imbalances" (Rusek et al., 2012, p. 534). Ghura and Grennes (1993) add that high levels of RER overvaluation are associated with periods of macroeconomic instability. consequently, policymakers should reduce/eliminate real exchange rate misalignments, especially those associated with large overvaluation processes.

In the short-run disturbances in the money markets play an important role on the domestic prices, on the behaviour of the observed real exchange rate and, therefore, on real exchange rate misalignments. Tanner (2002, p.3) suggests that while fiscal and financial fundamentals may help predict exchange rate crisis over the medium term, and contagion may be important, monetary policies play an important role in exchange rate crises, especially at or around the time of the crisis. Measures of exchange rate market pressures thus include exchange rate depreciations and international reserves.

In this paper a theoretical model explains the short-run relationship between real exchange rate misalignments and the market turbulence index (or their components, the nominal exchange rates, the interest rates and the international reserves), the macroeconomic risk, the high power money, the international inflation, the current and saving deposits net of commercial banks' reserves held in the central bank and the commercial banks' reserves held by the banks. Up to now the role of these variables on the behaviour of real exchange rate misalignments have not been studied.

A novelty of this research is the application, for Argentina, of Random Forest regression models to the theoretical relationships for the period January 1995 - October 2020. Real exchange rate misalignments are computed as the deviation of the actual real exchange rate from its (long-run) equilibrium value, which is obtained by the Hodrick and Prescott (or the Christiano-Fitzgerald) filter. The market turbulence index is measured, in line with Amado et al. (2004), the sum of the exchange rate, international reserves and the interest rates standardized by their corresponding volatility. The macroeconomic risk is proxied by the CBOE volatility index (VIX), which measure the market's expectations of future volatility of the international markets. The international inflation is proxied by the US inflation rate. The empirical application has added lagged variables of each of the real exchange rate misalignment determinants and the real exchange rate misalignment itself.

This paper finds evidence that the dynamics of the real exchange rate misalignments are influenced mainly by their two period lagged variables[1] as well as by the market turbulence index (or the nominal exchange rate); the aggregate influence of these variables is larger than the 60%. When the market turbulence index is disaggregated, its most explicative variable of real exchange rate misalignments, after their two lagged variables, is the nominal exchange rate. The high power money aggregate importance does not exceed, in general, the 8%.

The remainder of the paper is organized as follows: Section 2 provides a theoretical model that relates real exchange rate misalignments with their determinants, the data sources as well as the stylized facts, the corresponding methodology and the empirical results. Finally, section 3 concludes and provides insights for future research.

[1]Based on the Hodrick and Prescott based real exchange rate misalignment, Zarzosa Valdivia (2016) finds evidence of autoregressive of first order coefficients larger than one, although the sum of the aggregate autoregressive coefficients is lower than one.

# 2 Content

## 2.1 A theoretical view on Real Exchange Rate Misalignments:

### 2.1.1 Real Exchange Rate: Concept and Misalignments

The purchasing power parity (PPP) real exchange rate is a relative price that measures the value of domestic goods in terms of foreign goods. It is calculated as the quotient between the foreign and domestic goods, adjusted by the nominal real exchange rate. The multilateral or effective real exchange rate ($RER$) is a PPP real exchange rate that resumes all foreign price index in an aggregate price index weighted by the trade shares of the corresponding country with its main trade partners. Formally:

$$RER = \prod_{i=1}^{n} \frac{(E_i P_i^*)^{w_i}}{P} \tag{1}$$

where:
$P$ and $P_i^*$ refer to the consumer price index of the domestic country and of the country $i$,
$E_i$ indicate the nominal exchange rate of the domestic country with respect to the country $i$, respectively.
$w_i$ indicate the trade share of country $i$ with the domestic country.

The PPP real exchange rate is also known as the external real exchange rate because it compares the relative price of a basket of goods produced (or consumed) in different countries (Hinkle and Nsengiyumva, 1999). If the inflation in the domestic country is larger than elsewhere, ceteris paribus, "the real price of the domestic currency will be falling and the foreign price competitiveness improving against the home country" (Pentecost, 1993, p.5).

Real exchange rate misalignments measure deviations of the observed real exchange rate from its long-run value; positive and negative values represent periods of real *appreciations* and *depreciations*, respectively. Formally:

$$RER_{mis} = \frac{RER_x - RER}{RER_x} \tag{2}$$

where:
$RER$ and $RER_x$ are the observed and equilibrium real exchange rate, respectively.
$RER_{mis}$ the real exchange rate misalignment.

When the equilibrium and observed real exchange rate do not coincide, there are real exchange rate misalignments, with a correction that could occur through: a) nominal exchange rate depreciation or deflation under a flexible exchange rate regime and b) international reserves or interest rates movements under a fixed exchange rate regime, e.g. interest rates increase when central banks want to avoid drains of their international reserves.

Following Tanner (2002, p.3) monetary policies play an important role in exchange rate crises and that exchange rate market pressure measures include movements of the nominal exchange rates and the international reserves. When market turbulences are motivated by imbalances in the underlying fundamentals, Eichengreen et al. (1994, p.1) define speculative attack or crises as large movements in exchange rates, interest rates and international reserves.

In line with Amado et al. (2004, p.6), the market turbulence index is defined as the sum of the exchange rate, international reserves and the interest rates weighted by the inverse of their volatility. The index stems from the idea that market pressure increases when exchange rate devaluates (rises), interest rates increase and international reserves diminish. Under a floating exchange rate regime, we expect abrupt increases in the exchange rate as a crisis develops. Under a fixed exchange rate, prior to the devaluation, interest rates increase and international reserves diminish.

Taking into account the short-run nature of real exchange rate misalignment and the equilibrium of the money markets, Zarzosa Valdivia and Micheli (2020) develops a theoretical model in which real exchange rate misalignments depend on the GDP gap, interest rate, international inflation, nominal exchange rate devaluation/depreciation, domestic inflation, the macroeconomic risk and the $M_0$ monetary aggregate. Formally:

$$RER_{mis} = -\gamma_1 y + \gamma_2 \Delta i - \gamma_3 \pi^* - \gamma_4 \epsilon + \gamma_5 \Delta \sigma_\pi + \gamma_6 \frac{\Delta M_0}{M_0} \quad (3)$$

where:

$\gamma_i > 0$, except $\gamma_4 >< 0$

$\Delta$ is the change operator,

$y$ refers to the percentage change in the level of transactions,

$i$, $\pi$, $\epsilon$ are, respectively, the domestic nominal rate of interest, the domestic inflation and the rate of depreciation of the nominal exchange rate,

$M_0$ is the high power money,

$\sigma_\pi$ reflects the macroeconomic volatility or inestability.

When the interest rate increases, the demand for money holding diminishes. The consequent excess of money supply pressures domestic prices upwards, the observed real exchange rate downwards and consequently, the real exchange rate misalignment upwards.

Nominal exchange rate depreciation/devaluations reduce, at first, the real exchange rate misalignments. The reduction of demand for money holding, however, creates an excess supply of money, which in turn pressure inflation upwards. As a result, real exchange rate misalignments increase and the total effect of a depreciation/devaluation on real exchange rate misalignments are ambiguous.

When the government issues high power money, the supply of money increases and pressures inflation upwards. As a result, the observed real exchange rate diminishes and the real exchange rate misalignment increases.

Next, the relationships presented by equation 3 are estimated. The equilibrium real exchange rate is assumed to be exogenous and set by the smoothing methods proposed by Hodrick and Prescott (penalty $\lambda$ parameter equal to 14400 ) and the Christiano-Fitzgerald filters. The latter is best suited for series with unit roots. The international inflation is proxied by the US inflation. The macroeconomic risk is proxied by the international reserves and the VIX index. Additionally, the current and saving account deposits (net of the commercial banks' reserves on the central bank) and the commercial banks' reserves held by the banks have been added to 3.

## 2.2 Data sources and Stylized Facts

The relevant variables of the analysis are the multilateral real exchange rate ($RER$), the nominal exchange rate ($E$), the deposit from 30 to 50 days interest rate ($i_d$), the international reserves ($R$), the high power money ($M0$), the bank deposits (the sum of the checkable and saving deposits, $D$), the commercial bank money ($R_b$), the US consumer price index ($/pi*$), economic activity indicator ($EMAE$) and the volatility VIX index. The empirical application focuses on monthly data for the period January 1995 - October 2020.

The nominal exchange rates, the monetary base, and the bank deposits are obtained from the Argentinean Central Bank (BCRA). The multilateral real exchange rates up to 1997 has been obtained from the Argentinean Time Series API and thereafter from the Argentinean Central Bank.[2]

Seasonal adjusted data on economic activity is measured by the Monthly Economic Activity Estimator (EMAE), provided by the Argentinean Time Series API and the National Institute of Statistics and Census. The EMAE series has been extrapolated from 1993 and 2004 base year available data.

Deposit from 30 to 50 days interest rates, expressed in annual terms, are obtained up to 2009 from the Argentinean Central Bank, but thereafter from the International Financial Statistics (IFS) of the International Monetary Fund (IMF). International reserves are also provided by the IMF.

The CBO (Chicago Board Options Exchange) volatility index ($VIX$) and the US consumer price index are obtained from the Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis.

### 2.2.1 Stylized Facts

Figure 1 displays the evolution of the relevant variables for the period February 1995 to October 2020. Except for the real exchange rate misalignments, all variables are in percentage changes. The first chart, RERmis, present both real exchange rate misalignments, the dotted lines refer to the Christiano-Fitzgerald measure. The Hodrick and Prescott real exchange misalignment was negative from October 1996 to January 1999, with a negative peak of 9.42% in December 1998. It, however, increased up to the 33% before the collapse of the Argentinean fixed exchange rate regime in December 2001. By the end of June 2002, the observed real exchange rate exceeded its equilibrium level by 63% with a nominal exchange rate of $3.8 ($2.8 higher than its convertibility value of $1). After May 2003, they do not shown a clear trend; it increased temporarily during the international financial crisis, but was negative during December 2013 - December 2014 and June 2018 - June 2019. The evolution of the Christiano-Fitzgerald real exchange rate misalignment is similar to the Hodrick and Prescott measure, but its negative peaks lie in November 2001 and June 2002, with the 11% and 72.5% levels, respectively.

The nominal exchange rate was fixed to $1 before 2002. Thereafter, it increased up to June 2002, but decreased smoothly up to July 2005, when the overshooting of the huge 2002 devaluation disappeared. It exhibits a positive trend since November 2009. Its fluctuations before December 2015 were less pronounced than the period thereafter, in which the largest peaks lay between the 4% and 6% per month.

Figure 1 shows the deposit interest rate variations. Between June 1995 - May 2001 and June 2003 - May 2008, it was below the 10% . It fluctuated between -17 and 66 basis points during August 1995 and November 2000, while -650 a 722 basis points in the period January 2001 - April 2003. After April 2018, its fluctuations become more pronounced.

The variation of the international reserves (R chart) has a cyclical behaviour. They fluctuated around -2% to 2% before the year 2000 and between -4% to 4% after July 2015. Their fluctuations before October 2002 (after June 2015) were more pronounced than their fluctuations during November 2002 and May 2015. The Market turbulence index, MTI chart, has fluctuated between the 14 and -6 before the collapse of the convertibility regime, while between -3.5% and 9.7% between December 2018 and August 2019.

[2]While measuring the multilateral real exchange rate the Argentinean Central Bank has taking into account that Argentinean index prices were manipulated between 2007 and 2015; see ATE-INDEC (2014) and Berumen and Beker (2011)

| Variable | None | Constant | Trend & Constant | Variable | None | Constant | Trend & Constant |
|---|---|---|---|---|---|---|---|
| **RER_mis_HP** | -5.81 | -5.81 | -5.80 | **EMAE** | -13.02 | -13.09 | -13.12 |
| | *** | *** | *** | | *** | *** | *** |
| **RER_mis_CF** | -5.04 | -5.06 | -5.06 | **p_us** | -8.70 | -11.88 | -12.02 |
| | *** | *** | *** | | *** | *** | *** |
| **E** | -7.57 | -8.21 | -8.58 | **VIX** | -14.47 | -14.45 | -14.43 |
| | *** | *** | *** | | *** | *** | *** |
| **i_D** | -11.06 | -11.04 | -11.04 | **M0** | -10.22 | -12.40 | -12.72 |
| | *** | *** | *** | | *** | *** | *** |
| **R** | -13.72 | -13.78 | -13.83 | **B_b** | -17.14 | -19.12 | -19.86 |
| | *** | *** | *** | | *** | *** | *** |
| **MTI** | -8.79 | -8.93 | -9.17 | | | | |
| | *** | *** | *** | | | | |

Table 1: Observed Dickey-Fuller statistic of the Unit Root test

Trend and Constant, Constant and None refer to the unit root test with trend and constant, a constant and with nor constant neither trend. All the variables, except, the real exchange rate misalignments, deposit interest rates and the VIX index, refer to the percentage variations of the corresponding variable

The economic activity indicator exhibits also a cyclical behaviour. It increased between May 1995 and June 1998, diminished up to September 2002 and increased until July 2008. It diminished temporally due to the international financial crisis, but increased between July 2009 and January 2011. It has remained relatively constant up thereafter. It diminished about 11% (April 2020) after the start of the Covid 19 crisis.

The proxy variable of international inflation, the US inflation rate, has increased, in general along the analysed period, except during the international financial crisis (from August to December 2008).

The VIX volatility index increased from 100 to 160 between January 1995 and December 1998, were it remained up to February 2003. Thereafter, it decreased below 100 to increase again up to December 2011 (reaching the 200 level). It decreased again until July 2014, rose again up to 200 in September 2015, but diminished below 100 in January 2018. The VIX index reached a peak during the financial crisis (510, November 2008) and due to the start of the Covid $_19$ crisis (March 2020). The VIX index has fluctuated around the -25% and 25% with peaks of 70% in October 2008 and 107% in March 2020.

The monetary base, commercial bank money and the bank deposits exhibit similar evolution throughout the period. They increased slightly up to 1997, remained constant up to 2003, but shows a positive trend thereafter. Variations of the monetary base, the bank deposits and the commercial bank money have no clear trend for the period before the end of 2001. The monetary base growth, however, has been, in general, positive, with variation has exceeded the 10% monthly level after November 2019.

### 2.2.2 Unit root behaviour

Table 1 displays the observed Augmented Dickey-Fuller (ADF) values of the corresponding unit root test applied to each relevant variable; the null of the ADF test states that there is an unit root. It tells us that none of the corresponding variables exhibit unit root behaviour, even at the 10% level.

Due to the definition and measurement of the misalignments, they are stationary and their mean is zero. Regarding such stationarity, Zarzosa Valdivia (2016, p.6) suggests that ”real exchange

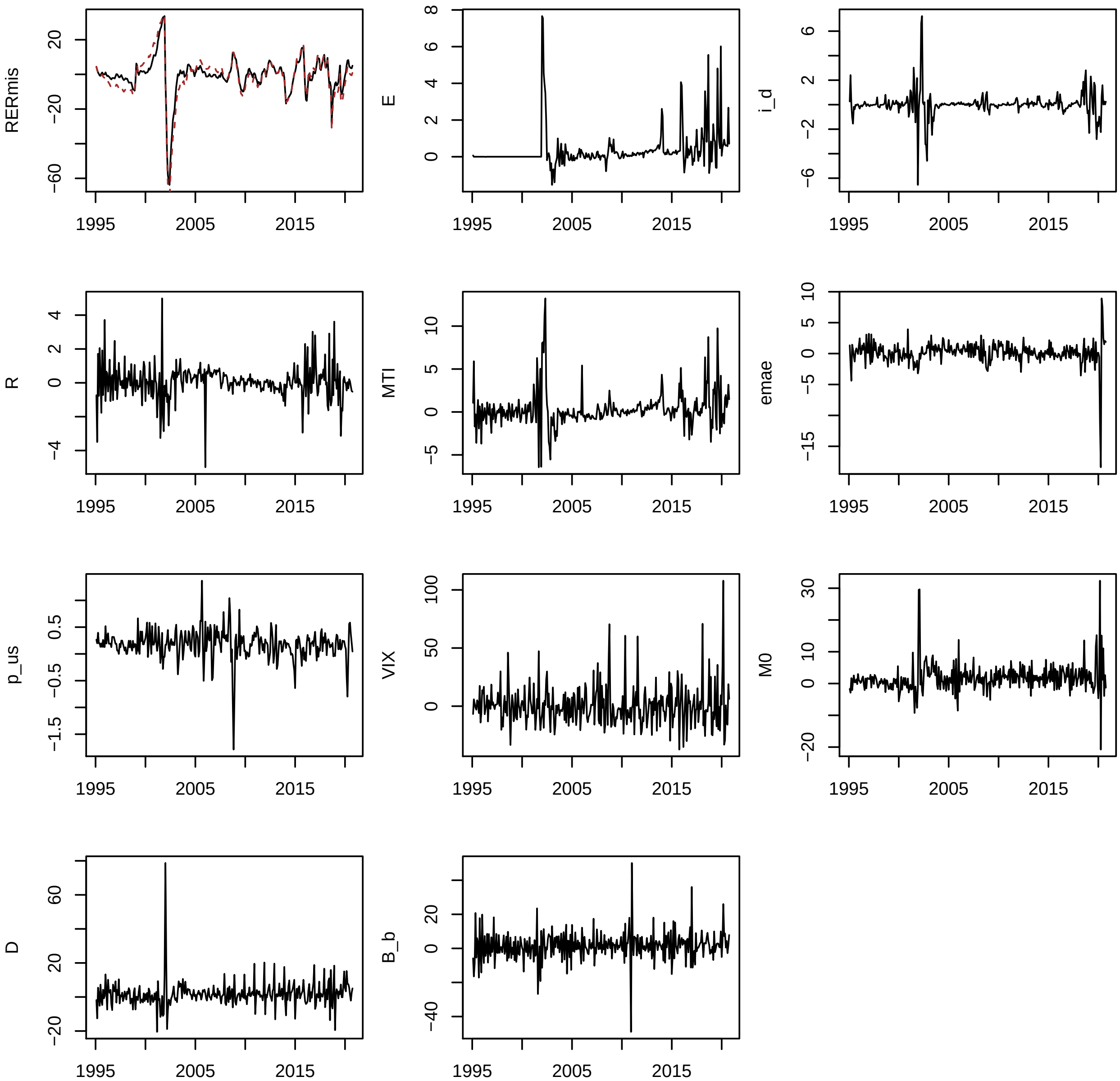


Figure 1: Relevant variables

rate misalignments do no exhibit a random walk pattern, but their evolution in a period might be influenced by their change in previous periods”. He finds for the Argentinean Hodrick and Prescott based real exchange rate misalignment a elasticity of 0.94 (at the 1% significance level) to its lagged value and an autoregressive process behaviour of order two, c) a high inertia with an overshooting behaviour.

In line with Robinson (1979, p. ix), the characteristics of the dynamic analysis, in the sense intended here, is that ”it cannot explain how an economy behaves, in given conditions, without reference to past history... past history is thus put into initial conditions, so that the analysis is static in itself, and yet part of a dynamic”.

| Method | Variables | mis_hp | mis_cf |
|---|---|---|---|
| LSO | E | 4 | 3 |
| | i | 5 | 5 |
| | R | 2 | 2 |
| | MTI | 3 | 3 |
| | emae | 2 | 2 |
| | p_us | 2 | 2 |
| | VIX | 2 | 2 |
| | M0 | 2 | 2 |
| | D | 2 | 2 |
| | B_b | 2 | 2 |
| AR | mis_hp | 2 | |
| | mis_cf | | 2 |

Table 2: Optimal lag selection order (LSO) and Auto-regressive order (AR)

## 2.3 Methodology

### 2.3.1 Dynamics and Lag variables

Real exchange rate misalignments are of short-term nature since the observed real exchange rate would move in time towards its equilibrium level. Real exchange rate misalignments might depend thus on the lags of its determinants because its lags are related to the dynamics of the adjustment process towards the equilibrium point. Based on the Bayesian information criteria, the lag length of each explanatory variable of the real exchange rate misalignments is determined by the optimal lag selection order method. Table 2 displays the lags that arise from applying, separately, the lag selection order method between the corresponding real exchange rate misalignment and each of its determinants. The lags related to the intrinsic dynamics of real exchange rate misalignments are the result of selecting the best, according to the Bayesian Criteria, auto-regressive moving average with exogenous variables; Table 2 shows that the autoregressive (AR) order of the real exchange rate misalignment is two.

### 2.3.2 Random Forest models

Random Forests (RFs) models, which were first developed by Breiman (2001), consist of an ensemble learning method, commonly used for classification and regression problems. It is a collection of decision trees that grow in randomly selected sub places of the feature space (Dudek, 2015). Random forest focuses on a training sample set, constructed by the Bagging Algorithm, and an out-of-bag sample is used to build an independent measure of the accuracy of the results. Following Luo et al. (2010, p.561), ”when building a base classifier, inner nodes are split with a random candidate attribute set. The final classification rule (or regression function) is the simple majority voting method (or the simple average method)”. As a result, each tree is constructed using a bootstrap sample coming from the learning sample and a random subset of features considered at each split node. The final decision is made by obtaining the ensemble by averaging the output. As Dudek (2015) shows, the bagging procedure improves the stability and accuracy of the model, reduces the variance (due to the fact that the correlation between trees is reduced) and helps to avoid overfitting.

The ’out-of-Bag’ (OOB) error refers to the error of the training points which are not contained in the bootstrap training set (around one-third of the points are left out in each bootstrap training set). This is an advantage of the random forest algorithm since OOB error is identical to that obtained by N-fold-cross-validation, but it is trained in one sequence, instead of many.

#### 2.3.3 Model scope and features importance

In this research, adding lagged variables for the real exchange rate misalignments, Equation (3) is estimated assuming the proxies for the macroeconomic volatility is the volatility VIX index and international reserves variations. To assess the role of the different features on each real exchange rate misalignment measure, the following RF regression models are developed:

- The MTI model: RER misalignments are regressed against the MTI index, US inflation and the percentage change of the a) volatility VIX index, b) economic activity indicator ($emae$), c) high-power money ($M_O$), d) bank deposits ($D$) and e) commercial bank money ($R_b$). In addition and in line with Table 2 lagged variables have been included for these explanatory as well as for the corresponding real exchange rate misalignment.
- The Full model:[3] A similar model to the previous one is re-estimate, but in this case the percentage change of the nominal exchange rate($E$) and of the international reserves ($R$) and the change of the deposit interest rate ($i$) are included instead of the MTI index.

As Luo et al. (2010) states, a feature is important if randomly exchanging its value reduces significantly the prediction accuracy. The variable importance measure of Breiman's original random forest method, based on CART classification trees, was selected over the impurity one since they "are a sensible means for variable selection in many of these applications, but are not reliable in situations where potential predictor variables vary in their scale of measurement or their number of categories" (Strobl et al., 2007).

The steps of the computation method can be summarized as follows:

1. After computing OOB Accuracy, the value of feature is randomly changed, and then is computed the OOB Accuracy again (named noised OOB Accuracy).
2. The difference between the OOB Accuracy and Noised OOB Accuracy is computed, and this value is measured as the importance of the feature.
3. Finally, this distance is scaled by the standard deviation of the variable.

Taking into account that some variables might have little effect on real exchange rate misalignments and taking a feature selection model is necessary to improve the model's effectiveness. As a result, the workflow order of analysis is as follows:

1. The data set is split, 70% (training sample) - 30% (testing sample).
2. The corresponding model is trained
3. A grid search is performed over a 2000 trees RF algorithm in order to get the values that minimize the OOB score. The values that are searched are:
    - MTRY: number of variables used to build each tree

[3] A shortcoming of using a market turbulence index rather than its components is that the influence of such components on the real exchange rate misalignments might not coincide

- Node Size: minimum size of terminal nodes (leafs of trees)
- Sample Fraction: fractions of observations to sample in the calculation of OOB Score.

4. Then, the best model is retrained in order to get, for the training and test set of the random forest models, the following metrics:

   (a) RMSE, root mean square error, which computes the root mean squared error between two numeric vectors (the estimated train/test and their corresponding observed series),

   (b) MAE, mean absolute error, which computes the average absolute difference between the corresponding series,

   (c) MAPE, mean absolute percentage error , which computes the average absolute percent difference between two numeric vectors; the percentage is measures w.r.t. the observed series,

   (d) MASE, mean absolute scale error, which computes the mean absolute scaled error between two numeric vectors; scaled in terms of the one-step naive forecast series.

5. In addition, the 'importance of each variable' of the best model is assessed.

6. A model checking is evaluated:

   - The top half of the dependent variables are selected to conform a new, shorter database.
   - The previous steps are re-applied, in order to assess if there were any changes in the metrics selected. If the feature selection was effective, the metrics decrease while the order of importance does not change significantly.

7. The time series models: The previous steps are re-applied, but in this case the data set is split in training sample (July 1995 - March 2020) and test sample (April 2020 to October 2020).

## 2.4 Empirical Model

### 2.4.1 Variables Importance

Figures 2, 3, 4 and 5 show the top 15 variables, in order of importance, of the estimated HP (CF) based real exchange rate misalignment measure for the MTI and Full models.

In the MTI models the most important variables are the real exchange rate misalignment lags and the market turbulence index. The aggregate importance of the former takes about the 50% (30%) of the importance for the HP (CF) based real exchange rate misalignment measure, while the importance of the market turbulence index lies around the 30% (38%) for the HP (CF) real exchange rate misalignment measure. Other important variables in the MTI model for the HP based real exchange rate misalignment measure are the monetary base, with an aggregate importance around the (8%), the deposits of the banks, with an aggregate importance around the (6%), the economic activity and the the US inflation with an importance below the 5%.

Regarding the full model, the lagged variables are important explanatory variables of the behaviour of both real exchange rate measures, with more than 35% (45%) of aggregated importance in the HP (CF) based real exchange rate misalignment model. These lags reflect the learning process involved in the correction process due to an exogenous shock. The most ranked explanatory variables is the nominal exchange rate with a 27% aggregate importance for both real exchange rate misalignment measures. In the models based on the HP real exchange rate misalignment the aggregate importance of the high power money, the international reserves and the deposit interest rates lies around the 5%. In the models based on the CF real exchange rate misalignment, the aggregate importance of the high power money, the international reserves,the banks deposits in the central bank are lower than the 5%, but the aggregate importance of the deposit interest rate lies around the 10%.

The variables importance for the time series models are displayed by Figures 6, 7, 8 and 9. According to the MTI models, the most ranked variables are the real exchange rate misalignments lags and the market turbulence index, with an aggregate importance of 50% (25%) and 30% (47%) for the HP (CF) real exchange rate misalignment measure. In addition, the aggregate importance of the monetary base, the bank deposits, the US inflation and the economic activity lie around the 7%, 5%, 2% and 1% (12.5%, 2.5%, 12.5% and 2%) for the HP (CF) real exchange rate misalignment measure.

The time series random forest full models show also that the influence of each of the MTI components on the real exchange rate misalignments differs; the most explanatory variables are the nominal exchange rate and the deposit interest rate with an aggregate importance of 30% (24%) and 10% (14%), respectively, for the HP (CF) real exchange rate misalignment measure. The aggregate influence of the remaining variables is not larger than 4%, with the monetary base, the international reserves and the bank deposits belonging to the top 15 importance variables.

### 2.4.2 Metrics

Table 3 displays the metrics related to the applied Random Forest models, for the train and test samples of the different models. As expected and for the standard models (samples 70%-30%), the full model metrics of both samples are lower than the MTI model metrics for any real exchange rate misalignment measures, except for the the mean absolute percentage error of the test sample of the full model for the HP real exchange rate based misalignment.

In the time series models, as expected, the full model metrics of the train samples are lower than the MTI models metrics. The full model metrics of the test samples for any real exchange rate misalignment measure is larger than the MTI model metrics, except for the mean average percentage error of the HP real exchange rate misalignment measure of the full model.

## 3 Conclusions and Further Research

This research develops a short-run theoretical model relates the real exchange rate misalignments with the market turbulence index (or the nominal exchange rate, the deposit interest rate and the international reserves), the international inflation, the economic activity, the volatility VIX index, the high power money, the bank deposits and the commercial bank money. For Argentina y for the period February 1995 - November 2020, this paper also applies different random forest models to evaluate the importance of the determinants of the real exchange rate misalignments, which is a novelty in the corresponding literature.

Measuring real exchange rate misalignments as deviations from the Hodrick and Prescott and Christiano-Fitzgerald long-run values. There is evidence that the dynamics of the real exchange rate misalignments are influenced mainly by their lagged variables and the Market turbulence index (or the nominal exchange rate); the aggregate influence of these variables is larger than the 60%. The aggregate importance of the high power money does not exceed the 8% in all models.

This research can be extended in various ways. First, in line with Zarzosa Valdivia (2016), ARMAX models can be applied to evaluate the dynamics of real exchange rate misalignments

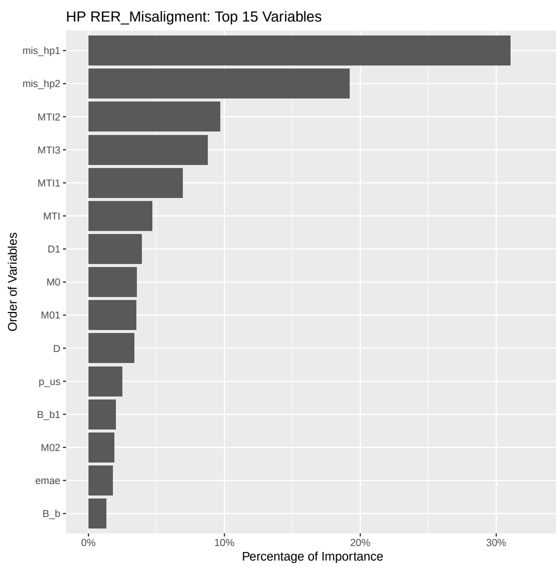


Figure 2: HP-MTI model

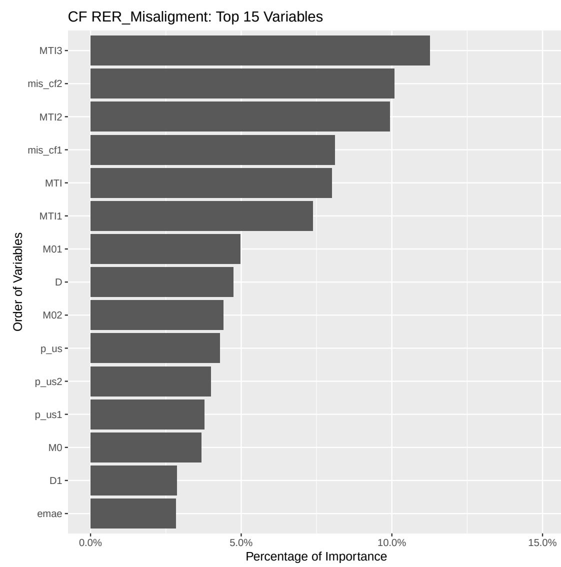


Figure 3: CF-MTI model

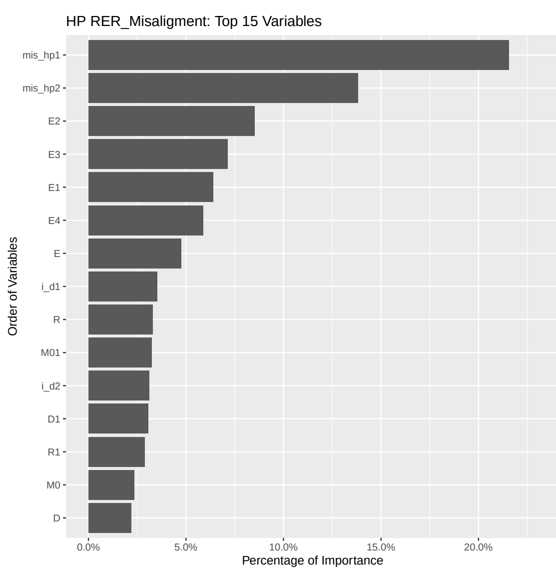


Figure 4: HP-Full model

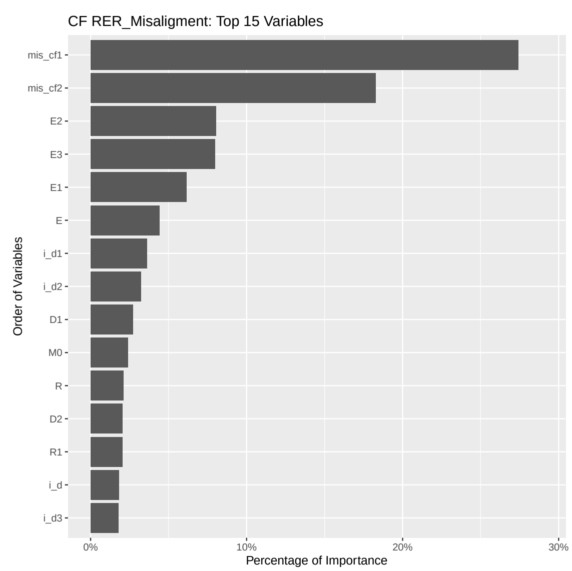


Figure 5: CF-Full model

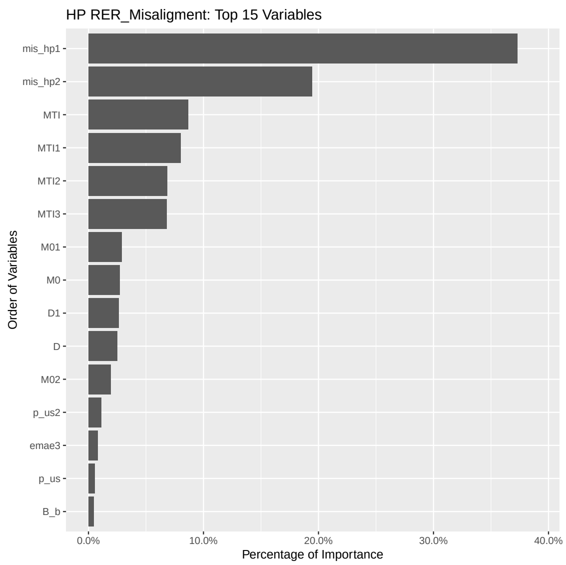


Figure 6: HP-MTI ts-model

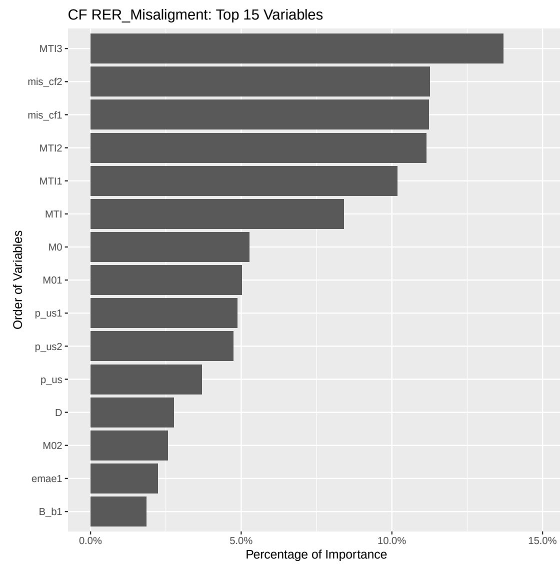


Figure 7: CF-MTI ts-model

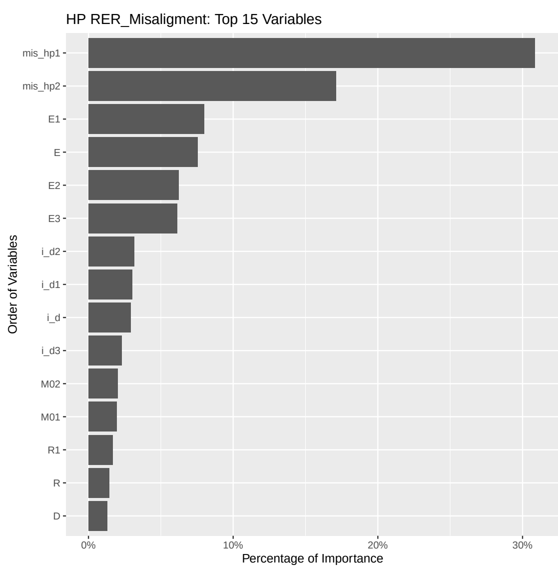


Figure 8: HP-Full ts-model

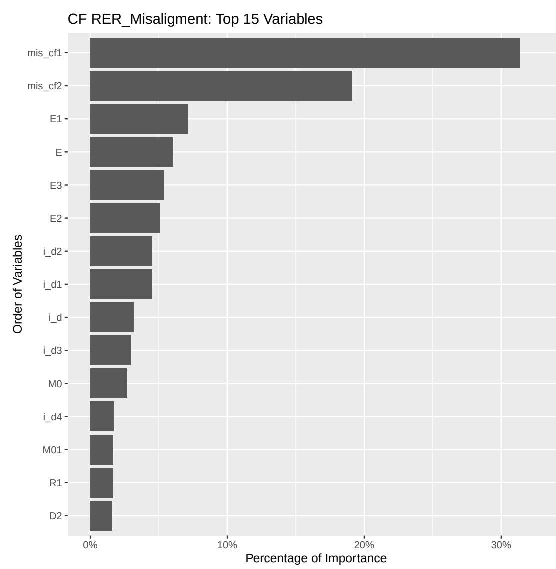


Figure 9: CF-Full ts-model

| Filters | CF | | | | HP | | | |
|---|---|---|---|---|---|---|---|---|
| Models | | Full Model | | MTI model | | Full Model | | MTI model | |

| Filters | | CF | | | | HP | | | |
|---|---|---|---|---|---|---|---|---|---|
| Models | | Full Model | | MTI model | | Full Model | | MTI model | |
| Sample | Metrics | Test | Train | Test | Train | Test | Train | Test | Train |
| 70%-30 % | mae | 4.385 | 1.384 | 8.733 | 3.412 | 3.805 | 1.677 | 4.157 | 1.845 |
| | mape | 2.314 | 0.618 | 2.362 | 0.969 | 1.476 | 0.897 | 1.076 | 1.268 |
| | mase | 1.423 | 0.691 | 2.833 | 1.715 | 1.253 | 0.866 | 1.369 | 0.959 |
| | rmse | 5.825 | 2.479 | 11.312 | 5.093 | 4.936 | 3.219 | 5.928 | 3.596 |
| Time series | mae | 2.641 | 1.446 | 1.189 | 3.459 | 2.360 | 1.339 | 2.517 | 1.402 |
| | mape | 4.484 | 0.600 | 1.553 | 0.776 | 0.475 | 0.686 | 0.709 | 0.771 |
| | mase | 2.347 | 0.617 | 0.585 | 1.487 | 2.188 | 0.587 | 1.305 | 0.618 |
| | rmse | 3.049 | 2.562 | 1.435 | 5.130 | 2.978 | 2.415 | 2.887 | 2.451 |

Table 3: Metrics of the corresponding Random Forest models

CF and refer to the HP refer to the Christiano and Fitzgerald and the Hodrick and Prescott filters used to calculate the misalignments of the real exchange rates. RMSE and MAE are the root mean square error and the absolute mean error, respectively. MTI (Full) refers to the models that include the MTI index (MTI components) and its (their) lagged variables

and the role of exogenous variables such as the market turbulence index or its components, the volatility VIX index and the economic activity. These ARMAX models can provide insights about the impact of the autoregressive or exogenous series on real exchange rate misalignments. Second, random forest models could be used to forecast real exchange rate misalingnments. Finally, the performance of the ARMAX and Random Forest models could be compared.

Economic policies should be aware of the variables that affect the real exchange rate misalignments in order to correct them. It also has to take into account that volatility of the domestic and foreign markets, reflected by the MTI and VIX indexes, play a role in the behaviour of real exchange rate misalignments.

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