



# **EXPORTS SINCE THE INTERNATIONAL FINANCIAL CRISIS**

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# Exports since the International Financial Crisis<sup>1</sup>

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## Abstract

The aim of this paper is to analyze the performance of several models for forecasting exports. We collected data on Portugal's real exports of goods and on the variables suggested by models based on the assumption of perfect competition and of monopolistic competition. We estimated Vector Autoregressive (VAR) models with those variables and compared the performance of the forecasts produced by those models with the forecasts obtained from simpler, univariate models, namely ARIMA models and Holt's linear trend model. We consider four alternative frameworks in which the forecasts might be produced. These scenarios correspond to "static forecasts", "recursive forecasts", "dynamic forecasts" and "dynamic forecasts with known exogenous variables". We also consider the computation of recursive forecasts including dummies related to the international financial crisis. The best model (according to the root mean squared error of the forecasts in the period since the start of the international financial crisis) depends on the scenario considered for the computation of the forecasts. The theory-based models do not produce forecasts that are clearly better than the forecasts produced by the simpler univariate models. In addition, the impact of the international financial crisis appears to be better represented by a temporary shock than by a permanent shock (with a constant effect). The results cast doubts on the relevance of traditional measures of competitiveness for the evolution of exports. As a consequence of the above, it is not clear that discussions of competitiveness that put the emphasis on costs, namely on wages, or on the exchange rate provide useful guides to policy.

**Keywords:** Competitiveness, exchange rate, exports, forecasting, productivity, wages.

**JEL classification:** D24, F11, F14, F17, F31.

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## 1. Introduction

The trade balance is often a matter of economic and political controversy, be it because of the possible consequences for domestic employment (see, e.g., Bação et al., 2015) or because of the belief that the imbalance is caused by foreign manipulation of the exchange rate (see, e.g., Bação et al., 2017). In Bação et al. (2018) we derived the implications of two models of exports, one starting from the assumption of perfect competition, the other starting from the assumption of monopolistic competition. The models predict that different variables will be relevant for assessing competitiveness. There was a role for production costs and for productivity in both models, and additional roles for foreign demand and the exchange rate (alongside foreign prices) in the monopolistic competition model. We then analyzed the empirical performance of those models using data for Portugal. The statistical tests yielded results that were not very favourable to either of the models. Overall, the results raised questions regarding the importance of wages and of the exchange for export behaviour.

In this paper we continue the analysis started in Bação et al. (2018). We now turn our attention to the forecasting performance of empirical models based on the perfect competition and monopolistic competition models. We compare the forecasts produced by those models to the forecasts produced by benchmark univariate models: ARIMA models and Holt's linear trend model. The forecasts are computed for the period 2008-2017. This period includes the final part of the Great Recession in the United States of America that emerged after the beginning of the international financial crisis – see, e.g. Christiano et al. (2015), Gertler and Gilchrist (2018) and Kehoe et al. (2018). The Great Recession was accompanied by a “great trade collapse” – see, e.g., Bems et al. (2013) and O'Rourke (2018). According to the data reported in Bems et al. (2013), between the first quarter of 2008 and the first quarter of 2009, the decline in real world trade was around 15%, which corresponded to about four times the decline in real world gross domestic product (GDP) during the same period. Although the dating of the Great Recession goes from late-2007 to mid-2019, its impact in Portugal was felt essentially during 2009. The international financial crisis was succeeded by the eurozone's sovereign debt crisis, which started at the end of 2009 in Greece and led to the implementation of a financial assistance programme in Portugal in 2011-2014. Portugal's recovery started in 2013. The 2009-2017 period is therefore a challenging period for forecasting models.

The paper is organized as follows. The next section presents a brief review of the models discussed in Bação et al. (2018). In section 3 we present the data collected for the

empirical analysis. We also discuss its adequacy to represent the variables included in the theoretical models. In section 4 we present the forecasting models and the frameworks employed in the computation and evaluation of the forecasts. In section 5 we present the results, i.e., we report the accuracy measures of the forecasts produced by the forecasting models under the alternative scenarios. We also discuss what the performance of the models implies for the theoretical models and for the analysis of the impact of the international financial crisis. Concluding remarks are offered in section 6.

## 2. Standard models of the behaviour of exporters

In Bação et al. (2018), we discussed the behaviour of an exporting firm under perfect competition and under monopolistic competition. We now summarize the key points of that presentation.

In the perfect competition model the main assumption is that the (international) price of the exported good is given. (We always assume that the markets for the production inputs are competitive, i.e., the firm takes as given the prices of the production inputs.) The firm makes seeks to maximize profits:

$$\Pi = PY - WL - RK - QZ \quad (1)$$

In the equation above,  $\Pi$  denotes profits,  $P$  is the price of the exported good (in units of the national currency),  $Y$  is the quantity produced (and exported – inventories are ignored),  $W$  is the cost (“wage”) of a unit of labor,  $L$  is the quantity of labor employed by the firm,  $R$  is the cost of a unit of capital (the “rental cost of capital”),  $K$  is the quantity of capital used in production,  $Q$  is the price of the intermediate goods used in the production of the exported good,  $Z$  is the quantity of those intermediate goods consumed by the firm.

The production function takes the usual Cobb-Douglas form:

$$Y = AK^\alpha L^\beta Z^\gamma \quad (2)$$

In the equation above,  $A$  denotes the level of technology. Bação et al. (2018) assume that, in the aggregate, returns to scale are decreasing:  $\alpha + \beta + \gamma < 1$ . The solution to the firm’s problem is given by:

$$Y = A^{\frac{1}{1-\alpha-\beta-\gamma}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha-\beta-\gamma}} \left(\frac{\beta}{w}\right)^{\frac{\beta}{1-\alpha-\beta-\gamma}} \left(\frac{\gamma}{q}\right)^{\frac{\gamma}{1-\alpha-\beta-\gamma}} \quad (3)$$

In the equation above,  $r$ ,  $w$  and  $q$  represent the “real” prices of the production inputs, obtained by dividing the nominal prices ( $W$ ,  $R$  and  $Q$ ) by the price of the output good ( $P$ ). Equation 3 tells us that exports are increasing in productivity and decreasing in the real prices of inputs. This perfect competition model is an example of an “export supply model” (see Bayar, 2018). The assumption of perfect competition implies that the firm can sell all its output at the current market price, which means that demand does not pose a constraint on exports. The plausibility of this is open to discussion. In addition, equation 3 also implies that any trend in exports must be a consequence of a trend in either productivity or in real input prices. As discussed in Bação et al. (2018), this implication is problematic when one considers, for example, the impact of the international financial crisis of 2007-2009.

The monopolistic competition model overcomes some of these problems. In the monopolistic competition model each firm produces a differentiated good which must compete with many other differentiated goods for space in the consumer’s budget. Therefore, a new equation is added to the model, describing the behavior of the demand curve faced by the monopolist firm. Bação et al. (2018) employ the usual functional form:

$$Y = \left(\frac{P^*}{EP}\right)^{\sigma} Y^* \quad (4)$$

In equation 4,  $P^*$  is the foreign price index (the foreign price is measured in units of the foreign currency),  $E$  is the nominal exchange rate (units of foreign currency necessary to purchase one unit of the national currency, a decrease corresponds to a depreciation of the national currency),  $Y^*$  is the measure of foreign demand and  $\sigma$  is a parameter that measures the price-elasticity of demand (assumed to be larger than one). Exports are now given by:

$$Y = A^{\frac{1}{\theta}} \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\alpha+\beta+\gamma}{\theta}} \left(\frac{\alpha}{r^*}\right)^{\frac{\alpha}{\theta}} \left(\frac{\beta}{w^*}\right)^{\frac{\beta}{\theta}} \left(\frac{\gamma}{q^*}\right)^{\frac{\gamma}{\theta}} Y^{*\frac{\alpha+\beta+\gamma}{\sigma\theta}} \quad (5)$$

Parameter  $\theta$  is:

$$\theta = 1 - \frac{\sigma-1}{\sigma}(\alpha + \beta + \gamma) \quad (6)$$

The “real” prices of the production inputs ( $r^*$ ,  $w^*$  and  $q^*$ ) are now defined by the ratio of the nominal prices to the foreign price index ( $P^*$ ) converted to the national currency (i.e.,  $P^*$  divided by the exchange rate  $E$ ). This monopolistic competition model integrates both supply and demand factors in the determination of exports. It provides an alternative explanation for a trend in exports: it may be the consequence of a trend in foreign demand.

### 3. The data

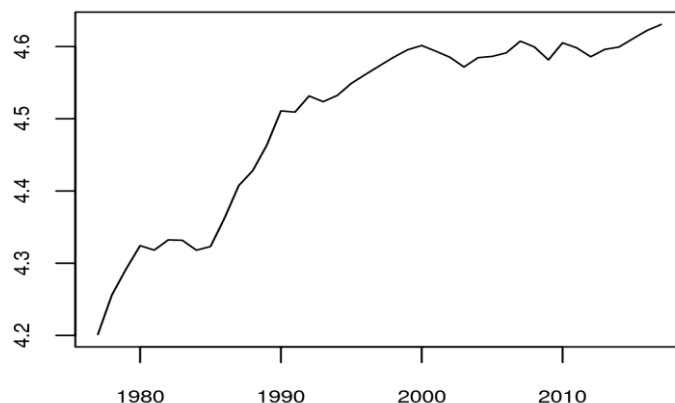
The models reviewed in the previous section suggest several variables that may be useful for forecasting exports. Note that, following Bação et al. (2018), we will focus on exports of goods. In other words, we will not deal with exports of services. Exports of services are likely to be more affected by fluctuations in tourism-related flows. Tourism demand has been subjected to several shocks in recent years, namely as a consequence of the Arab Spring that began in 2010.

Together, the perfect competition and the monopolistic competition models indicate that we need data on productivity, wages, the cost of capital, the cost of intermediate consumption, foreign demand and foreign prices, the exchange rate, besides real exports (the dependent variable in the models) and export prices. For productivity in Portugal (variable  $A$  in the models of the previous section) we will use the total factor productivity series provided by the European Commission in its AMECO database.<sup>2</sup> A shortcoming of this choice is that the AMECO series attempts to measure the productivity of the economy as a whole, not the productivity of the exporting firms. Given that we are focusing on the exports of goods, we are leaving out exports produced in the service sector of the economy. The service sector is usually thought to be a sector in which the scope for productivity gains is smaller, i.e., productivity in the service sector tends not to grow or to grow at a slower pace than in manufacturing (or agriculture). This hypothesis forms the basis for Baumol’s “cost disease” – for a recent discussion, see Baumol (2012) – and is also related to the Balassa-Samuelson effect (Balassa, 1964, and Samuelson, 1964) – see Alexandre and Bação (2013). By using that overall measure of productivity, it is possible that we are understating the growth of productivity in exporting

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<sup>2</sup> The AMECO database may be consulted or downloaded from [https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/macro-economic-database-ameco/ameco-database\\_en](https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/macro-economic-database-ameco/ameco-database_en). We used the version released on November 8, 2018.

firms. Nevertheless, if the growth of productivity in exporting firms is (at least approximately, in our sample) a multiple of overall productivity growth, then the overall productivity measure provided by AMECO will still be useful. Figure 1 shows the evolution of this series (in logarithm) between 1977 and 2017. According to this measure, productivity in Portugal was basically stagnated between 2000 and 2014, but appears to have resumed growth in 2015-2017.



**Figure 1: Total factor productivity in Portugal (logarithm)**

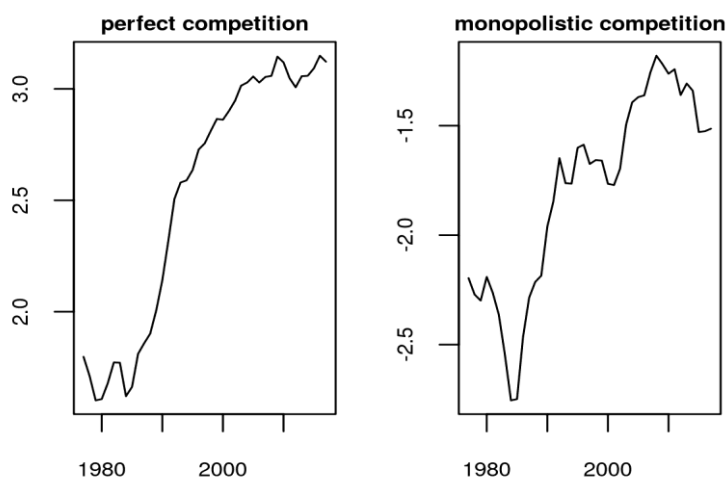
Source: AMECO.

As for wages, we resort to compensation of employees, per employee (values provided by Banco de Portugal with its Economic Bulletin, June 2018<sup>3</sup>), as a measure of the average nominal wage in Portugal (variable  $W$  in the models of the previous section). One may argue that this measure may underestimate the level of wages in the exporting firms. For instance, if wages are related to labour productivity and labour productivity is higher in exporting firms, wages will be higher in exporting firms than in the rest of the economy. However, if the labour market is competitive and workers may shift from the service sector to the (exporting) manufacturing sector, then wages should tend to be equalized across sectors. In fact, this is one key argument in both Baumol's cost disease and the Balassa-Samuelson effect. If this is the case, then the national average wage should not be too far apart from the wage paid by exporting firms. Nevertheless, there are some sectors for which the assumption of a competitive labour market, with workers shifting between sectors, is harder to accept. In particular, this is the case of the public sector. For the Portuguese case, Campos and Pereira (2009) report that, overall, workers in the public sector enjoy a premium relative to workers in the private sector. The premium exists even after controlling for observable individual characteristics, and is larger for lower wages. According to Campos and Pereira (2009), the premium is especially large in

<sup>3</sup> Available at <https://www.bportugal.pt/en/publications/banco-de-portugal>.

health and education. Campos and Pereira (2009) relate this to the bargaining power of public servants in those sectors. Campos et al. (2017) reach a similar conclusion (regarding the “noncompetitive environment” which protects public servants) after analyzing micro- and macro-data for a set of OECD countries. The effect of these issues on the relation between the national average wage and the wage paid by exporting firms is not clear. We therefore proceed as if the bias is negligible (at least in what concerns the growth rate of the nominal wage).

As the previous section made clear, the “real wage” is computed differently depending on the model being used. In the perfect competition model, the real wage is the ratio of the nominal wage (the national average nominal wage, discussed in the previous paragraph) to the price of national exports (variable  $P$  in the previous section). However, in the monopolistic competition model, the appropriate deflator is the foreign price index divided by the exchange rate (units of foreign currency necessary to purchase one unit of the national currency). Figure 2 shows the evolution of the two measures of real wages. The general trend is similar in both series, but the monopolistic competition measure is more volatile, displaying marked declines in the mid-1980s, in the 1990s and in recent years.



**Figure 2: Measures of real wages in Portugal (logarithm)**

**Source:** Authors’ computations using data from Banco de Portugal. The “perfect competition” wage is obtained by dividing the nominal wage by the exports deflator. The “monopolistic competition” wage is obtained by dividing the nominal wage by the foreign price index converted to the national currency.

The cost of capital (variable  $R$  in the models of the previous section) is especially difficult to measure. The theoretical models indicate that this variable should stand for the “rental cost of capital”, that is to say the “user cost of capital” (see, e.g., the original derivation in Jorgenson, 1963, or the textbook presentation in Branson, 1989): how much it costs to use

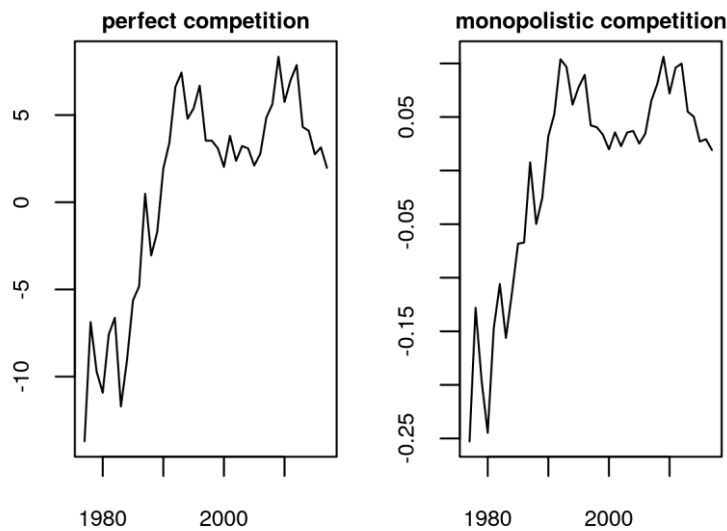


one unit of fixed capital during one period of time. As in Bação et al. (2018), we use the following formula to compute our estimate of the nominal cost of capital:

$$R_t = \delta \cdot \lambda_t + \tau_t \cdot \lambda_{t-1} - (\lambda_t - \lambda_{t-1}) \quad (7)$$

In equation 7,  $\delta$  is the annual rate of depreciation of the capital stock. It is computed using AMECO data for the consumption of fixed capital in Portugal.  $\lambda$  is a measure of the price of capital goods and  $\tau$  is the real interest rate obtained using the GDP deflator, both series retrieved from AMECO. Given the availability of data, we chose to use the short-term real interest rate instead of the long-term real interest rate. Note that, if the price of capital goods is roughly constant over time, then the evolution of the user cost of capital will be approximately reflect the evolution of the real interest rate. Alternatively, if the price of capital goods is growing at a roughly constant pace over time, then the real interest rate may still be a useful indicator of the cost of capital. However, if the price of capital goods departs from those linearity assumptions, then the real interest rate may be a misleading indicator of the cost of capital. Therefore we decided to use the result of equation 7 as our measure of the (nominal) cost of capital. As in the case of wages, the nominal cost of capital must be deflated – using a different deflator for each case – to obtain the relevant quantity according to the two models reviewed in the previous section.

Figure 3 shows the evolution of the perfect competition and monopolistic competition measures of the real cost of capital. Note that, in face of the nature of this variable and of its similarity with the interest rate, we do not take the logarithm of the cost of capital. The two measures display a broadly similar behaviour in our sample.



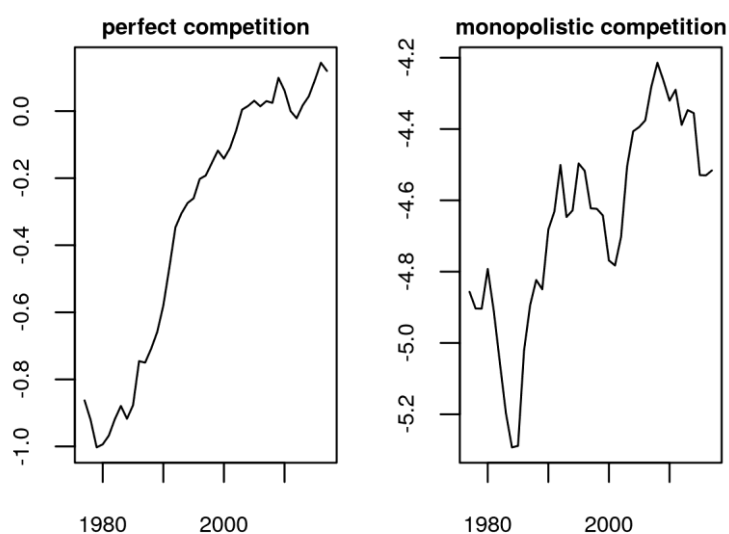
**Figure 3: Measures of the real cost of capital in Portugal**

**Source:** Authors' computations using data from Banco de Portugal. The “perfect competition” cost of capital is obtained by dividing the nominal cost of capital by the exports deflator. The “monopolistic competition” cost of capital is obtained by dividing the nominal cost of capital by the foreign price index converted to the national currency.

Another variable which, given the data available to us, is difficult to measure is the cost of intermediate consumption. We decided to use the GDP deflator (also from Banco de Portugal’s Economic Bulletin, June 2018) as our measure of the cost of intermediate consumption. One may ask whether the prices of the intermediate goods used in the production of goods that will be exported exhibit the same sort of behaviour that the GDP deflator. The GDP deflator measures the evolution of the prices of the final goods produced in the country. If the cost of the intermediate goods used in the production of the final goods included in GDP goes up, then we should observe some tendency towards an upward adjustment of the prices of the final goods. Obviously, the GDP deflator is far from being the ideal indicator of the price of intermediate consumption, but we were unable to find an alternative indicator with clearly preferable properties. The price of oil might be an alternative. Rotemberg and Woodford (1996) remarked that many empirical studies indicate that oil price shocks had significant impacts on economic activity, but that the reason for the significance of their impact was unclear, especially given that oil costs represent a minor component of production costs. Rotemberg and Woodford (1996) suggest that imperfect competition might be the missing element in the reasoning. Finn (2000) showed that the same impact could be observed in a model with perfect competition and a variable rate of capacity utilization. Aguiar-Conraria and Wen (2007) argue that both those models fail to adequately describe the US data circa the first two oil shocks. Instead, Aguiar-Conraria and Wen (2007) propose a model in which oil price shocks lead to externalities across

firms, which create a multiplier-accelerator effect on the macroeconomy. These results suggest that future research may find it useful to experiment with alternatives such as the price of oil.

Figure 4 shows the evolution of the perfect competition and monopolistic competition measures of the real cost of intermediate consumption. The series in Figure 4 resemble the two series obtained for the real wage (recall Figure 2). Thus, as in the case of the real wage, the monopolistic competition measure of the cost of intermediate consumption is more volatile than the perfect competition measure.



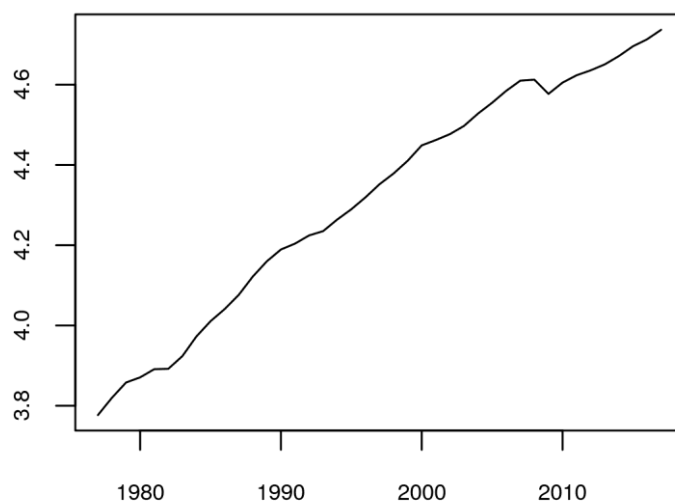
**Figure 4: Measures of the real cost of intermediate consumption in Portugal**

**Source:** Authors’ computations using data from Banco de Portugal. The “perfect competition” cost of intermediate consumption is obtained by dividing the GDP deflator by the exports deflator. The “monopolistic competition” intermediate consumption is obtained by dividing the GDP deflator by the foreign price index converted to the national currency.

As in Bação et al. (2018), our measure of foreign demand (variable  $Y^*$  in the models of the previous section) is the real GDP of the set of OECD countries (volume index downloaded from the OECD.Stat website, <https://stats.oecd.org/>). Perhaps a better indicator would be a weighted average of the GDP of Portugal’s trading partners, with the weights given by the share of each partner in Portugal’s exports, or, more generally, in Portugal’s foreign trade, as is the case when computing effective exchange rate indices – see, e.g., Klau and Fung (2006), on the methodology used by the Bank for International Settlements, and Alexandre et al. (2009) for an application to the Portuguese case, both at the aggregate and at the sector level. Naturally, this alternative would introduce additional data requirements that might not be easy to meet over the whole period covered by our sample. Another alternative with similar characteristics (including the need to meet steeper data requirements) would be to use as weights the (inverse

of the) geographical distance to each trading partner, in the spirit of the celebrated gravity model of international trade – see Chaney (2018) for a recent discussion of the foundations of this model. It might also be possible to integrate the Import-intensity-Adjusted Demand (IAD) indicator proposed by Bussière et al. (2013) into a framework for measuring foreign demand, but, as in the alternatives mentioned before, the additional data requirements would make such an approach much more demanding. As a result, in this paper we continue to use the same assumption as Bação et al. (2018) and resort to the OECD’s real GDP as a proxy for foreign demand.

Figure 5 shows how real GDP (in logarithms) has evolved in the OECD countries during the period covered by our sample. The impact of the international financial crisis is clearly visible in 2009. The growth trend was resumed in 2010, but it appears that the new growth trend is below the growth trend that one would observe by extrapolating the data points just before the start of the international financial crisis. This suggests that the international financial crisis left permanent scars on the economies of the OECD countries. Given this, it is not surprising that the behaviour of exports also displays some signs of instability (or structural break) around the same time, as discussed by the literature that deals with the “great trade collapse” – recall section 1.

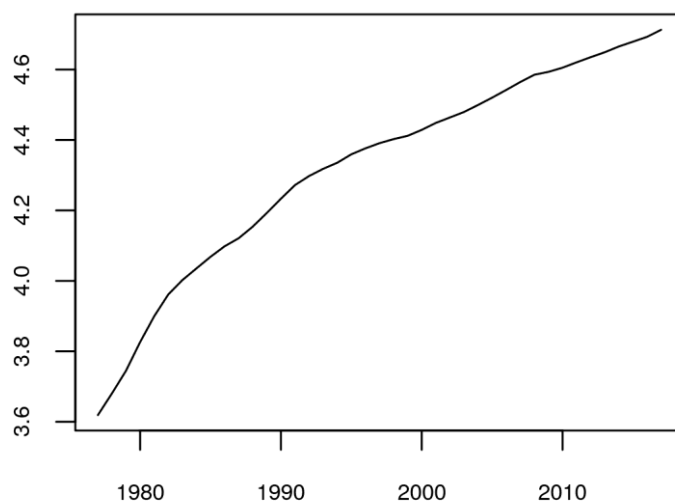


**Figure 5: OECD GDP (volume index, logarithm)**

Source: OECD.

In face of our choice for the indicator of foreign demand, the natural choice for the foreign price index (variable  $P^*$  in the models of the previous section) is the deflator for the

OECD's GDP. The time series for this variable is in Figure 6. The path of this variable is much smoother than the path of real GDP – the impact of international financial crisis is now barely noticeable.



**Figure 6: OECD GDP deflator (logarithm)**

Source: OECD.

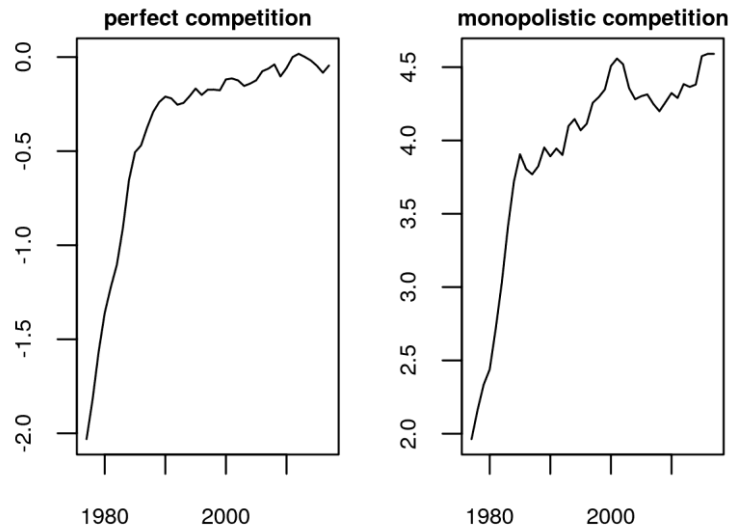
Foreign prices are used to compute “real” values of the prices of inputs in the production function: labour (wages), capital (cost of capital) and intermediate consumption (price of intermediate goods). However, since the foreign price index measures the evolution of foreign prices in the foreign currency (in this case, the OECD's GDP is measured in US dollars) we need to convert it into the domestic currency. To do that, we collected data on the exchange rate of the US dollar against the euro and the Portuguese escudo. Both series were downloaded from the BPSStat statistics online website, made available by Banco de Portugal.<sup>4</sup> The foreign price index is a requirement of the monopolistic competition model discussed in the previous section. In the perfect competition model the appropriate deflator is the price of exports (of goods, since we are leaving services outside of the scope of our analysis). The deflator for exports of goods was also collected from Banco de Portugal's Economic Bulletin, June 2018.

Figure 7 shows the evolution of the two deflators (in logarithms) employed in our empirical analysis. The deflator based on the foreign price index is more volatile. Given that the foreign price index itself appeared to be relatively smooth (recall Figure 6), the additional volatility reflects swings in the exchange rate of the euro (or, until 1998, of the Portuguese

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<sup>4</sup> The internet address is <https://www.bportugal.pt/estatisticasweb/sdie.aspx?Lang=en-GB&mlid=1354>.

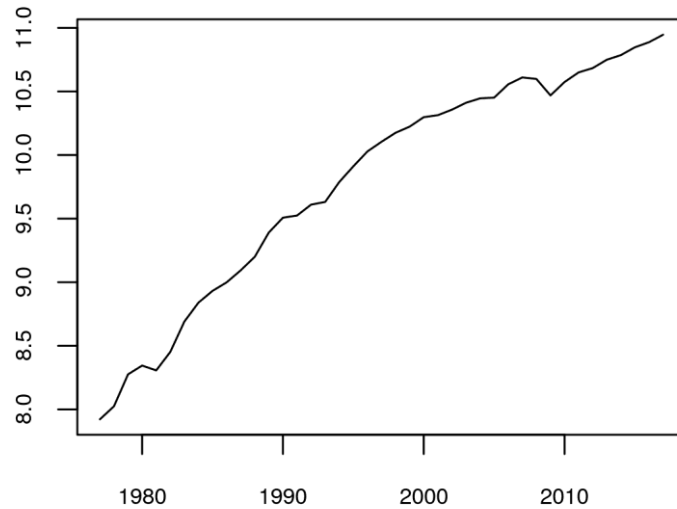
escudo) vis-à-vis the US dollar. This also accounts for the additional volatility observed previously (Figures 2, 3 and 4) in the real prices of the production inputs in the case of the monopolistic competition model.



**Figure 7: Deflators (logarithms)**

**Source:** Authors’ computations based on data from Banco de Portugal and OECD. The “perfect competition” deflator is the deflator of Portugal’s exports of goods. The “monopolistic competition” deflator is the ratio of the OECD’s GDP deflator to the exchange rate of the euro in terms of US dollars.

The final element in our dataset is the most important: real exports of goods. This series also comes from Banco de Portugal’s Economic Bulletin, June 2018. The time series may be viewed in Figure 8. The perturbation associated with the international financial crisis is visible. The profile appears to be similar to that observed in the foreign demand variable (OECD’s real GDP, Figure 5), reinforcing the notion that this may be an adequate empirical counterpart to the theoretical concept.



**Figure 8: Real exports of goods (logarithm)**

Source: Banco de Portugal.

#### 4. Forecasting models

We employ four types of models for forecasting Portugal's exports of goods after the start of the international financial crisis: a VAR model including exports and the variables suggested by the perfect competition model (productivity, real wage, real cost of capital, real cost of intermediate consumption, using the price of exports as the deflator for obtaining the real prices of inputs); a VAR model including exports and the variables suggested by the monopolistic competition model (productivity, foreign demand, real wage, real cost of capital, real cost of intermediate consumption, using the foreign price index divided by the exchange rate as the deflator for obtaining the real prices of inputs); ARIMA models; and Holt's linear trend model (HLT). The last two models (ARIMA and HLT) only make use of past values of exports to compute forecasts. In the sense that they do not employ additional sources of information in the computation of forecasts, these two models appear to be at a disadvantage relatively to the two VAR models. Nevertheless, there are several instances in which these simpler models may perform better than the VAR models. For example, the theoretical models may provide misleading indications, because their assumptions may be implausible. Or the empirical counterparts to the variables that appear in the theoretical models may be inadequate (recall the discussion in the previous section). Or the relation between exports and the other variables may have undergone changes through time (structural change in the parameters of the

model). Or the relation between exports and the variables in the theoretical models may only provide useful information concerning the behaviour of exports contemporaneously. Note that the VAR models relate the current value of the variables in the VAR model (in our case, exports and the variables suggested by either the perfect competition model or the monopolistic competition model) to lagged values of those variables, whereas the theoretical models apparently suggest the existence of a relation between the contemporaneous values of the variables.

A VAR model is a model of the form:

$$\mathbf{X}_t = \mathbf{B}_0 + \mathbf{B}_1\mathbf{X}_{t-1} + \dots + \mathbf{B}_p\mathbf{X}_{t-p} + \epsilon_t \quad (8)$$

In equation 8,  $X$  is a vector composed of exports (the logarithm of Portugal's real exports of goods) and the variables suggested by either the perfect competition model or the monopolistic competition model (all in logarithms, except the real cost of capital – recall the previous section). Equation 8 makes clear the need for selecting the order of the VAR model (the number of lags,  $p$ , to include in the model). Given the number of observations available, we decided to use both a VAR of order one and a VAR of order two. Note that the VAR model allows for cointegration between the variables, which was the focus of the empirical analysis in Bação et al. (2018).

An ARIMA( $p,d,q$ ) model may be written as:

$$y_t = c + \phi_1 y_{t-1} + \dots + \phi_p y_{t-p} + \epsilon_t + \theta_1 \epsilon_{t-1} + \dots + \theta_q \epsilon_{t-q} \quad (9)$$

In equation 9,  $y$  is the  $d$ -th difference of the variable being modelled (in our case, exports), with the condition that if  $d=0$ , then  $y$  is just the variable being modelled. In the case of an ARIMA model, besides  $d$ , we also need to choose values for  $p$  (the number of lags of the dependent variable, i.e., the order of the autoregressive component) and  $q$  (the number of lags of the shocks, i.e., the order of the moving average component). We decided to use ARIMA models with  $d=0$ ,  $d=1$  and  $d=2$ . The case where  $d=0$  is the most general, encompassing the other two cases. The case where  $d=1$  imposes one unit root, while  $d=2$  imposes two unit roots. Imposing one unit root may be useful for modelling a series with a trend. Assuming two unit roots may be useful when the trend is changing over time – see, e.g., Hendry (2006) for a discussion of forecasting in the presence of structural breaks. As for the parameters  $p$  and  $q$ ,



they will be selected so as to minimize the Akaike Information Criterion (AIC).<sup>5</sup> Nevertheless, this procedure requires that one defines the maximum number of lags allowed in the ARIMA model, say  $pmax$  and  $qmax$ . Then the procedure will compute the AIC for all ARIMA models (given the chosen  $d$ ) with  $1 \leq p \leq pmax$  and  $1 \leq q \leq qmax$ , and choose the combination of lags that minimizes the AIC (note that all the models will be estimated on the same sample). The issue then is the choice of  $pmax$  and  $qmax$ . Our experience indicates that the estimation procedure tends to fail when more than four lags are employed. Therefore we set  $pmax = qmax = 4$ . However, if the optimal combination uses four lags, that is to say, lies at the border of the predefined set, we redo the procedure with  $pmax = qmax = 5$ , so as to check whether our choice of the maximum was unduly restrictive.

Holt's linear trend method is an exponential smoothing method with two parameters (see, e.g., Hyndman and Athanasopoulos, 2018). Each parameter controls the evolution of one of the components that the method assumes that determine the evolution of the series that is to be forecasted: the level ( $l_t$ ) and the slope of the trend ( $b_t$ ). The forecasts are computed using the following equations:

$$\hat{y}_{T+h|T} = l_T + h \cdot b_T \quad (10)$$

$$l_t = \alpha y_t + (1 - \alpha)(l_{t-1} + b_{t-1}) \quad (11)$$

$$b_t = \beta(l_t - l_{t-1}) + (1 - \beta)b_{t-1} \quad (12)$$

The values of the parameters ( $\alpha, \beta$ ) are chosen so as to minimize the mean squared error.

We will therefore have eight basic models: the perfect competition VAR of order 1, the perfect competition VAR of order 2, the monopolistic competition VAR of order 1, the monopolistic competition VAR of order 2, the ARIMA model on the level of exports (recall that we use the logarithm of real exports of goods), the ARIMA model on the first difference of exports, the ARIMA model on the second difference of exports, and Holt's linear trend model. However, the forecasting performance of these models can be compared under different circumstances. We will compare the forecasts under the following scenarios.

The first scenario assumes that we are forecasting the path of exports from 2008 until 2017 using only the information available until 2007. In other words, we estimate the

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<sup>5</sup> All computations were performed using Gretl 2019a.

parameters of the models using the data until 2007 and then use those parameters to forecasting exports in the following years. In this case, the VAR models will be forecasting exports and all the other variables that are included in them. We call the forecasts obtained in this scenario “dynamic forecasts”.

In the second scenario we enlarge the information set in a limited way: we compute the VAR forecasts of exports using the actual values observed for the other variables in the VAR models, although the parameters are still those that were estimated using the data until 2007. This allows us to discuss whether the forecasting errors in exports are due to the forecasting errors in the other variables. If there is a strong relation between the variables (lagged) then the forecast errors for exports should also be smaller when using the actual values of the other variables in the computation of the forecasts. This procedure will give us “dynamic forecasts with known X”. Obviously, ARIMA and HLT forecasts are the same in the first and in the second scenarios, since they do not depend on the other variables.

In the third scenario we continue to estimate the parameters using the data until 2007. However, we now compute one-step-ahead forecasts, i.e., we use the data until 2007 to forecast 2008, the data until 2008 to forecast 2009, and so on. This means we do not need to compute forecasts on the basis of forecasts, as we did in the first two scenarios. If the forecasting model is adequate, then forecast errors should reflect only shocks. The forecasts provided in this scenario are “static forecasts”.

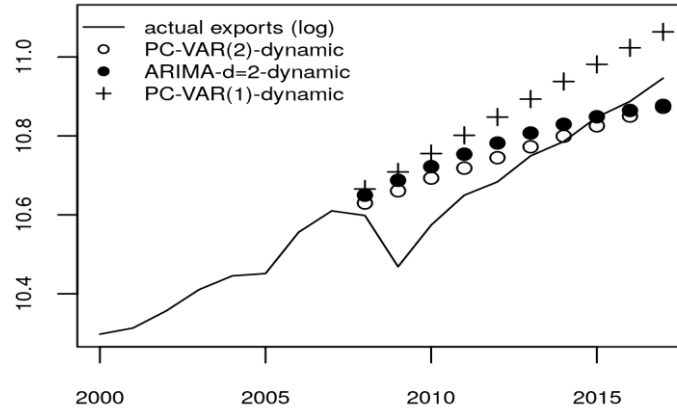
In the fourth scenario we re-estimate the parameters every year. That is to say, the forecasts are still computed one-step-ahead, as in the previous scenario, but now they are computed using parameters estimated using all the data until the date of the making of the forecast. These will be “recursive forecasts”. The impact of structural breaks that may have occurred at the time of the beginning of the international financial crisis should be mitigated by using re-estimated coefficients. We go one step further and allow a break in the constant term of the VAR and ARIMA models, in the spirit of Clements and Hendry (1996). Two versions are employed. In one version, we introduce a dummy (in all the estimations that use data until at least 2009) for the year 2009 (the year in which the impact of the international financial crisis was stronger). In the other version, the dummy takes the value 1 in all years starting in 2009. In this second version, the assumption is that the impact of the international financial crisis on the constant term may have been permanent, whereas in the first version it may have been temporary. Note that the HLT forecasts in these two additional versions of this scenario are the same as the recursive forecasts.

The forecasts obtained with the different models in the scenarios described above will be compared using the usual statistic: the root mean squared error (RMSE). However, we will also report the mean error (ME), the mean absolute error (MAE), Theil's U, and the decomposition of the mean squared error into the mean (UM), the regression (UR) and the disturbance (UD) components. Notice that we do not report forecast accuracy measures based on percent errors. Given that the variable to be forecasted is already in logarithms, we believe that the computation of percent errors (relative to the logarithm of the series) would not yield interesting insights.

## 5. Results

The VAR of order two based on the perfect competition model provided the best dynamic forecasts – see Table 1. However, the regression component of the MSE is large, implying that the forecast errors are correlated with the forecasts. The MSE of the forecasts from the other VAR forecasts, as well as from the ARIMA model with  $d=1$  and from the HLT, is essentially due to the bias. This means that the problem with those forecasts is that they forecast the continuation of the pre-2009 growth trend after 2008, but the actual growth appears to have shifted down. Figure 9 illustrates this point. It also shows that the perfect competition VAR(2) forecasts are very similar to the forecasts from the ARIMA with  $d=2$ . They are essentially capturing the slowing down of the growth of exports in the 1990s and 2000s – compare Figure 8 and notice the curvature of the graph in that period.

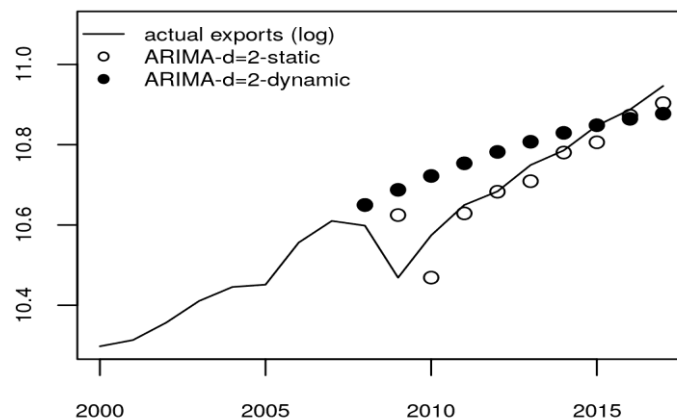
When the dynamic forecasts employ the actual values of the other variables in the VAR models, the performance worsens in the case of the perfect competition model and only slightly improves in the case of the monopolistic competition model – see Table 2. The RMSEs of the VAR forecasts are of the same magnitude as the RMSEs of the univariate models. This is a somewhat unexpected outcome. It may mean that those other variables are not very useful for forecasting exports, and therefore, although not necessarily, may also be insufficient for providing an adequate explanation of the behaviour of exports.



**Figure 9: Dynamic forecasts**

**Source:** Authors' computations. "PC-VAR(2)-dynamic": dynamic forecasts from the VAR of order two inspired by the perfect competition model. "ARIMA-d=2-dynamic": dynamic forecasts from the ARMA model for the second difference of exports. "PC-VAR(1)-dynamic": dynamic forecasts from the VAR of order one inspired by the perfect competition model.

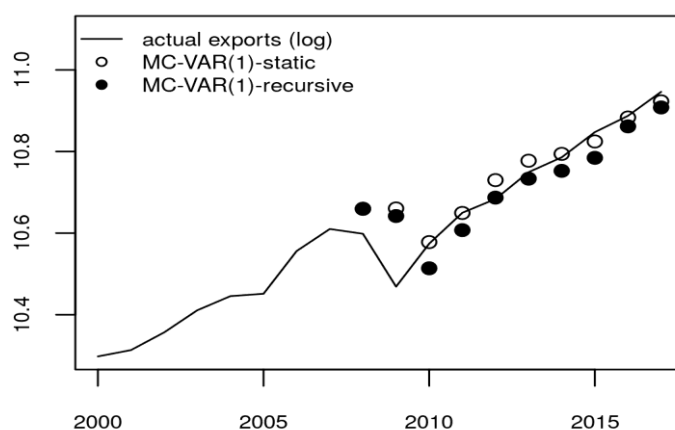
Table 3 shows the forecast accuracy measures for the static forecasts. The RMSEs are very similar across the forecasting models. Nevertheless the best RMSE belongs to the ARIMA model with  $d=2$ . (If we used the MAE instead, the best forecasting model would be the VAR of order one inspired by the monopolistic competition model.) Figure 10 shows that knowledge of what happened to exports in the year before clearly helps improve the forecasts. Naturally, the forecast for 2009 is still off the mark, and the forecast for 2010 is also unsatisfactory, but afterwards the forecast performance becomes much better. By definition, the dynamic forecasts ignore the 2009 shock and just extrapolate the preceding trend.



**Figure 10: Static versus dynamic forecasts**

**Source:** Authors' computations. "ARIMA-d=2-static": static forecasts from the ARMA model for the second difference of exports. "ARIMA-d=2-dynamic": dynamic forecasts from the ARMA model for the second difference of exports.

Table 4 reports the accuracy measures for plain recursive forecasts. Again the RMSEs are basically indistinguishable across models. The best RMSE now belongs to the VAR of order one inspired by the monopolistic competition model (while the best MAE is produced by the HLT model). The recursive forecasts are not very different from the static forecasts (see Figure 11). Indeed the RMSE of the static forecasts is actually lower than the RMSE of the recursive forecasts for many of the models. This suggests that merely obtaining new estimates of the same parameters using more data does not seem to be useful for forecasting exports after 2008. It appears that either there was no structural break, only a shock, or the models are unable to adjust to the kind of break that occurred with the international financial crisis.

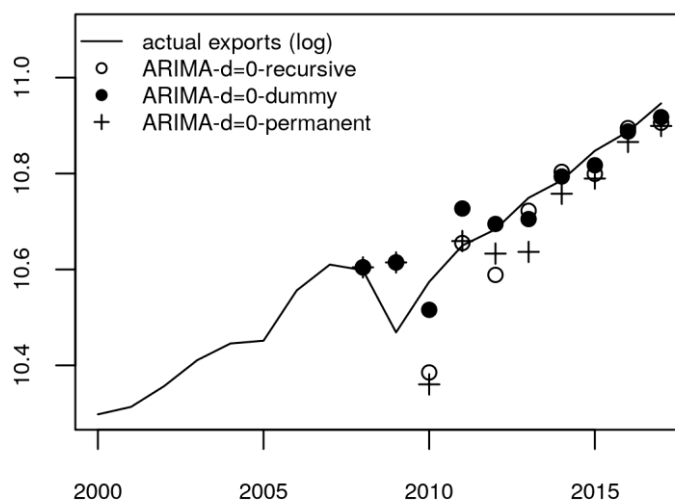


**Figure 11: Static versus recursive forecasts**

**Source:** Authors' computations. "MC-VAR(1)-static": static forecasts from the VAR of order one inspired by the monopolistic competition model. "MC-VAR(1)-recursive": recursive forecasts from the VAR of order one inspired by the monopolistic competition model.

Tables 5 and 6 help understand what the issue is. Introducing the 2009 dummy generally improves the performance of the forecasts. (Note that HLT is not affected by this issue and that results are not reported for the ARIMA model with  $d=2$  because the estimation of this model failed when dummies were included.) However, introducing the dummy that equals one after 2008 (the permanent-effect dummy) clearly deteriorates the performance of the forecasting models (see Figure 12). The implication seems to be that the international financial crisis had an impact on exports that is best modelled as a temporary shock, instead of a permanent one, at least a permanent shock with a constant coefficient – perhaps the international financial crisis had a non-negligible long-term effect that is different from the clearly non-negligible short-term effect. An alternative argument in favour of a permanent effect of the crisis could be based on the fact that a shock to a unit root process has permanent effects. Nevertheless, the fact that the

best forecasting model in the recursive scenarios is the ARIMA model with  $d=0$  and the 2009 dummy casts some doubt on the assumption of a unit root in exports: if the unit root were appropriate, one would expect the ARIMA model with  $d=1$  and the 2009 dummy to produce the best forecasts, although it may be argued that ten forecasts constitute too small a sample to draw conclusions.



**Figure 12: Recursive forecasts and intercept corrections**

**Source:** Authors' computations. "ARIMA-d=0-recursive": recursive forecasts from the ARMA model for exports. "ARIMA-d=0-dummy": recursive forecasts from the ARMA model for exports with a dummy for 2009. "ARIMA-d=0-permanent": recursive forecasts from the ARMA model for exports with a dummy for the post-2008 period.

**Table 1: Accuracy measures for dynamic forecasts**

|      | Perfect comp. |         | Monopol.comp. |         | ARIMA  |        |        | HLT    |
|------|---------------|---------|---------------|---------|--------|--------|--------|--------|
|      | VAR(1)        | VAR(2)  | VAR(1)        | VAR(2)  | $d=0$  | $d=1$  | $d=2$  |        |
| ME   | -0.1487       | -0.0376 | -0.1378       | -0.2350 | 0.1070 | -      | -      | -      |
| RMSE | 0.1545        | 0.0827  | 0.1450        | 0.2420  | 0.2026 | 0.3947 | 0.1017 | 0.2784 |
| MAE  | 0.1487        | 0.0641  | 0.1378        | 0.2350  | 0.1557 | 0.3741 | 0.0815 | 0.2688 |
| U    | 2.1729        | 1.1719  | 2.0425        | 3.3990  | 2.8327 | 5.5409 | 1.4337 | 3.9103 |
| UM   | 0.9259        | 0.2068  | 0.9036        | 0.9434  | 0.2791 | 0.8985 | 0.3852 | 0.9322 |
| UR   | 0.0036        | 0.5141  | 0.0103        | 0.0275  | 0.4928 | 0.0908 | 0.3510 | 0.0460 |
| UD   | 0.0705        | 0.2791  | 0.0861        | 0.0292  | 0.2281 | 0.0107 | 0.2638 | 0.0218 |

**Notes:** ME: mean error. RMSE: root mean squared error. MAE: mean absolute error. U: Theil's U. UM: mean component of MSE. UR: regression component of MSE. UD: disturbance component of MSE.

**Table 2: Accuracy measures for dynamic forecasts with known X**

|      | Perfect comp. |         | Monopol.comp. |         | ARIMA  |        |        | HLT    |
|------|---------------|---------|---------------|---------|--------|--------|--------|--------|
|      | VAR(1)        | VAR(2)  | VAR(1)        | VAR(2)  | $d=0$  | $d=1$  | $d=2$  |        |
| ME   | -0.3337       | -0.0182 | -0.1053       | -0.2303 | 0.1070 | -      | -      | -      |
| RMSE | 0.3515        | 0.1409  | 0.1250        | 0.2384  | 0.2026 | 0.3947 | 0.1017 | 0.2784 |
| MAE  | 0.3337        | 0.1246  | 0.1053        | 0.2303  | 0.1557 | 0.3741 | 0.0815 | 0.2688 |
| U    | 4.9460        | 1.9912  | 1.7618        | 3.3621  | 2.8327 | 5.5409 | 1.4337 | 3.9103 |
| UM   | 0.9014        | 0.0168  | 0.7106        | 0.9334  | 0.2791 | 0.8985 | 0.3852 | 0.9322 |
| UR   | 0.0813        | 0.0099  | 0.1046        | 0.0034  | 0.4928 | 0.0908 | 0.3510 | 0.0460 |
| UD   | 0.0173        | 0.9733  | 0.1848        | 0.0631  | 0.2281 | 0.0107 | 0.2638 | 0.0218 |

**Notes:** ME: mean error. RMSE: root mean squared error. MAE: mean absolute error. U: Theil's U. UM: mean component of MSE. UR: regression component of MSE. UD: disturbance component of MSE.

**Table 3: Accuracy measures for static forecasts**

|      | Perfect comp. |        | Monopol.comp. |         | ARIMA  |        |        | HLT    |
|------|---------------|--------|---------------|---------|--------|--------|--------|--------|
|      | VAR(1)        | VAR(2) | VAR(1)        | VAR(2)  | $d=0$  | $d=1$  | $d=2$  |        |
| ME   | -0.0334       | 0.0058 | -0.0288       | -0.0804 | 0.0198 | -      | 0.0064 | -      |
| RMSE | 0.0733        | 0.0670 | 0.0668        | 0.0967  | 0.0813 | 0.0775 | 0.0663 | 0.0697 |
| MAE  | 0.0475        | 0.0495 | 0.0390        | 0.0804  | 0.0590 | 0.0565 | 0.0479 | 0.0442 |
| U    | 0.9999        | 0.9416 | 0.9110        | 1.3293  | 1.1639 | 1.0208 | 0.9177 | 0.9275 |
| UM   | 0.2070        | 0.0076 | 0.1867        | 0.6901  | 0.0590 | 0.3286 | 0.0094 | 0.0686 |
| UR   | 0.1242        | 0.1504 | 0.1659        | 0.0467  | 0.0918 | 0.0008 | 0.0025 | 0.0012 |
| UD   | 0.6688        | 0.8420 | 0.6474        | 0.2631  | 0.8492 | 0.6707 | 0.9881 | 0.9302 |

**Notes:** ME: mean error. RMSE: root mean squared error. MAE: mean absolute error. U: Theil's U. UM: mean component of MSE. UR: regression component of MSE. UD: disturbance component of MSE.

**Table 4: Accuracy measures for recursive forecasts**

|      | Perfect comp. |        | Monopol.comp. |         | ARIMA  |        |        | HLT    |
|------|---------------|--------|---------------|---------|--------|--------|--------|--------|
|      | VAR(1)        | VAR(2) | VAR(1)        | VAR(2)  | $d=0$  | $d=1$  | $d=2$  |        |
| ME   | -0.0002       | 0.0259 | 0.0042        | -0.0016 | 0.0217 | -      | 0.0173 | -      |
| RMSE | 0.0713        | 0.0772 | 0.0683        | 0.0892  | 0.0843 | 0.0786 | 0.0746 | 0.0722 |
| MAE  | 0.0517        | 0.0658 | 0.0517        | 0.0617  | 0.0582 | 0.0535 | 0.0575 | 0.0473 |
| U    | 0.9702        | 1.0906 | 0.9326        | 1.2271  | 1.2084 | 1.0392 | 1.0419 | 0.9663 |
| UM   | 0.0000        | 0.1128 | 0.0037        | 0.0003  | 0.0663 | 0.1748 | 0.0539 | 0.0442 |
| UR   | 0.0616        | 0.0008 | 0.0462        | 0.0589  | 0.1276 | 0.0189 | 0.0235 | 0.0030 |
| UD   | 0.9384        | 0.8864 | 0.9501        | 0.9408  | 0.8061 | 0.8064 | 0.9226 | 0.9528 |

**Notes:** ME: mean error. RMSE: root mean squared error. MAE: mean absolute error. U: Theil's U. UM: mean component of MSE. UR: regression component of MSE. UD: disturbance component of MSE.

**Table 5: Accuracy measures for recursive forecasts with dummy**

|      | Perfect comp. |        | Monopol.comp. |         | ARIMA   |         | HLT     |
|------|---------------|--------|---------------|---------|---------|---------|---------|
|      | VAR(1)        | VAR(2) | VAR(1)        | VAR(2)  | $d=0$   | $d=1$   |         |
| ME   | -0.0206       | 0.0012 | -0.0153       | -0.0329 | -0.0087 | -0.0407 | -0.0152 |
| RMSE | 0.0682        | 0.0618 | 0.0620        | 0.0711  | 0.0588  | 0.0763  | 0.0722  |
| MAE  | 0.0435        | 0.0442 | 0.0404        | 0.0512  | 0.0410  | 0.0549  | 0.0473  |
| U    | 0.9235        | 0.8680 | 0.8385        | 0.9478  | 0.8388  | 1.0019  | 0.9663  |
| UM   | 0.0908        | 0.0004 | 0.0608        | 0.2144  | 0.0219  | 0.2844  | 0.0442  |
| UR   | 0.1608        | 0.1235 | 0.1803        | 0.1965  | 0.0273  | 0.0023  | 0.0030  |
| UD   | 0.7484        | 0.8762 | 0.7589        | 0.5891  | 0.9508  | 0.7133  | 0.9528  |

**Notes:** ME: mean error. RMSE: root mean squared error. MAE: mean absolute error. U: Theil's U. UM: mean component of MSE. UR: regression component of MSE. UD: disturbance component of MSE.

**Table 6: Accuracy measures for recursive forecasts with dummy (permanent)**

|      | Perfect comp. |        | Monopol.comp. |        | ARIMA  |        | HLT     |
|------|---------------|--------|---------------|--------|--------|--------|---------|
|      | VAR(1)        | VAR(2) | VAR(1)        | VAR(2) | $d=0$  | $d=1$  |         |
| ME   | 0.0324        | 0.0473 | 0.0296        | 0.0278 | 0.0371 | 0.0129 | -0.0152 |
| RMSE | 0.1036        | 0.1029 | 0.0948        | 0.1024 | 0.0945 | 0.1107 | 0.0722  |
| MAE  | 0.0839        | 0.0872 | 0.0765        | 0.0817 | 0.0693 | 0.0713 | 0.0473  |
| U    | 1.4508        | 1.4637 | 1.3282        | 1.4200 | 1.3529 | 1.5332 | 0.9663  |
| UM   | 0.0977        | 0.2116 | 0.0975        | 0.0735 | 0.1539 | 0.0137 | 0.0442  |
| UR   | 0.0903        | 0.0708 | 0.0744        | 0.1154 | 0.0970 | 0.2674 | 0.0030  |
| UD   | 0.8120        | 0.7177 | 0.8281        | 0.8110 | 0.7491 | 0.7189 | 0.9528  |

**Notes:** ME: mean error. RMSE: root mean squared error. MAE: mean absolute error. U: Theil's U. UM: mean component of MSE. UR: regression component of MSE. UD: disturbance component of MSE.

## 6. Conclusion

In this paper we analyzed the forecasting performance of several models of exports. Our focus was on the performance of the models based on the theoretical models discussed in Bação et al. (2018). As in Bação et al. (2018), our results indicate that those models provide insufficient explanations of the behaviour of Portugal's exports of goods. In fact, the forecasting performance of the VAR models that make use of the variables suggested by those theoretical models is barely different from the forecasting performance of univariate models, i.e., models that do not make use of additional information apart from that contained in the past of the exports of goods, namely ARIMA models and Holt's linear trend model. Therefore, discussions about the competitiveness of Portuguese firms that centre on cost pressures (in particular



coming from wages) or on the impossibility of a unilateral devaluation of the national currency (given that Portugal joined the eurozone) may be misguided.

Our results also suggest that the impact of the international financial crisis appears to be best represented by a temporary shock rather than by a permanent shock (with a constant coefficient). This is one of the issues that deserves further research. It is possible that the international financial crisis may have long-term effects on the economy (a permanent “scar”), but that the magnitude of that impact is different from the magnitude of the short-term impact. It is curious that Portugal’s exports of goods appeared to be slowing down prior to the crisis, but that they now seem to exceed the forecasts obtained by extrapolating that trend, despite the negative impact of the crisis.

Naturally, another issue that deserves further research is the modelling of exports. If the standard theoretical models appear to be of little help, what additional elements should be brought on board? One possibility may be the impact of structural breaks prior to the international financial crisis. Another possibility may be, for example, to introduce elements related to the “domestic demand pressure” discussed in, e.g., Belke et al. (2015), Esteves and Rua (2015) and Bobeica et al. (2016).

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