Output in the Portuguese post-2008 period: A general equilibrium narrative

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Abstract
We use Bayesian methods to estimate a simplified version of *PESSOA*, a medium scale small-open Dynamic Stochastic General Equilibrium model featuring key characteristics of an economy integrated in a monetary union. Financial factors emerge as the most important driving force of business cycle fluctuations since the Euro Area inception. The 2008–2009 recession was primarily driven by external and tecnhological factors, whereas the 2011–2013 downturn was triggered by fiscal and financial developments, and latter amplified by technology shocks. (JEL: C11, C13, E20, E32)

Introduction

General equilibrium models are widely used in macroeconomic analysis due to their strong microfounded theoretical foundations, emerging as a powerful story-telling device. Until early 2000s, Dynamic Stochastic General Equilibrium (DSGE) models were mostly calibrated, due to the lack of well-developed and sufficiently powerful econometric tools and to the computationally intensive burden associated with their estimation.

With recent advances in computation, alongside with important theoretical developments (*e.g.* Schorfheide 2000), Bayesian methods promptly emerged as a powerful and well-suited method to estimate and quantitatively evaluate medium and large scale DSGE models, bringing forth a vast literature in the field. Many studies have documented the empirical possibilities of estimated DSGE models, even when compared with more traditional econometric tools. The studies of Christiano *et al.* (2011, 2014, 2015)—concluding that financial shocks have been an important source of

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business cycle fluctuations, playing a key role in the most recent period—constitute fresh influential work on the field. The implementation and estimation of DSGE models has also assumed a relevant role among a number of policy-making institutions, such as the *Riksbank* (Adolfson *et al.* 2008), the *Bundesbank* (Gadatsch *et al.* 2015), the *Bank of Finland* (Kilponen *et al.* 2016), the *European Central Bank* (Christoffel *et al.* 2008), the *Banco Central do Brasil* (de Castro *et al.* 2011), or the *European Commission* (Ratto *et al.* 2009), just to name a few.

We use Bayesian methods to estimate a simplified version of *PESSOA*, a medium scale small-open DSGE model featuring key characteristics of an economy integrated in a monetary union. *PESSOA* features powerful non-Ricardian effects, imperfect market competition, and a number of nominal and real rigidities. The core structure draws from Kumhof *et al.* (2010). Financial frictions à la Bernanke *et al.* (1999), and explored for instance in Christiano *et al.* (2011), are encompassed within the model, allowing the identification of financial shocks. As usual in New Keynesian DSGE models, *PESSOA* shares some aspects with influential references in the field (*e.g.* Smets and Wouters 2003; Christiano *et al.* 2005; Adolfson *et al.* 2007), mainly in what regards market imperfections and frictions, though it presents some unique features. The overlapping generations scheme, along the lines initially suggested by Blanchard (1985) and Yaari (1965), together with a magnified life-cycle income profile, endogenously trigger an important degree of myopia among agents, breaking the traditional Ricardian equivalence and generating realistic private consumption responses to government expenditure shocks (Blanchard 1985; Galí *et al.* 2007). In addition, the stochastic finite lifetime framework enables the endogenous determination of the net foreign asset position of the economy in the steady state, by limiting the amount of assets/debt that households can accumulate (Harrison *et al.* 2005), and posits a positive correlation between public debt and the net foreign debt position.

We estimate the model for Portugal with quarterly observations over the 1999:1–2015:4 period using twenty four observable time series, which include real, nominal and financial variables. In line with Christiano *et al.* (2011), we remove the mean from each of the first-differenced time series and thus isolate the estimation from significant differences in exogenous trend growths. The stochastic behavior of the model is driven by twenty four structural shocks, grouped into five distinct categories: preference/technology disturbances; domestic markups; fiscal; financial; and, finally, external factors. We take advantage herein of several estimation byproducts—namely historical and variance decompositions—to shed some light on Portuguese business cycle fluctuations, with a particular focus in the post-2008 period.

Financial factors emerge as the most important driving force of business cycle fluctuations since the euro area inception. High frequency movements

are however largely influenced by technology and external factors. The 2008–2009 recession was primarily driven by these two factors, whereas the 2011–2013 downturn was triggered by fiscal and financial developments, and later amplified by technology shocks.

The remainder of the article is organized as follows. The next section provides a short description of the model. We continue by presenting the database and the stochastic content of PESSOA. This is followed by a section with a general equilibrium narrative for GDP. The last section concludes.

The model

PESSOA is a DSGE model for a small open economy integrated in a monetary union. It features a multi-sectoral production structure, non-Ricardian characteristics, imperfect market competition, and a number of nominal, real and financial frictions. The structure used herein is slightly simplified in comparison with the calibrated version used on several occasions for policy analysis and simulation.[1]

Trade and financial flows are restricted to euro area countries, which are immune to domestic shocks, a consequence of the small-open economy framework. Domestic interest rates can only deviate from the reference rate of the Monetary Authority—hereafter the European Central Bank (ECB)—by an exogenous risk premium. The relative law of one price holds in the long run, implying that any domestic inflationary process *vis-à-vis* the euro area must be fully canceled out later through a desinflationary process and *vice-versa*. The external sector is represented by a Bayesian VAR model encompassing foreign output, interest rates, and inflation.

The economic environment is composed of ten types of agents: households, labor unions, manufacturers (intermediate goods producers), distributors (final goods producers), the government, capital goods producers, entrepreneurs, banks, foreign agents (the remaining euro area), and the ECB. Figure 1 depicts a bird's eye view of key interactions between agents.

Households evolve according to the overlapping generations scheme first proposed in Blanchard (1985). They are subject to stochastic finite lifetimes and face an identical and constant probability of death, independent of age (see Frenkel and Razin 1996; Harrison *et al.* 2005; Bayoumi and Sgherri 2006).

1. Technical details of the original version can be found in Almeida *et al.* 2013a. For examples of applications in a calibrated framework, see Almeida *et al.* (2009, 2010, 2013b); Castro *et al.* (2013, 2015). As compared with the initial version of *PESSOA*, we simplify the intermediate and final goods sectors by collapsing the tradable and non-tradable sectors into one single sector, to attenuate identifiability issues.

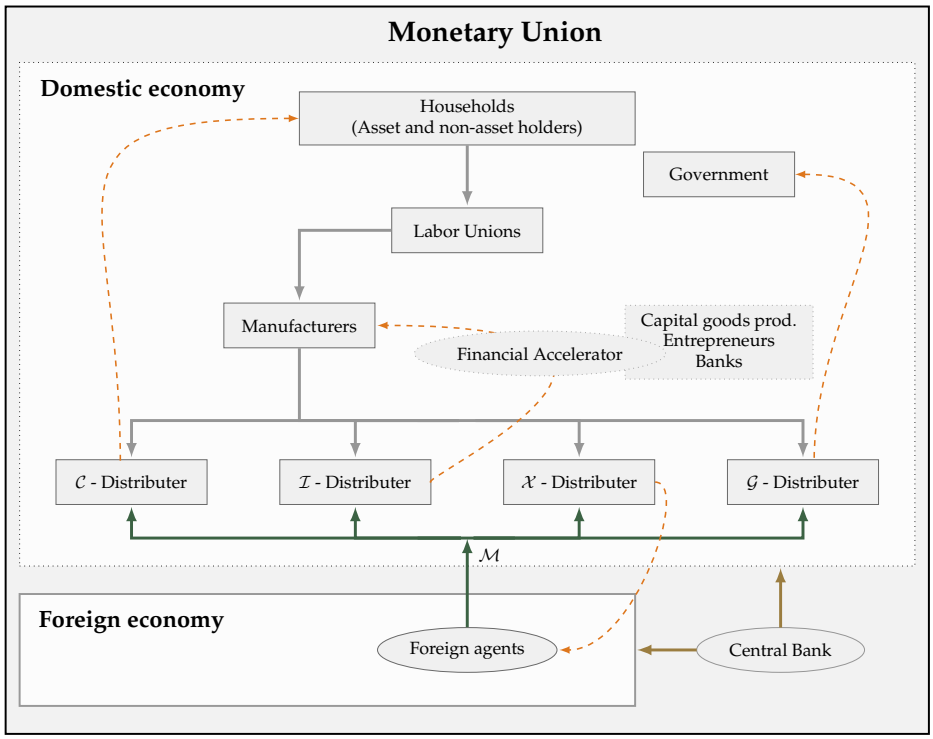

FIGURE 1: A bird's eye view of *PESSOA*.

Source: The authors.

Notes: Identifier C stands for consumption goods, I for investment goods, G for government consumption goods, X for export goods, and M for import goods. The financial accelerator mechanism comprises capital goods producers, entrepreneurs, and banks. Filled lines of the domestic and foreign economies identify input suppliers, *e.g.* Households supply labor to Labor Unions; dotted lines identify customers, *e.g.* Households buy consumption goods from the $\mathcal{C}$ - Distributer.

Population is constant, implying that in each period the number of newborns equals those who perish. Two household types coexist in each and every period: asset holders, who are able to smooth out consumption over lifetime by trading assets; and hand-to-mouth households, who have no access to asset markets and therefore consume all their income in each and every period.

The model has intrinsic non-Ricardian features. Hand-to-mouth households do not smooth consumption and are always contemporaneously affected by all fiscal policy decisions. Asset holders strongly prefer to finance government expenditure through public debt issuance, since future taxes will be charged largely on yet-to-be born generations (Buiter 1988). Non-Ricardian effects are magnified by the life-cycle income profile, which shifts the proneness of agents towards paying taxes later, when labor income is

lower. Additionally, the model features distortionary taxation on household's consumption, labor, and capital income. All households are remunerated for labor services rented to labor unions and may receive transfers from both the government and abroad. Asset holders also earn interest on bond holdings, receive dividends from firms, and a remuneration for financial services (in the bankruptcy monitoring of firms).

Labor unions hire labor services from households and rent them to manufacturers operating in the intermediate goods sector. They are perfectly competitive in the input market and monopolistically competitive in the output market, charging a markup to manufacturers and therefore creating a wedge between the wage paid by these firms and the wage received by households. Unions' profits are distributed to households in the form of dividends.

Manufacturers combine capital, rented from entrepreneurs, with labor services, hired from labor unions, to produce an intermediate good, which is thereafter sold to distributors. Manufacturers are perfectly competitive in the input market and monopolistically competitive in the output market, and face quadratic adjustment costs on price changes. They pay social security taxes on their payroll and capital income taxes on profits.

The financial accelerator mechanism depicted in Figure 1 comprises capital goods producers, entrepreneurs, and banks, along the lines of Bernanke *et al.* (1999) and Christiano *et al.* (2010). Financial frictions affect the after-tax return on capital and therefore capital accumulation. Capital goods producers are the exclusive producers of capital. Before each production cycle, they buy the undepreciated capital from entrepreneurs and combine it with investment goods bought from distributors to produce new installed capital, which is thereafter sold to entrepreneurs. Capital goods producers face quadratic adjustment costs when changing investment levels and are assumed to operate in a perfectly competitive environment in both input and output markets.

Entrepreneurs' actions have a direct effect on the capital accumulation of the economy. They do not have sufficient funds to finance desired capital purchases, but can cover the funding gap by borrowing from banks. They begin by choosing the optimal level of capital purchases. With net worth taken as given, such decision directly determines the balance sheet composition of the firm and therefore leverage. Entrepreneurs face a risky environment in which idiosyncratic shocks change the value of the capital stock (after the balance sheet composition has been decided). They are also responsible for selecting the capital utilization rate that maximizes the present discounted value of after-tax profits from the renting activity. At the end of each period, entrepreneurs buy the new capital stock from capital goods producers, and rent it for usage in the production process. Entrepreneurs pay a capital income tax on their profits.

Banks operate in a perfectly competitive environment, and their sole role is to borrow funds from asset holders and lend them to entrepreneurs. If an entrepreneur goes bankrupt, due to an adverse idiosyncratic shock, the bank must pay all bankruptcy costs to asset holders, such as auditing costs, asset liquidation or business interruption effects. Since capital acquisitions are risky, so are the loans of banks, who therefore charge a spread over the nationwide interest rate to cover for bankruptcy losses. Even though individual loans are risky, the aggregate banks' portfolio is risk free since each bank holds a fully diversified portfolio of loans. The contract celebrated between the entrepreneur and the bank features a menu of state contingent interest rates that ensure zero profits in each period and in all possible states of the world. All households loans are therefore secure at all times.

Distributors combine domestic intermediate goods with imported goods (identified in Figure 1 by $\mathcal{M}$) to produce all final goods. Consumption goods ($\mathcal{C}$) are acquired by households, government consumption goods ($\mathcal{G}$) by the government, and export goods ($\mathcal{X}$) by foreign distributors. Investment goods ($\mathcal{I}$), acquired by capital goods producers, are a key component of the financial accelerator mechanism. Analogously to manufacturers, distributors are perfectly competitive in the input market and monopolistically competitive in the output market and face quadratic adjustment costs on price changes. They pay capital income taxes on profits.

Government spending comprises not only the above-mentioned acquisition of public consumption goods from distributors but also lumpsum transfers to households and interest outlays. Spending is financed through tax levies on wage income, capital income, and households' consumption, and eventually through transfers from abroad. The government may issue one-period bonds to finance expenditure, paying an interest rate on public debt. Wage income taxes—henceforth referred to as labor taxes—include the contributions paid by employees and the payroll tax paid by manufacturers. Changes in taxes paid by employees ensure that debt follows a nonexplosive path, although automatic stabilization policies allow for the fiscal balance to temporarily deviate from the pre-determined target level.

The rest of the world corresponds to the rest of the monetary union, and thus the nominal efective exchange rate is irrevocably set to unity. The domestic economy interacts with the foreign economy via the goods market and the financial market. In the goods market, domestic distributors buy imported goods from abroad to be used in the production of final goods. Likewise for foreign distributors, who buy export goods from domestic distributors. In the international financial market, asset holders trade assets to smooth out consumption.

Observed variables and structural shocks

We estimate the model with quarterly observations over the 1999:1–2015:4 period using twenty four observable time series, which include real, nominal and financial variables. All endogenous variables and their transformation, prior to estimation, are reported in Table 1.

It should be noted that observed data transformations isolate the estimation from exogenous influences not directly accounted by the model's structure. The revenue-to-GDP ratio from payroll taxes and the social benefits-to-GDP ratio are two examples of observed data endowed with in-sample trends that are to a great extent related with a protracted increase in social protection and with aging. The model is not designed to capture these features, which assume a structural nature. To properly take into account their high frequency movement we computed the first (log) difference. We also demean most time series—thus suppressing exogenous trend growth differences or level differences—to favor the business cycle content of observed data and to avoid trending exogenous processes that affect the great ratios. All quarterly observations are seasonally adjusted. Whenever adjusted official series were not available, the transformation was performed using X12 ARIMA.

With the exception of foreign variables, we allow for measurement errors to take into account measurement noise in macro data. The variance of measurement errors is calibrated at 5 percent of the variance of each data series, except for financial data, where a higher noise justifies a larger value, of 25 percent.

We follow common practice in the literature and calibrate several non-identifiable or weakly identified parameters according to related empirical studies or micro evidence, or by matching "great ratios" or any other quantifiable steady-state measure. Prior information is combined with the likelihood to obtain the posterior kernel, which is maximized through a numerical optimization routine to obtain an estimate for the posterior mode and the corresponding variance-covariance matrix. This information is used as an input to initialize the Random-Walk Metropolis-Hastings algorithm, yielding a sample from the posterior density of model parameters. We compute 4 parallel chains of 1 million draws each, and discard the first 500 thousand as the burn-in phase. All estimation byproducts are evaluated at the posterior mean. Observed data series used in estimation and smoothed variables without measurement error are, in general, virtually identical, with the exception of credit growth and credit spread, where the higher measurement error drives a wedge between the two.[2]

2. All details can be found in Júlio and Maria (2017), including calibration options and prior and posterior distribution analysis. There may exist minor quantitative differences against the results reported herein, with no effect on the main messages.

Observed variables	Transformation
Real side	
GDP, per capita	First log difference, demeaned
Private consumption, per capita	First log difference, demeaned
Public consumption and investment, per capita	First log difference, demeaned
Private investment, per capita	First log difference, demeaned
Exports, per capita	First log difference, demeaned
Imports, per capita	First log difference, demeaned
Real wages, per capita	First log difference, demeaned
Hours worked, per capita	First log difference, demeaned
Nominal side	
GDP deflator	First log difference, demeaned
Private consumption deflator	First log difference, demeaned
Public consumption and investment deflator	First log difference, demeaned
Private investment deflator	First log difference, demeaned
Exports deflator	First log difference, demeaned
Fiscal policy	
Revenue-to-GDP ratio: indirect taxes	Level, demeaned
Revenue-to-GDP ratio: household income taxes	Level, demeaned
Revenue-to-GDP ratio: corporate taxes	Level, demeaned
Revenue-to-GDP ratio: Payroll taxes	First log difference, demeaned
Expenditure-to-GDP ratio: social benefits	First log difference, demeaned
Financial side	
Nationwide risk premium	Level (pp)
Real loans to Non-financial corporations, per capita	First log difference, demeaned
Corporate interest rate spread	Level (pp), demeaned
Euro area data	
Real GDP, per capita	First log difference, demeaned
GDP deflator	First log difference, demeaned
3-month EURIBOR	Level, demeaned

TABLE 1. Observed variables.

Source: Statistics Portugal, EUROSTAT and Banco de Portugal.

Notes: *Per capita* aggregates are computed with the overall population. Real wages are deflated by the private consumption deflator. Real loans are deflated by the GDP deflator. The nationwide risk premium is exogenously measured by the spread on the implicit interest rate on Portuguese government bonds *vis-à-vis* German bonds. The corporate interest rate spread is computed as the difference between the interest rate paid by non-financial corporations and the nationwide interest rate, which includes the risk premium. Percentage points are abbreviated to "pp."

The stochastic behavior of *PESSOA* is driven by twenty four structural shocks, which are aggregated into five categories, namely "Preferences & technology", "Domestic Markups", "Fiscal", "Financial" and "External/foreign" disturbances. The information content of each category is clarified in Table 2, which also includes the agent reported in Figure 1 that is directly affected

Component	Agent	Processes
Preference/technology shocks		
Consumption/labor supply choice	Households	AR(1)
Imports efficiency	*All distributors*	AR(1)
Stationary labor-augmenting technology	Manufacturer	AR(1)
Unit root labor-augmenting technology	Manufacturer	AR(1)
Private investment efficiency	Capital goods producer	AR(1)
Domestic markup shocks		
Wages	Labour Unions	AR(1)
Consumption prices	$\mathcal{C}$ - Distributor	iid
Investment prices	$\mathcal{I}$ - Distributor	iid
Government goods prices	$\mathcal{G}$ - Distributor	iid
Export prices	$\mathcal{X}$ - Distributor	iid
Fiscal shocks		
Public consumption and investment	Government	AR(1)
Transfers	Government	AR(1)
Tax rates: labour	Government	AR(1)
Tax rates: consumption	Government	AR(1)
Tax rates: capital	Government	AR(1)
Fiscal rule	Government	AR(1)
Financial shocks		
Nationwide risk premium	*Several*	AR(1)
Borrowers' riskiness	Entrepreneur	AR(1)
Entrepreneurial net worth	Entrepreneur	AR(1)
External/foreign shocks		
Import prices markup	*All Distributors*	iid
Export market share	$\mathcal{X}$ - Distributor	AR(1)
Euro-area inflation	$\mathcal{X}$ - Distributor	BVAR
Euro-area GDP growth	$\mathcal{X}$ - Distributor	BVAR
Euro area interest rate	*Several*	BVAR

TABLE 2. Stochastic content of *PESSOA*.

Source: the authors.

Notes: The unit-root labor-augmenting technology shock is implemented by assuming that the first difference of the shock follows a stationary AR(1) process. The Portuguese interest rate is defined as the sum of the Euro area interest rate and the exogenous nationwide risk premium. Column "Agent" identifies the agent reported in Figure 1 that is directly affected by the shock, whenever applicable. Column "Processes" identifies whether the iid-normal error terms are associated with autoregressive processes of order one.

by the shock, whenever applicable, although from a general equilibrium perspective all agents are potentially affected at all times by all disturbances.

Twenty-one shocks affect directly the domestic economy, either through iid or first-order autoregressive processes. The remaining three shocks, namely those driving euro area inflation, output and interest rate are pinned down

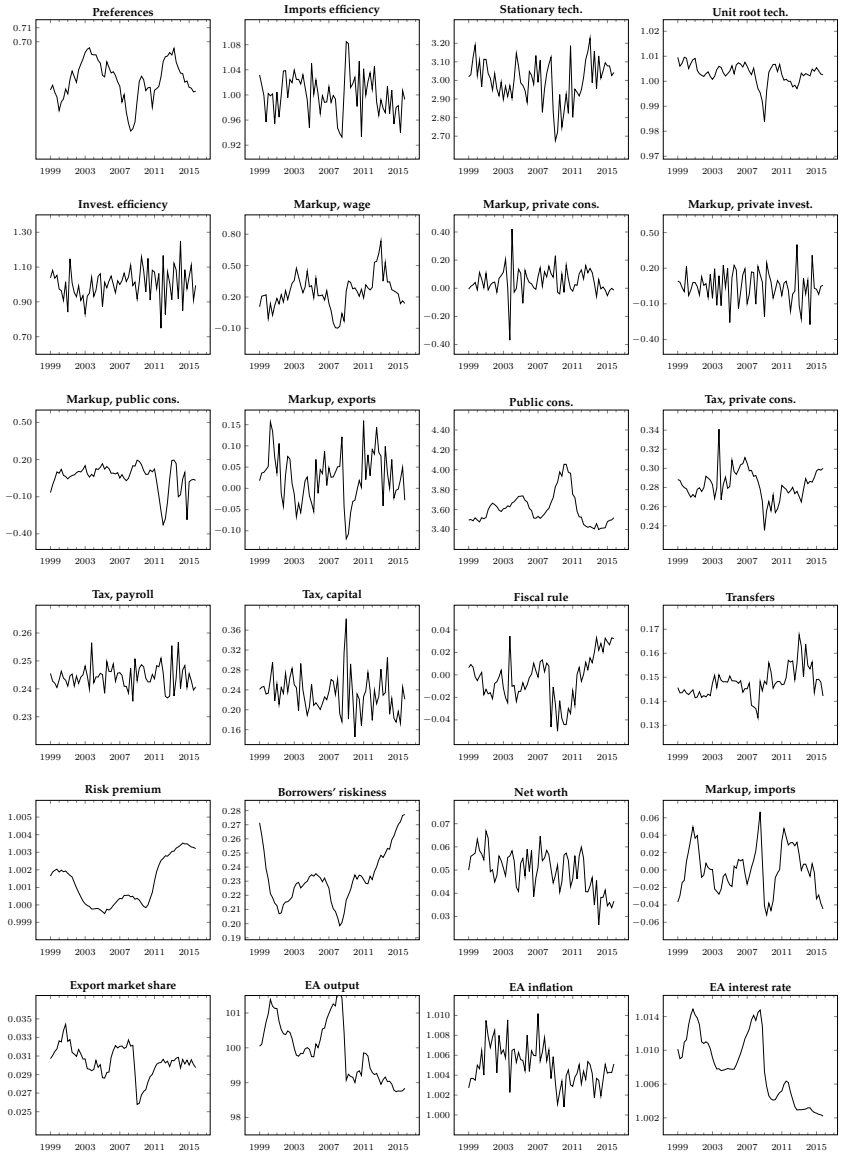

FIGURE 2: Smoothed shock processes.

Source: The authors.

Notes: Steady-state values can be found in Júlio and Maria (2017). The assumed processes behind each disturbance is reported in the last column of Table 2. "EA" identifies an Euro Area variable. EA output is set at 100 in the steady state.

by a Bayesian VAR (BVAR) *à la* Christiano *et al.* (2011), estimated jointly with the DSGE model. Figure 2 reports the estimated smoothed shocks over the 1999:1-2015:4 period.

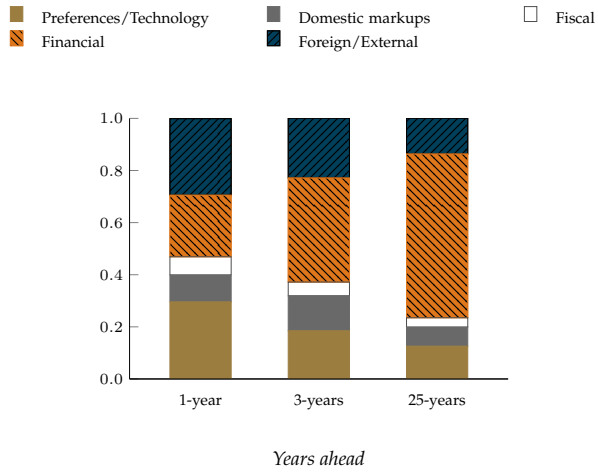

FIGURE 3: Forecast error variance decomposition for GDP.

Source: the authors.

Notes: The decomposition refers to the stationary component of the Portuguese GDP level, obtained after controlling for the level of technology.

A general equilibrium narrative for GDP

Figure 3 depicts the forecast error variance decomposition for the stationary component of GDP at horizons of 1, 3, and 25 years, while Figure 4 depicts the historical decomposition of year-on-year changes according to the above-mentioned five categories.

The most significant result associated with the variance decomposition outcome is the growing importance of financial factors as the time horizon increases. This tendency begins by dampening the effect of preference and technology shocks, and over longer horizons also of foreign/external factors. Domestic markups and fiscal policy decisions play a more limited role over all time horizons.

The relevance of financial factors is primarily attributed to the borrower's riskiness shock, which is always dominant in comparison with the remaining disturbances of this category. The relevance of this shock, which features a high persistence, is in line with recent empirical literature (Christiano *et al.* 2014). Nationwide risk premium is also relevant but particularly over short-term horizons. Over the medium and long run the entrepreneurial net worth shock becomes relatively more important.

The historical decomposition of the Portuguese GDP growth rate, computed on a quarterly basis over the 1999:1–2015:4 period, reveals that preference and technology shocks are key high frequency contributors, depicting a significant link with both GDP upturns and downturns.

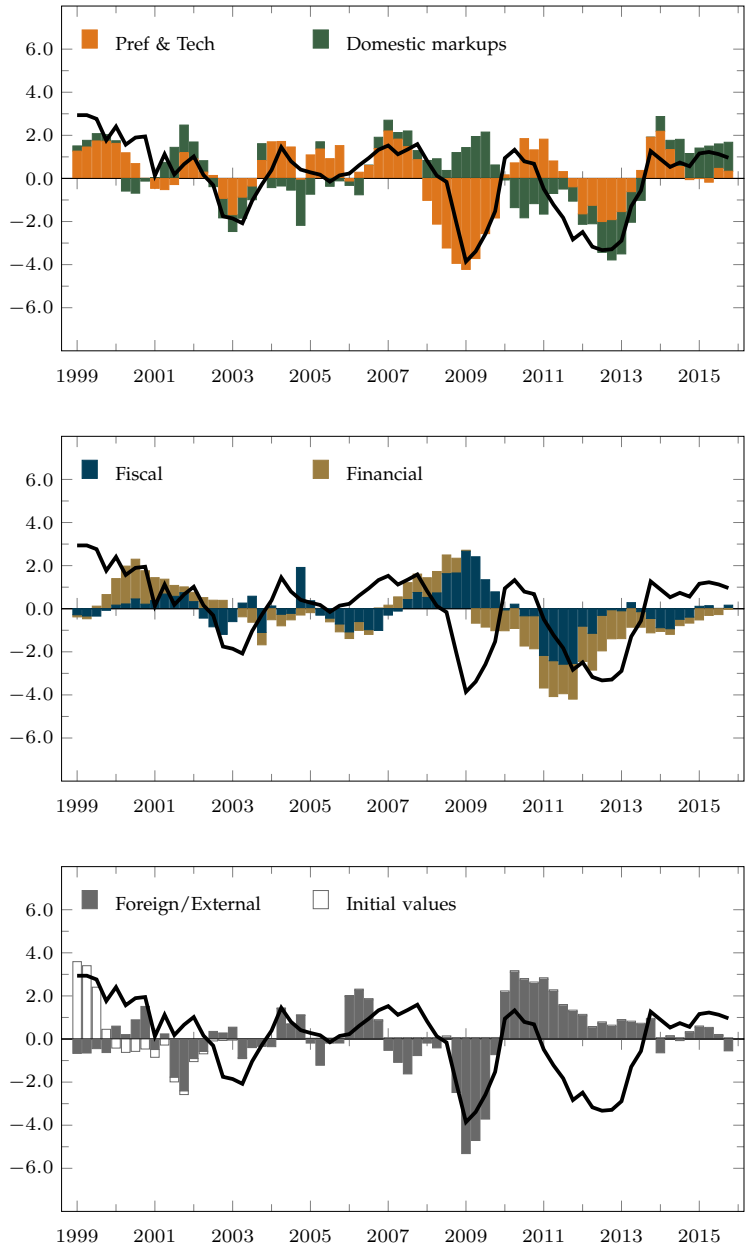

FIGURE 4: Historical decomposition of Portuguese GDP growth.

Source: The authors.

Notes: All results are in deviations from steady-state values. GDP growth is measured in terms of year-on-year changes. In *PESSOA*, the steady-state growth rate is identical in Portugal and in the Euro Area, and exogenously set at 1.2% (in line with the Euro Area average growth over the 1999:1–2015:4 period). Further details can be found in Júlio and Maria (2017). The information content of each category is clarified in Table 2. The vertical axis of each graph is in percentage for GDP growth (black line) and in percentage points for the contributions (bars).

Fiscal factors are neither systematically procyclical nor countercyclical, while financial and foreign/external factors feature a relatively high persistence, oscillating between protracted negative and positive contributions. The average contribution of financial factors over the sample period is negative, largely due to the last five years outcome, in contrast with the contribution of foreign/external factors. Domestic markup shocks are a more erratic category, explained to some extent by the assumed processes clarified in Table 2.[3]

The smoothed values of shock processes in financial variables suggest that Portugal was moderately disrupted by the 2008 worldwide financial turbulence.[4] The 2009 collapse in world trade and the concomitant decline in Euro Area GDP resulted however in powerful negative external shocks, accompanied by significant preferences/technology disturbances. GDP growth tumbled as a result, despite outweighing contributions from the fiscal side, most notably from government consumption, consumption taxes, and labor income taxes.

Foreign/external factors, influenced by the recovery of world trade, were the main driving force behind the economic recovery of early 2010, placing GDP growth near steady-state levels. However, domestic macroeconomic fragilities and financial markets turbulence triggered adverse financial shocks, especially an increase in the nationwide risk premium—incorporated in *PESSOA* as an exogenous development—and in borrower's riskiness. GDP plummeted again in early 2011, backed by a harsh fiscal adjustment where government consumption and investment plunged and taxes—especially on consumption and labor—hiked. The harsher part of the fiscal adjustment lasted until early 2012, though GDP growth remained below the steady-state level until late 2013, due to shocks on preferences/technology.

Portuguese GDP growth recovered from the double dip with the reversal of the effects triggered by some of these shocks, remaining above the steady-state growth rate from 2014 onwards. Domestic markups—in particular the wage markup—and external factors emerged as the main contributors to positive GDP growth in this later period.

Figure 5 draws the contribution of selected disturbances, among the twenty four structural shocks presented in Table 2, taking into account their correlation with the endogenous variable after 2008, and their relative importance. Results show that the 2009–10 downturn was particularly dominated by two structural shocks: the unit root technology and the exports market share shocks, mostly reflecting the worldwide economic turbulence, the fall in Euro Area GDP, and the 2009 collapse in world trade.

3. Due to identification difficulties, wage markup shocks are the only ones assumed to follow an AR(1) process.

4. The imports efficiency shock was a key depressing driver during 2008.

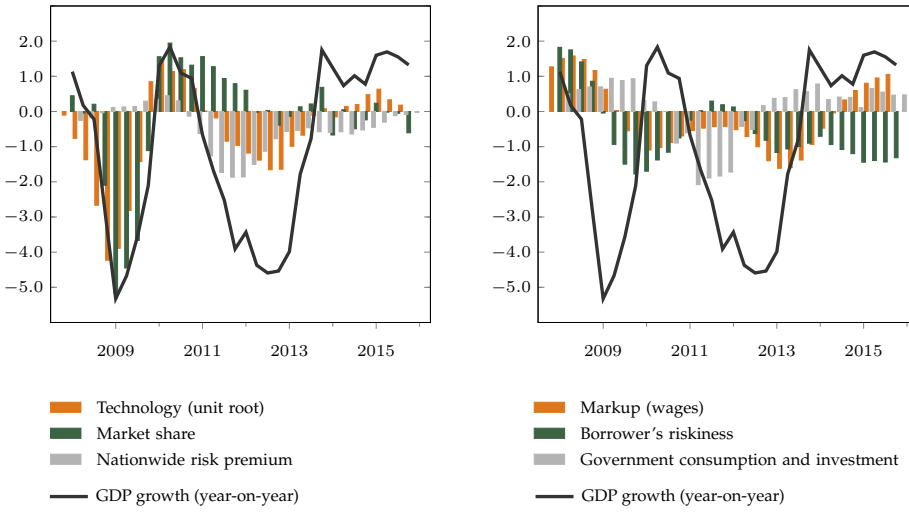

FIGURE 5: Contributions to GDP growth—selected shocks.

Source: The authors.

Notes: All results are in deviations from steady-state values. GDP growth is measured in terms of year-on-year changes.

The 2011–13 downturn was no longer dominated by two focal shocks and instead had more granular contributions. The unit root technology shock still emerges as an important disturbance, but the export market share no longer contributes to hinder GDP growth. Among all fiscal disturbances, justified by the adjustment process that the economy underwent over this period, the negative contribution of public consumption and investment was the most important. The adverse impact of the nationwide risk premium is also highlighted in Figure 5.

Finally, wage markup and borrower's riskiness shocks deserve a special emphasis in the Portuguese post-2008 period: both depicted a persistent dampening effect on GDP growth. However, the negative contribution of the wage markup disturbance came to an halt by 2014:4, turning to positive thereafter, whereas borrower's riskiness continued to wane on GDP growth.[5]

5. The wage markup shock is computed as a wedge between the theoretical perfect competition wage and the one effectively received by households, the latter included in the information set that we used to estimate the model. See Júlio and Maria (2017) for more details.

Concluding remarks

This article presents the results of an estimated version of *PESSOA*, a medium-scale small-open Dynamic Stochastic General Equilibrium model for the Portuguese economy.

Our findings suggest that fluctuations in financial factors are the most important driving force of the business cycle since the euro area inception, and played an important role in recent events. The post-2008 period is marked by a persistent increase in borrower's riskiness that in 2015 is still waning on GDP growth.

The Portuguese 2009–10 downturn was dominated by two focal effects: the unit root technology and the exports market share shocks, reflecting the worldwide financial turbulence, the fall in Euro Area GDP, and the 2009 collapse in world trade. The 2011–13 downturn has a more granular nature, although unit root technology shocks remain a key contributor. It includes for instance an important fiscal element, particularly the reduction in public consumption and investment, as well as a significant increase in risk (including the nationwide risk premium and the borrowers' riskiness).

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