Banco de Portugal Economic Studies

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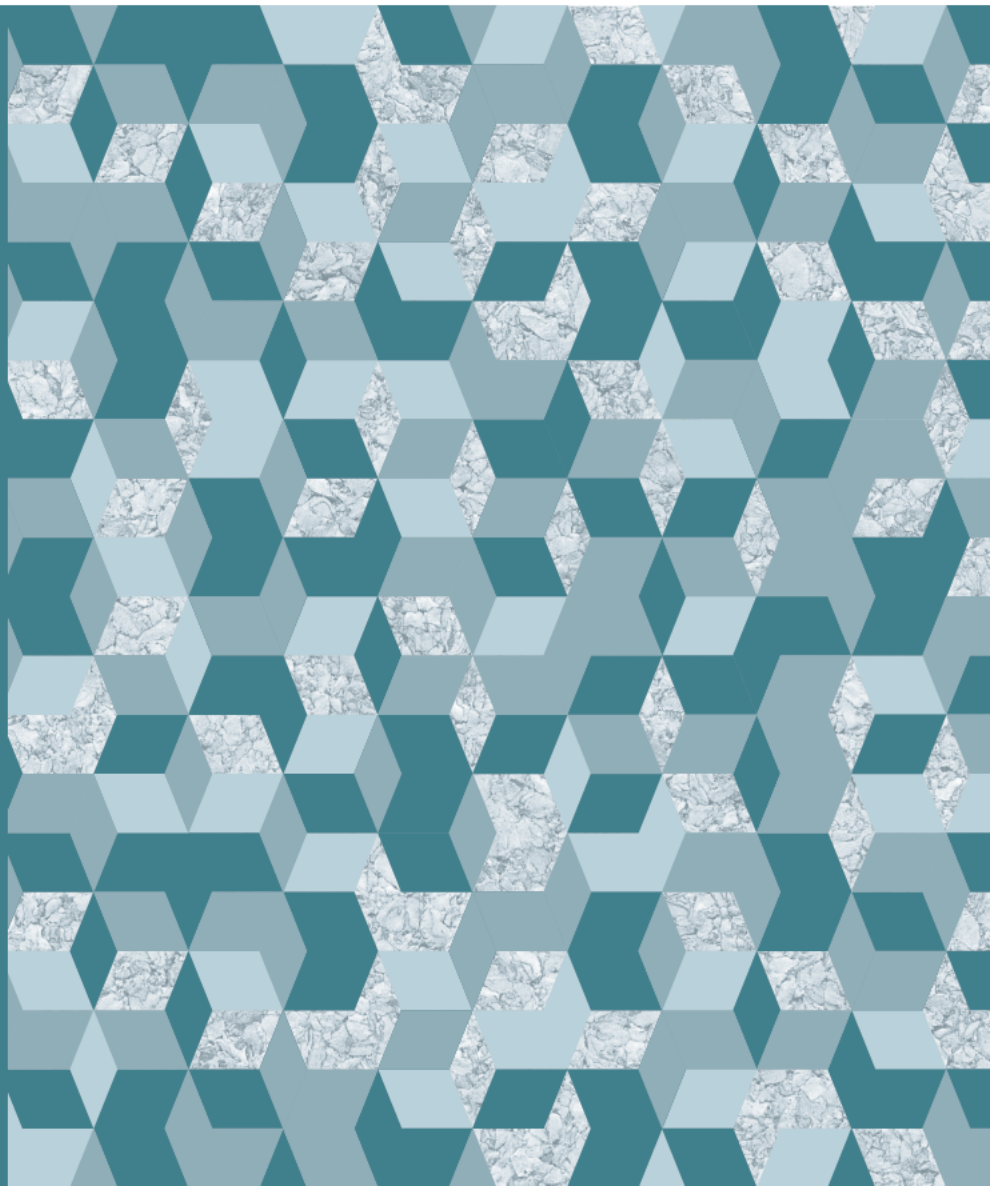

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Lisbon, 2017 • www.bportugal.pt

BANCO DE PORTUGAL ECONOMIC STUDIES | Volume III - n.º 2 | Lisbon 2017 • Banco de Portugal Av. Almirante Reis, 71 | 1150-012 Lisboa • www.bportugal.pt • Edition Economics and Research Department • Design Communication Directorate | Image and Graphic Design Unit | Editing and Publishing Unit • ISSN 2183-5217 (online)

Content

Editorial

April 2017

The second issue of Banco de Portugal Economic Studies for 2017 contains three diverse essays that cover the private returns to investment in education, an analysis of recent Portuguese business cycles through the lens of a Dynamic Stochastic General Equilibrium model, and a study of the impact of measurable uncertainty on macroeconomic variables. These essays have substantial contributions that improve our knowledge of the Portuguese economy and provide relevant information for policy makers.

The first paper, by Maria Manuel Campos and Hugo Reis, is titled "Revisiting the returns to schooling in the Portuguese economy". It is well known that Portugal's labor force was structurally characterized by low average levels of schooling comparing to other European countries. Since workers with higher levels of schooling were scarce, it came as no surprise that the rates of return to education were high by international standards. This was true in particular for higher (tertiary) education. Despite still lagging relative to other European countries, in the last 30 years Portugal has seen a large increase in the average levels of schooling of the labor force. This increase in supply, on its own, might have led to a drop in the rates of return to education. However, as in other countries, over time there has been a change in the production technologies of most industries increasing the demand for skilled and more educated workers. What was the outcome of the interplay between the larger supply and the larger demand for education? This is what the paper by Campos and Reis examines in depth by analyzing data from "Quadros de Pessoal" for the years 1986-2013 and reporting a large set of results that are well worth reading in detail.

What are some of the most interesting results in the paper? The basic results can be summarized as this: 1)average returns to schooling are high, reaching over 7% in 2013; 2)returns to schooling are higher for women (despite lower wages for otherwise similar characteristics); 3)the returns are higher at the top than at the bottom of the distribution of wages; 4)returns increased between 1986 and 2013. By focusing on "Quadros de Pessoal" data the estimates of the returns do not include the likely effects of schooling on employment rates and unemployment spells, but one suspects that including those effects might have led to even higher estimates for the rates of return to education.

The detailed results presented in the paper are also quite important. The wage premium for completing the 9th grade over those with less education roughly halved from 1986 to 2013 whereas it roughly doubled when comparing workers with secondary education versus those with the 9th grade alone. During the same period wages of male (female) workers with

tertiary education went from being 34% (33%) above those of workers with a secondary education to 45% (50%) above. However, in the more recent years of 2008-2013 there was a small decrease in the returns to tertiary education, with the drop being relatively larger for the youngest workers. The authors do not comment on that result but it may be early to ascertain whether these changes were due to the Great Recession or, instead, if they signal a structural change.

Despite these recent changes, the bottom line is that the overall returns to education are still quite high and education remains a remarkably good investment.

The second paper in this issue, by Cristina Manteu and Sara Serra, is titled "Impact of uncertainty measures on the Portuguese economy". It is intuitive that increasing levels of uncertainty have deleterious effects on economic activity, in particular when the decisions by economic agents have some irreversibility attached. Firms may cancel investment and hiring, consumers may postpone purchases of big ticket items, financial markets witness the growth of risk premia and prudent agents increase the levels of defensive behavior such as reducing consumption in order to bolster precautionary savings. All these changes in behavior add up and contribute to increases in the magnitudes of business cycles. The paper by Manteu and Serra examines quantitative measures of uncertainty and tracks their impact on GDP, investment and private consumption.

The paper starts by dealing with diverse ways researchers have used to measure uncertainty. A first group of measures is based on volatilities and risk spreads in financial markets. Other measures take into account the frequency of use of terms associated to economic uncertainty in the media. A third group of measures is based on the levels of disagreement revealed by economic forecasters or in surveys of economic sentiment. In the paper the authors combine measures of uncertainty of these three types to form a synthetic indicator of uncertainty for Portugal.

There are several findings of interest. The time series of the composite indicator shows increases in uncertainty during the last three recessions in Portugal and a decline since 2012. The annual and quarterly percent changes of the composite indicator have strong negative correlations with the changes in GDP, investment and private consumption. There is a high degree of similarity between the uncertainty measures for Portugal and for the euro area.

One potential problem with the basic results is that the link between peaks in measures of uncertainty and recessions is so tight that it might be the case these measures were mostly just a "reflection" of crisis times and thus that they did not add much to our understanding of economic fluctuations and ability to forecast them. That is not the case as the authors show convincingly. They dealt with the problem by conducting a careful and thorough multivariate analysis in the form of vector autoregressions

estimating models for the time-series properties of GDP, investment and private consumption together with a set of variables including the uncertainty measures, interest rates, inflation, employment, stocks of loans, etc.. The main result obtained is that the inclusion of uncertainty variables in the models improves the precision of the models' forecasts (somewhat less in the case of investment), in particular in the post-sovereign crisis period. The impulse response functions obtained from the models quantify the initial impact and its time-path of a shock on uncertainty. The consequences of the shocks as determined by the models are sizeable and statistically significant. Finally, the authors conduct a decomposition analysis, breaking down the GDP, investment and consumption annual rates of change into contributions from uncertainty and contributions from other factors. GDP shows the most relevant role for uncertainty, with negative contributions for GDP growth between 2008 and 2013, turning into positive contributions up to 2016. All in all, these results prove that uncertainty measures are not just "reflections" and that they provide additional information explaining the evolution of the main domestic macroeconomic variables.

In the third paper, by Paulo Júlio and José R. Maria and entitled "Output in the Portuguese post-2008 period: A general equilibrium narrative", the authors estimate the parameters of PESSOA, a small-open economy model conceived with the characteristics of an economy integrated in a monetary union in mind, and use it to provide an analysis of the shocks that have driven the fluctuations of the Portuguese economy since 2008. PESSOA is a Dynamic Stochastic General Equilibrium model and, as such, endowed with strong microeconomic theoretical foundations. It is built adopting a New Keynesian Economics approach with non-Ricardian effects, imperfect market competition, and a number of nominal and real rigidities.

The non-Ricardian effects come from a modeling structure with overlapping generations with life-cycle models where agents have stochastic finite lifetimes. They imply that government expenditure and its financing generate private consumption responses that do not lead to fiscal policy neutrality. Some households have assets and can use them to smooth consumption, whilst others are constrained by current income. The inclusion of financial frictions is done through a financial accelerator feature where firms need credit to operate, paying an interest cost which depends on the firms' leverage position and on bankruptcy costs. This approach allows the model to be explicit about financial shocks and to put them and their consequences under a magnifying glass. The small-economy assumption leads to domestic interest rates differing from central bank rates only by an exogenously determined risk premium. Monopolistic competition is present in labor and output markets. Capital goods producers face adjustment costs when changing investment levels and distributors have the same type of costs when changing prices.

The model is estimated for Portugal with quarterly observations over 1999-2015 and using 24 observable time series. The authors isolate the estimation from exogenous trend growth by removing the mean from each of the first-differenced time series. All quarterly observations are seasonally adjusted. The stochastic behavior of the model is driven by 24 structural shocks, grouped into five distinct categories: preference or technology disturbances; domestic markups; fiscal; financial; and external factors. The model is estimated by Bayesian methods and among the results reported in the paper are estimates of the shocks over time and, using the five categories, the variance decomposition for GDP.

The results that emerge from the model say that the 2008-2009 downturn was particularly dominated by shocks on technology and exports, reflecting the worldwide recession. The 2011-13 downturn had different sources: technological shocks were still important but not shocks on exports. Other relevant shocks with negative roles included public consumption and investment, a result of the adjustment process that the economy underwent over this period. Financial shocks were paramount on the 2008-2015 period with increases in both the country's and the borrowers' risk premia having a large impact on the cyclical evolution of GDP.

Revisiting the returns to schooling in the Portuguese economy

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April 2017

Abstract
This paper provides an overview of the evolution of the private returns to schooling in the Portuguese economy along the 1986-2013 period. We estimate the returns separately for men and women, at the mean and along the conditional wage distribution. Returns to schooling are found to be high, particularly for women, and to increase along the distribution. Our results point that the magnitude of the returns increased throughout the 1986-2013 period, but particularly in the 1990s. We also provide estimates of the relative wage premium associated with specific levels of educational attainment. The returns are highest for tertiary education. In the first decades under analysis, relative wage premia associated with the 9th grade stand above those estimated for secondary education, whereas in the most recent period these differences are negligible. All in all, our results suggest that education remains a profitable investment for individual agents. This is a valuable piece of information also for policymakers, who should take it into account together with the social returns to education when designing policies and incentive schemes. (JEL: I26, J31, C21)

Introduction

As formalized in Becker (1962), the assessment of the private returns to schooling provides a key piece of information for the individual decision determining the optimal level of investment in formal education. Regardless of the potential social returns to education, information on private returns is also relevant for policymakers, guiding them in the design of programs and incentive schemes to promote individual investment in education.

Individual returns to schooling are typically measured as the proportional increment in earnings resulting from an additional year of education on the basis of the so-called Mincerian wage equation (Mincer (1974)). There is a wide strand of empirical literature shedding light on the magnitudes and

Acknowledgements: We thank comments and suggestions by Nuno Alves, Cláudia Braz, Isabel H. Correia, Andy Garin, Miguel Gouveia, Pedro Portugal, Pedro Raposo and participants in a seminar held at Banco de Portugal. The views herein expressed are our own and do not necessarily coincide with those of Banco de Portugal or the Eurosystem.

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explanatory factors of returns to schooling in both advanced and emerging economies. Card (1999) provides a comprehensive review of existing literature on returns to schooling. Cross-country estimates are presented in, for instance, Psacharopoulos (1994), Martins and Pereira (2004), Psacharopoulos and Patrinos (2004) and Montenegro and Patrinos (2014).

International comparisons show that returns obtained for Portugal rank high among other European Union countries. Their evolution over the last decades may however have changed reflecting important reshufflings in the educational composition of the labour force that may have affected the way the market values education and specific schooling levels. In particular, female participation increased considerably in the last decades and women are increasingly more educated than men. More generally, the overall supply of workers completing tertiary and secondary education sharply increased, reflecting higher individual investment in university degrees, particularly since mid-1990s. At the same time, there was a strong reduction in the percentage of individuals with less than 9 years of education, reflecting the enactment of specific legislation extending compulsory schooling.[1]

This paper aims to complement the existing evidence on returns to schooling in the Portuguese economy and provide an overview of how they have changed since the late 1980s. In particular, we use *Quadros de Pessoal* data (QP henceforth) spanning the 1986-2013 period to estimate the returns to schooling separately for men and women, at the mean and along the conditional wage distribution. We also provide estimates of the relative wage premium associated with specific levels of educational attainment. The main goal of this paper is to provide a comprehensive description of the evolution of returns to schooling in this period, without claiming a causal relationship between schooling and earnings.

In broad terms, our results may be summarized as follows: the returns to schooling are found to be high, particularly in the case of women, and to increase along the distribution. The returns are highest for tertiary education. In the first decades under analysis, relative returns to the 9th grade stand above those estimated for secondary education. In the most recent period these differences are negligible, in line with the typical evolution in advanced economies (Montenegro and Patrinos (2014)). The detailed analysis undertaken in this paper allows the pinpointing of exceptions to these general findings.

1. Note that in spite of the remarkable changes underwent by the Portuguese economy in recent decades, the share of workers with at least secondary education remains the lowest in the European Union. According to Labour Force Survey data made available by the Eurostat, in 2016, 46.8 per cent of employed individuals in Portugal had completed either secondary or tertiary educational attainment. This figure compares with 73.4 per cent in the European Union as a whole.

Our results are broadly in line with previous studies on the estimation of the private returns to schooling in the Portuguese economy. Vieira (1999), using QP data for the 1982-1992 period, found evidence of returns to schooling of approximately 7 per cent at the mean of the wage distribution. Acknowledging that conventional estimates based on Mincerian equations are hampered by the so-called "ability bias", Vieira (1999) attempts to circumvent it by estimating the returns to schooling using instrumental variables (IV). Specifically, the author uses changes to compulsory schooling legislation as an exogenous source of variation in educational attainment. This results in lower - albeit still positive - returns to education. Sousa *et al.* (2015) also focus only on returns at the mean of the distribution. Using QP data spanning the 1986-2009 period and a standard Mincer equation, they found returns of 10.0 per cent in the case of men and close to 10.5 per cent for women in the last year under analysis. Sousa *et al.* (2015) also use IV, presenting results based on three different instruments: changes to compulsory education, quarter of birth and the average education by region in the year the individual first entered school. In this case estimates of returns to schooling are higher than those obtained using OLS, but show a similar evolution over time.

There are other studies that assess the returns at different points of the conditional wage distribution - not only at the mean. Machado and Mata (1998), using QP data for the 1982-1994 period, found returns ranging from 4 to 11 per cent, respectively at its lower and upper part (and aroud 7-8 per cent at the mean). Similar evidence is provided in Hartog *et al.* (2001). In the latter case, however, the authors consider a richer set of covariates in the regressions, which yields slightly lower returns than in Machado and Mata (1998). Martins and Pereira (2004) also provide estimates of returns to schooling at different points of the distribution. Using the 1995 wave of QP, they find increasing returns along the distribution (of 6.5 and 14.5 per cent, respectively at the bottom and at the top of the distribution).

Alves *et al.* (2010) and Portugal (2004) provide estimates of the returns to tertiary education. In both cases, the authors find positive and significant returns benefiting individuals with university degrees (relative to non-university educated counterparts). Alves *et al.* (2010) provide estimates of the tertiary education wage premium at different points of the distribution and on the basis of QP data for 1982, 1995 and 2006. In the latter year, they find returns ranging from approximately 45 per cent to almost 100 per cent, respectively at lower and upper quantiles of the distribution.

It is worth highlighting that we do not resort to IV or control function methods for estimating the private returns to schooling. Estimates based on these methods are highly dependent on the sub-sample whose schooling attainment is affected by the change in the instrument chosen for the analysis. Different instruments yield different estimates of the returns to schooling and lead to different interpretations (Imbens and Angrist (1994)). Moreover, we are interested in providing a broad picture of the evolution of returns along the

1986-2013 period and, as shown in Sousa *et al.* (2015), relying in IV estimates does not change the overall evolution.

Finally, note also that our paper focuses only on the *private* (or individual) returns to education and does not address the *social* returns to education. The latter stem from the existence of positive externalities (from higher labour productivity, to lowering crime rates, improving overall health standards, decreasing mortality rates, or promoting better citizenship and voting decisions - refer to Lochner (2011) for a comprehensive review). Assessing these effects are out of the scope of this article.

The paper is organized as follows: Section 2 presents the data source, also providing a comprehensive analysis of descriptive statistics. Section 3 describes the theoretical framework underlying the estimations presented in the article, whereas Section 4 sheds light on the strategy used to implement the analysis. Section 5 lists the key results of the article. Finally, Section 6 presents the main conclusions and discusses topics relevant in terms of education policy.

Data description

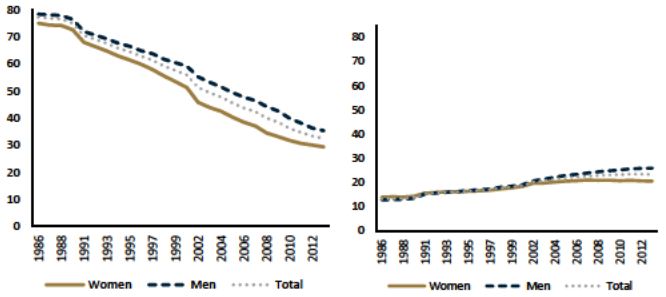
Data are drawn from *Quadros de Pessoal*, a matched employer-employee dataset including a personal identification number that allows the tracing of individuals across time. The information is based on a compulsory survey conducted annually by the Ministry of Social Security. Data covers every establishment paying wages in the Portuguese private sector: general government, military staff, self-employed and household employees are thus excluded. The questionnaire covers attributes of workers and firms. Regarding the former, it includes information on gender, age, education, occupation, industry, tenure and earnings, among other dimensions. For the purpose of our analysis, we use data covering the 1986-2013 period (except 1990 and 2001 for which data are not available). We focus on a sub-sample made of full- and part-time employees aged between 16 and 65 years.

We define wages as the sum of every work-related category of income (including base salary, overtime pay, and other regular payments). Hourly wages are adjusted for the whole amount of working hours, both normal and supplementary. Real wages are computed on the basis of each year's Consumer Price Index (taking 1986 as the base-year). In QP, individual educational attainment corresponds to a categorical variable reporting the highest level completed.[2] An additional variable providing information on the minimum number of school years required to complete the highest educational level reported was also created.

2. More precisely, we consider the mode of the highest level of education reported throughout the panel.

Table 1 briefly describes selected QP waves used for the analysis. It provides evidence of a remarkable increase in the average schooling, from 5.6 to 9.9 years, respectively in 1986 and 2013. This reflects a significant drop in the share of employees reporting lower educational levels and a strong increase in the percentage with either secondary or tertiary education (Figure 1).

This evolution was particularly noticeable in the case of female employees. They are, on average, more educated than men throughout the entire period under analysis and this disparity widened in the last decade. In particular, the percentage of female employees with an university degree increased from 2.3 per cent in the 1986 wave of QP to 22.0 per cent in 2013 (panel D of Figure 1).



(A) Individuals who did not complete 9th grade

(B) Individuals who completed the 9th grade

(C) Individuals who completed secondary education (12 years)

(D) Individuals who completed tertiary education

FIGURE 1: Employees by level of educational attainment (percentage).

Source: Authors' calculations based on *Quadros de Pessoal*.

In spite of their better educational endowments, QP data show that, on average, women earn consistently lower wages than male employees over the whole period (Figure 2). Nonetheless, although the two genders have experienced similar real wage increases in the first part of the 1986-2013 period, women's earnings have been growing more sharply than men's since 2000 (Figure 3). As emphasised in Cardoso *et al.* (2016), this evolution may be explained by a composition effect stemming from the higher educational

		1986	1991	1996	2000	2005	2010	2013
Women	Education (years)	5.73	6.54	7.37	8.16	9.17	10.09	10.39
		[3.42]	[3.57]	[3.84]	[4.05]	[4.26]	[4.38]	[4.38]
	Age (years)	32.34	32.24	34.18	35.08	36.56	38.06	39.37
		[10.2]	[10.26]	[10.15]	[10.15]	[10.17]	[10.31]	[10.21]
	Tenure (years)	8.55	7.34	7.77	7.21	7.21	7.61	8.53
		[7.15]	[7.83]	[7.98]	[7.97]	[7.66]	[7.92]	[8.2]
	No. obs.	327,634	467,428	584,109	714,836	836,568	923,898	901,793
	% of total	33.1	36.7	39.9	41.5	42.2	45.2	47.3
Men	Education (years)	5.50	6.17	6.89	7.40	8.18	9.03	9.45
		[3.33]	[3.5]	[3.7]	[3.81]	[3.96]	[4.08]	[4.08]
	Age (years)	36.30	36.35	36.88	37.27	37.79	39.01	39.92
		[11.65]	[11.74]	[11.32]	[11.16]	[10.84]	[10.68]	[10.5]
	Tenure (years)	9.56	8.93	8.84	8.11	7.73	8.14	8.89
		[8.05]	[8.71]	[8.62]	[8.52]	[8.07]	[8.27]	[8.54]
	No. obs.	662,723	806,480	880,628	1,009,561	1,144,560	1,118,236	1,003,012
	% of total	66.9	63.3	60.1	58.5	57.8	54.8	52.7
Total	Education (years)	5.6	6.31	7.08	7.71	8.60	9.51	9.9
		[3.36]	[3.53]	[3.76]	[3.93]	[4.12]	[4.25]	[4.25]
	Age (years)	34.99	34.84	35.80	36.36	37.27	38.58	39.66
		[11.35]	[11.39]	[10.95]	[10.8]	[10.58]	[10.53]	[10.37]
	Tenure (years)	9.23	8.34	8.42	7.73	7.51	7.90	8.72
		[3.36]	[3.53]	[3.76]	[3.93]	[4.12]	[4.25]	[4.25]
	No. obs.	990,357	1,273,908	1,464,737	1,724,397	1,981,128	2,042,134	1,904,805

TABLE 1. Descriptive statistics.

Source: Authors' calculations based on *Quadros de Pessoal*.
Notes: Unless otherwise specified, the table reports averages (and standard-deviations in brackets). Variable "tenure" corresponds to the number of years working in the current firm.

level of the women joining the labour market. Indeed, on average, wages for university- educated women, who represent an increasing share of our

sample, grew more than wages of males with the same educational level (Figure 4).

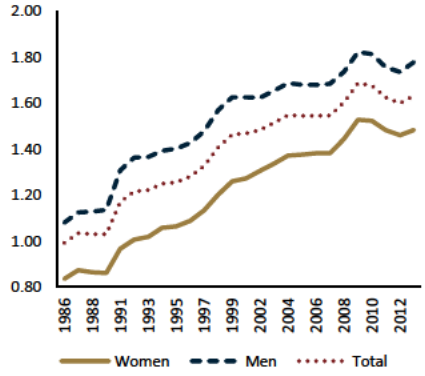


FIGURE 2: Average real wage per hour (in euro).

Source: Authors' calculations based on *Quadros de Pessoal*.
Note: The chart depicts the average real wage per hour worked in each wave of QP (deflated using CPI, 1986 base year).

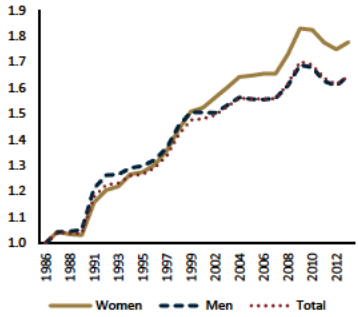


FIGURE 3: Real wage growth (index 1986=1).
Source: Authors' calculations based on *Quadros de Pessoal*.

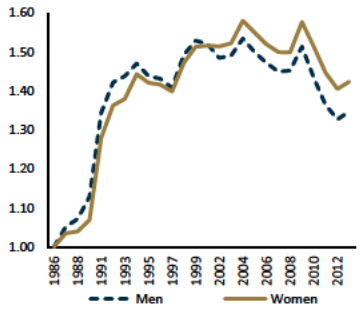
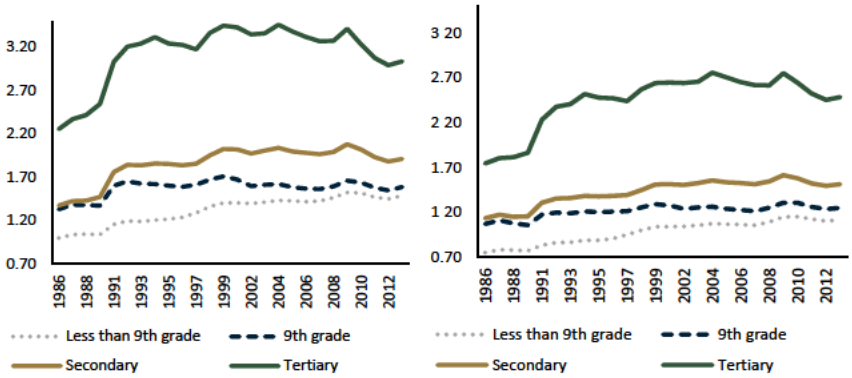


FIGURE 4: Real wage growth for workers with tertiary education (index 1986=1).
Source: Authors' calculations based on *Quadros de Pessoal*.

Figure 5 depicts the average real wage by educational level along the 1986-2013 period. As expected, wages increase with education but differences between workers with tertiary education and their less educated counterparts are particularly significant. This differential widened up to 1995, remained relatively constant up to mid-2000s and, more recently, it has been shrinking.

Focusing on workers with lower educational level, Figure 5 also points out that while in the late 1980s wages of individuals who did not complete the 9th grade were considerably below those referring to workers who did, this difference almost disappears in more recent QP waves. Conversely, whereas

in the beginning of the period average real wages were similar among workers with the 9th grade and those having completed secondary schooling, the gap between the two groups has been widening since the 1990s.



(A) Male workers (B) Female workers

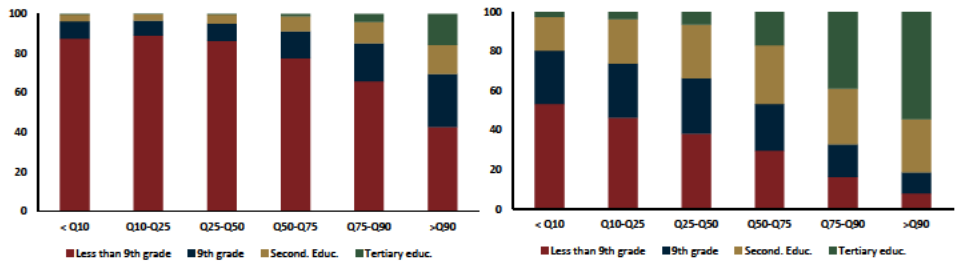
FIGURE 5: Average hourly wage by educational level.
Source: Authors' calculations based on *Quadros de Pessoal*.

For both genders the distribution of wages has shifted to the right and become slightly less compressed than in the late 1980s (details depicted in Appendix A). This increase in wage inequality was particularly noticeable at the upper tail of the distribution and only up to mid-1990s, having remained stable since then. The wage distribution is more compressed in the case of less educated individuals.

The educational *composition* of individuals across the distribution changed considerable along the 1986-2013 period. While in 1986 the share of workers with tertiary (or even secondary) educational attainment with below-median wages was low, it increases when focusing on the 2013 wave of QP (Figure 6). Although this may reflect a wide range of aspects and changes in the composition of private employment or in the productive structure of the economy, it can also be interpreted as a symptom of an over-education phenomenon.

Theoretical framework

Becker (1962) pioneered in applying utility theory to investment in education. In his framework the proportional pecuniary returns associated with educational attainment are a key component of the individual decision on whether and by how much to invest in human capital. In particular, individuals select the optimal number of years of schooling so as to maximise



(A) 1986 data (B) 2013 data

FIGURE 6: Educational composition of the wage distribution.

Source: Authors' calculations based on *Quadros de Pessoal*.

the discounted present value of future earnings net of the cost of schooling. This corresponds to an optimization problem whose solution is such that individuals would continue to invest in additional education up to the point where the marginal benefits match the marginal costs.

Mincer (1974) provided an empirical approximation to the marginal benefits' side of the individuals' optimization problem. In particular, the so-called traditional Mincerian wage equation corresponds to:

$$\ln y_i = \alpha + \beta S_i + \lambda_1 Exp_i + \lambda_2 Exp_i^2 + \varepsilon_i \tag{1}$$

where β corresponds to the pecuniary return from an additional year of formal education and Exp refers to individuals' experience in the labour market. As the bulk of literature on the relationship between education and earnings, we rely on Mincer's framework for the estimation of the returns to schooling.

Card (1999) made it clear that the decision on how much to invest in schooling is very much conditional on individual preferences and it is subject to individual heterogeneity, both in terms of the marginal returns to schooling (determined by, for instance, differences in individual ability) and in terms of its costs (accounting for differences in rates of substitution between schooling and future earnings on the basis of, *eg*, access to funds or personal taste). This implies a heterogeneous effects framework in which the way covariates affect wages varies across individuals.

Empirical strategy

To estimate the returns to schooling in the Portuguese economy we adopt the standard approach relying on Mincerian wage regressions such as the one in Equation (1). The regressions are run separately for each wave of QP, assuming

a cross-sectional set-up. We adopt a homogeneous effect framework, in the sense that we assume that the impact of schooling on wages of is the same for all individuals: $\beta_i = \beta_1 = ... = \beta_N$, for all $i = 1, ..., N$.

Moreover, we take individuals' age as a proxy for overall labour market experience and, in line with Mincer (1974), we also consider a second order polynomial. Our regressions include a set of other covariates: the individual's tenure in the current firm (also as a second order polynomial), the logarithm of the current firm's size and, when pooling data jointly for men and women, gender dummies (equal to one for male employees). We allow for some additional flexibility by running the wage regressions separately for men and women using the same set of covariates, except for the gender dummy.[3].

Returns to an additional year of schooling

Our baseline specification corresponds to

$$\ln y_i = \alpha + \beta S_i + \lambda_1 age_i + \lambda_2 age_i^2 + \mathbf{x}_i^T \gamma + \varepsilon_i \tag{2}$$

where y_i corresponds to individuals' real hourly wage (deflated using CPI taking 1986 as the base year) and S_i represents the minimum number of schooling years required to complete the highest level reported by the individual. As such, coefficient β, our parameter of interest, represents the per cent increase in hourly wage resulting from an additional year of schooling estimated using Ordinary Least Squares (OLS). Vector $\mathbf{x}_i$ groups the set of observable characteristics aforementioned and estimates for the parameters in vector γ measure the respective marginal impact on y_i. Finally, the marginal impact of age is given by $\hat{\lambda}_1 + 2 * \hat{\lambda}_2 age_i$, where age_i refers to the worker's age.

In spite of adopting a homogeneous effect set-up, we allow for some heterogeneity in the returns by letting them change depending on the individuals' placement along the conditional distribution of wages. In particular, we also run our baseline specification within the Quantile Regression (QR) framework proposed in Koenker and Bassett (1978). This allows our covariates to affect the shape and tail behaviour of the conditional wage distribution and implies assuming

$$\ln y_i = \alpha_\theta + \beta_\theta S_i + \lambda_{1,\theta} age_i + \lambda_{2,\theta} age_i^2 + \mathbf{x}_i^T \gamma_\theta + \varepsilon_{\theta,i}, \tag{3}$$

where θ represents different quantiles of the conditional distribution of hourly wages: $\theta = \{0.1, 0.25, 0.5, 0.75, 0.9\}$. Therefore, β_θ corresponds to the return

3. For the purpose of assessing robustness of the estimates, we also ran regressions including industry and region controls. This brings down the magnitude of the coefficient associated with schooling attainment, but the evolution of returns over time is same (Appendix B)

to an additional year of schooling at the θ-th quantile of distribution of the logarithm of hourly wages conditional on the individuals' observed attributes. By assessing the returns to schooling at these different quantiles, we complement the evidence provided by OLS, which refers to the mean of the wage distribution.

Returns to specific education levels

In addition to the baseline specification, we also consider an alternative specification in which the highest completed level of schooling is included on the basis of dummy variables:

$$\ln y_i = \alpha + \sum_{j=2}^{4} \beta_j E_{j,i} + \lambda_1 age_i + \lambda_2 age_i^2 + \mathbf{x}_i^T \gamma + \varepsilon_i, \tag{4}$$

where $E_j, j = \{1, 2, 3, 4\}$ are indicator variables that equal one for individuals reporting each of the following levels of schooling attainment: 1) less than the 9th grade; 2) 9th grade; 3) secondary education; and 4) tertiary education. The first category is omitted in the regressions. In this case, each $\beta_j, j > 1$ corresponds to the wage premium benefiting individuals holding schooling level j vis-à-vis comparable counterparts with less than the 9th grade ($j = 1$). We also implement this alternative specification within a QR framework:

$$\ln y_i = \alpha_\theta + \sum_{j=2}^{4} \beta_{\theta,j} E_{j,i} + \lambda_{1,\theta} age_i + \lambda_{2,\theta} age_i^2 + \mathbf{x}_i^T \gamma_\theta + \varepsilon_{\theta,i}, \tag{5}$$

As pointed out by Card (2001), estimates of returns to schooling based on Mincerian wage equations may be hampered by two sources of bias. In the first place, there may be mismeasurements in terms of the individual schooling, in which case estimates of β would be downward biased. Although the possibility of measurement errors cannot be ruled-out, as we are using an administrative data source we are confident that erroneous cases are negligible in our sample.

The second source of bias arises from fact that we are not controlling for the whole set of individual-specific attributes that affect wages ("ability bias"). These factors - some of which are not observable - are included in error term ε_i. If they are also correlated with schooling attainment, generating endogeneity, the estimator would also be inconsistent. Since the standard Mincerian equation does not account for the impact of individual innate ability on wages and educational level, $\hat{\beta}$ would be upward biased. As we are interested in providing a broad overview of returns to schooling along the 1986-2013 period and not on analysing causal relationships, we do not apply methods such as IV or control function for circumventing these issues.

Moreover, estimates based on these methods are highly dependent on the sub-sample whose schooling attainment is affected by the change in the elected instruments (Imbens and Angrist (1994)).

Findings

Returns to an additional year of schooling

Figure 7 presents the estimates of returns to schooling obtained from running OLS regressions with specification (2) in each available wave of QP.[4]

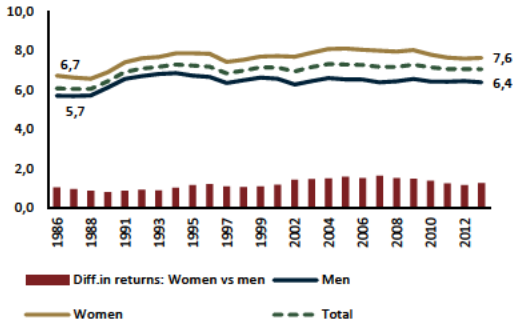


FIGURE 7: OLS-based returns to an additional year of schooling.

Source: Authors' calculations based on *Quadros de Pessoal*.
Note: The chart depicts the coefficient of S_i estimated on the basis of specification (2) using OLS. Coefficients are significant at the 1% level.

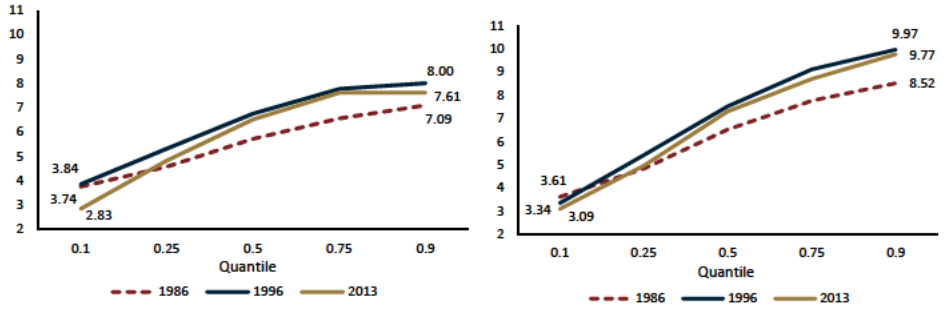
It provides evidence of positive returns to an additional year of schooling both in the case of men and women. In the latter case, the estimated returns are slightly higher, over the whole period in analysis: in 2013, an additional year of schooling is estimated to yield, on average, a 7.6 per cent increase in females' hourly wage, whereas for men the estimated increment stands at 6.4 per cent. The gender gap in the returns is statistically significant along the entire period and has remained relatively stable since 1986. Over time, there has been a slight increase in the returns for both genders. This increase was

4. All coefficients are significant. Table B.1 in Appendix B presents the full set of results of non-gender specific regressions for selected years. Results obtained for the whole 1986-2013 period, also split for male and female workers, are available upon request. Table B.1 also presents the results of the estimation of specification (2) controlling for industry and region effects. Introducing these additional covariates yields a decrease in the magnitude of the returns to schooling, but the overall picture does not change.

particularly marked along the 1990s and in more recent decades the returns remained relatively constant, albeit with a minor drop as of 2009.[5]

Results presented in Figure 7 refer to the estimates of returns to an additional year of schooling *at the mean* of the conditional wage distribution. Such evidence may hide important differences at different points of the distribution. By relying on the QR framework we are able to estimate the returns to schooling at different quantiles. Results obtained with this methodology are summarized in Figure 8.

Figure 8 indeed shows that the magnitude of the estimates for the returns to schooling changes considerably along the distribution. For instance, estimates obtained on the basis of OLS using the 2013 wave of QP and pooling data for both men and women point that an additional year of schooling implies a mean 6.4 per cent increase on wages. This figure masks the fact that, applying the same procedure to the same data but using the QR framework, one additional year of schooling yields a 3.1 per cent wage increase at the 1st decile of the distribution and a 8.8 per cent impact at the 9th.



(A) Male workers (B) Female workers

FIGURE 8: Returns to schooling across the wage distribution (per cent).

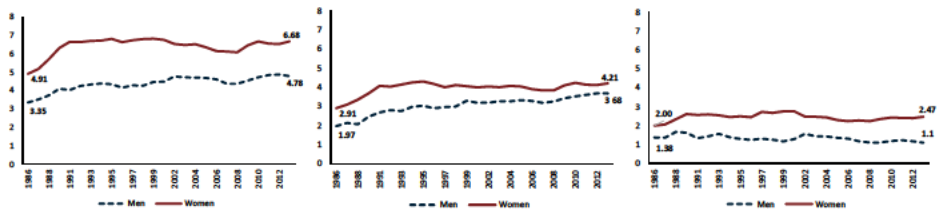
Source: Authors' calculations based on *Quadros de Pessoal*.
Note: The charts depict the per cent wage increment from an additional year of schooling, obtained on the basis of specification (3). For greater detail refer to Appendix B.

In fact, estimates of returns to schooling increase along the wage distribution. This feature holds for both genders, but it is particularly noticeable in the case of women. Evidence presented in Figure 8 also clarifies that the increase in returns to schooling along 1986-2013 period holds only for individuals placed above the 25th quantile of the wage distribution. Returns estimated at its lower tail using the 2013 QP wave stand below those obtained

5. Significance tests show that this drop, although small, is statistically significant.

using the 1986 data. Moreover, up to 2003, evidence of higher returns for women also holds only above the 1st decile of the distribution.[6]

The comparison between the returns to schooling estimated at different points of the distribution provides a measure of their dispersion. Such comparison, illustrated in Figure 9, shows in the first place that, across the whole distribution, returns are more dispersed among women than among men. In both cases, inequality in returns widened along the 1986-2013 period, but it was particularly noticeable in the case of female employees and in the early 1990s. This evolution seems to be largely driven by developments at the lower part of the conditional wage distribution, since at the upper quantiles inequality in returns has remained relatively stable. Moreover, among high earners variability in the returns is lower than at the lower part of the wage distribution.



(A) Q90 vs Q10 (B) Q50 vs Q10 (C) Q90 vs Q50

FIGURE 9: Dispersion in returns to schooling (percentage points).

Source: Authors' calculations based on *Quadros de Pessoal*.
Note: The charts depict the difference between the returns to schooling estimated for different points of the distribution.

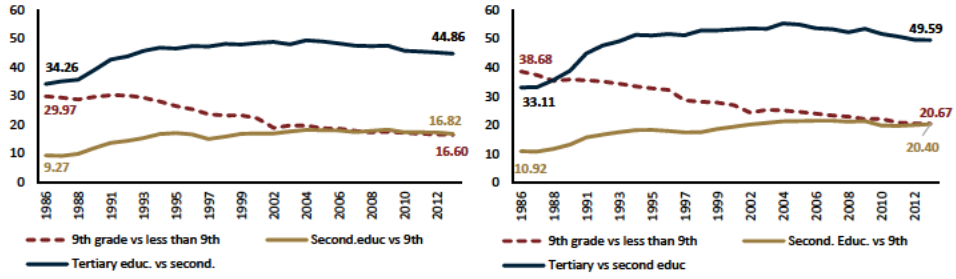
Returns to specific education levels

On the basis of specifications (4) and (5) it is possible to assess the average wage premium associated with specific levels of education. In this case, coefficients β_j, $j = \{2, 3, 4\}$, represent the wage gain from completing schooling level j relative to individuals who have not completed the 9th grade (corresponding to education level $j = 1$, the omitted category. As we are interested in the wage gain relative to the schooling level immediately

6. Note that the differences in the returns estimated on the basis of QR for the 1986 and 2013 waves of QP are found to be statistically significant.

before, we plot in Figure 10 the difference in the coefficients estimated using specification (4) as follows:

$$r_{9th} = \beta_2$$
$$r_{secondary} = \beta_3 - \beta_2$$
$$r_{tertiary} = \beta_4 - \beta_3$$



(A) Male workers (B) Female workers

FIGURE 10: Returns to schooling at the mean of the wage distribution by educational attainment (per cent).

Source: Authors' calculations based on *Quadros de Pessoal*.
Note: The charts depict the per cent wage premium associated with each educational level relative to level immediately before. For greater detail refer to Appendix B.

In the first place, Figure 10 confirms that women benefit from larger returns to education than men, except as regards the relative premium associated with tertiary education in the first years of the sample. It also shows that the increase over time in overall returns to schooling documented in the previous subsection is largely driven by the evolution of the premium associated with tertiary education. Indeed, in the beginning of the 1986-2013 period, completing an university degree is estimated to yield male workers a 34.3 per cent premium vis-à-vis completing secondary education, while for women such figure stands at 33.1 per cent. Results obtained using the 2013 wave of QP imply that men holding an university degree enjoy a 44.9 per cent wage premium relative to comparable workers who complete only secondary education. For women, such figure stands at 49.6 per cent.

Regarding secondary education, there is evidence that the gain relative to completing only the 9th grade increased along the 1986-2013, but it is still considerably below the one referring to tertiary education: 16.8 per cent for men and 20.4 per cent for women. The increase in the premia estimated for secondary and tertiary education occurred against a background of an expansion in the pool of workers holding these schooling levels, suggesting that it may have been demand-driven.

The premium for tertiary education increased markedly in the first half of the 1990s - especially in the case of women - and then remained stable

up to 2009, when there is a minor decline in its magnitude. Evidence from regressions focusing specifically on university-educated individuals aged between 25 and 45 suggests that the younger workers benefit from lower returns to schooling and have experienced a slightly larger drop in returns than the overall sample (Figure 11).

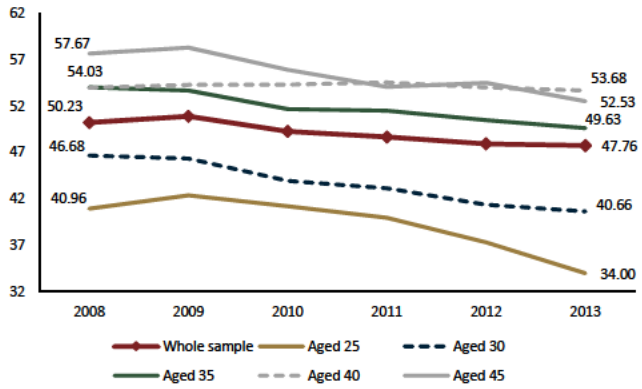


FIGURE 11: Returns to tertiary education in the post-2009 period for younger cohorts (per cent).

Source: Authors' calculations based on *Quadros de Pessoal*.
Note: The chart depicts the relative wage increment from obtaining an university degree vis-à-vis completing only secondary education. Figures are obtained pooling data for both men and women.

Finally, it is worth highlighting the sharp decline in the premium associated with completing the 9th grade. In the late-1980s, it was very close to the relative wage gain enjoyed by individuals holding an university degree (in the case of women it was in fact higher). Since then, our estimates suggest a decline and the magnitude estimated on the basis of 2013 data corresponds to approximately half the figures obtained with the 1986 QP wave. This evolution is in line with the pattern typically found for advanced economies (Montenegro and Patrinos (2014)).

The drop in the returns to the 9th grade has been accompanied by an increase in the share of employees reporting it as the highest level completed (and a sharp decline in those holding less than the 9th grade). This evolution, plotted in Figure 12, may be related to the fact that compulsory schooling was extended to the 9th grade in 1986. The measure applied only to individuals born as of 1980, which would be showing up in QP data as of 1996.

However, even older individuals who were still attaining school in 1986 may have anticipated that the market would start valuing completion of the 9th grade and decided to study longer - either to complete just the 9th grade or further levels as a differentiation factor. This would result in a decline in the

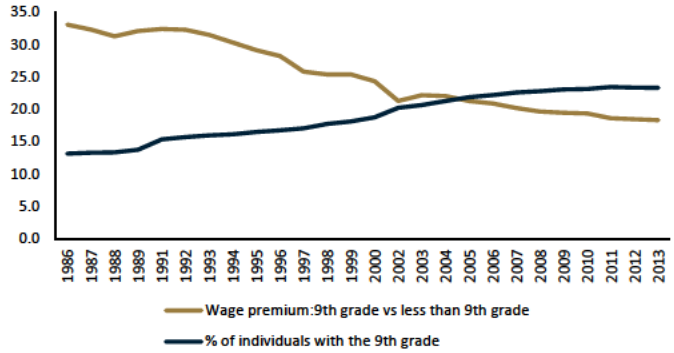
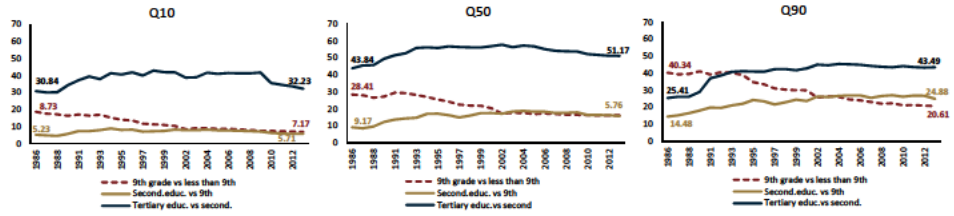


FIGURE 12: Returns to completing the 9th grade *vs* share of individuals with the 9th grade.

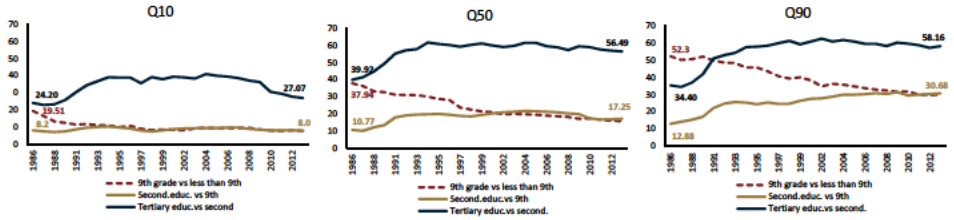
Source: Authors' calculations based on *Quadros de Pessoal*.

share of individuals with less than the 9th grade even before the first cohorts affected by the legal change join the labour force. Although it is not possible to establish a causality link between this decline and the drop in the returns to the 9th grade, *ceteris paribus*, an expansion in the pool of workers who have completed the latter level would in principle result in such an evolution. This suggests that the drop in the premium for completing the 9th grade was supply-driven. Additionally, this evolution may have been reinforced by selection effects. In particular, it is arguable that the individuals who drop-out after completing the 9th grade in the recent period differ from those who did it some years or decades ago, in terms of characteristics that may result in lower returns to schooling (eg, younger 9th grade drop-outs may be expected to have, on average, poorer innate ability endowments, or less favourable family backgrounds).

Evidence obtained from QR estimates of specification (5), presented in Figure 13, shows that, for women, the relative premium from completing tertiary education increases along the wage distribution. In the case of male employees, such evidence holds only below the 9th decile. Figure 13 also suggests that the rise in the relative return to university degrees occurred throughout the wage distribution, but it is more noticeable at the upper quantiles and in the case of women. Regarding the already mentioned drop in the magnitude of the returns as of 2009, it appears to result from developments at the lower tail of the conditional distribution. Finally, regarding the premia estimated for completing secondary education and the 9th grade, their average evolutions are driven by results in the upper quantiles, as below the median of the wage distribution they have remained broadly constant.



(A) Male workers



(B) Female workers

FIGURE 13: Returns to schooling across the wage distribution by educational attainment (per cent).

Source: Authors' calculations based on *Quadros de Pessoal*.

Discussion and concluding remarks

This article provided evidence of the existence of private returns to schooling in the Portuguese economy. The returns increased in the late-1980s and the 1990s, especially as regards tertiary education. This occurred in parallel with an expansion of the pool of workers holding university degrees, suggesting it was surpassed by a rise in the demand for skilled labour. During the late-1990s and early-2000s, the returns remained relatively constant, largely reflecting the stabilization of the wage premium for tertiary education. In the post-2009 period, however, our results point to a minor decrease in the magnitude of the returns, both in the case of tertiary and secondary education.

In spite of these changes along the 1986-2013 period, the overall picture does not change: the returns to schooling are found to be higher in the case of women and to increase along the wage distribution and with educational attainment: formal education appears to be more valued for women and high-pay and high-skill jobs. Several factors may be put forward as possible explanations of the evolution of returns to schooling just described.

A phenomenon of over-education, which we have indeed documented, is the first one: over-education, measured as a non-negligible share of highly-educated workers in blue-collar occupations, results in their placement in the bottom quantiles of the wage distribution. This translates into low returns

to schooling for these individuals, increasing dispersion within the same educational level and contributing to explain the pattern of increasing returns along the distribution.

The effects of over-education may be a reflection of qualitative aspects of schooling: while the estimation of the returns takes only into account the *quantity* of educational attainment, it disregards factors such as school quality or the different valuation attributed to different areas of study. Attending poor-quality schools or investing in a field of study that receives low valuation in the labour market would, in principle, result in low-pay jobs and in positions requiring low skills.

We cannot rule-out the possibility that the developments hereby described are affected by the fact that individual differences in ability (or other unobserved attributes) are not being controlled for. In particular, it is expectable that differences in individual ability play a bigger role in explaining the dispersion in returns among more skilled workers. For low-educated individuals, by contrast, differences shall be relatively washed-down. Not controlling for these differences would result in an overestimation of returns to schooling in the upper quantiles of the distribution and reinforce the effects of over-education and low school quality.

In spite of focusing only on the *private* returns to education, our results unveil important messages for individuals and policymakers alike: in Portugal, education remains a profitable investment for individual agents and policymakers must take this into account when designing policies and incentive schemes.

The returns are highest for tertiary education and it is likely that individuals will continue to invest in education and, in particular, in university degrees. Compulsory schooling has recently been extended to 12 years, encompassing secondary education. This may also provide incentives for individuals that would otherwise leave school to go further and complete a tertiary educational level to differentiate themselves from the holders of secondary schooling. These factors would in principle result in the expansion of the student population in the next decades but are likely to be counteracted by demographic trends.

Against a background of tight budgetary constraints, the challenge for policymakers relies in ensuring the quality of public school system while providing low-income households conditions to access tertiary level education. Moreover, this cannot be done at the expense of low quality pre-school or elementary education, as investments in lower schooling levels increase the returns to subsequent ones[7]. These tensions may require a reshuffling in terms of the funding sources of public expenditure on education policy. A common suggestion relies on increasing the share of costs supported

7. Refer to Heckman and Cunha (2007).

by the individuals in tertiary education. This line of reasoning is based on the idea that *social* returns to schooling are relatively lower for tertiary levels, whereas *private* returns are high - an evidence supported by our empirical findings. Examples of measures aimed at increasing individual participation in financing include mere increases in tuition or the recently higher education reform in the UK encompassing the setting-up of loan scheme that is contingent on graduates' future earnings. Resorting to this sort of measures may create additional leeway to reinforce support to low-income households.

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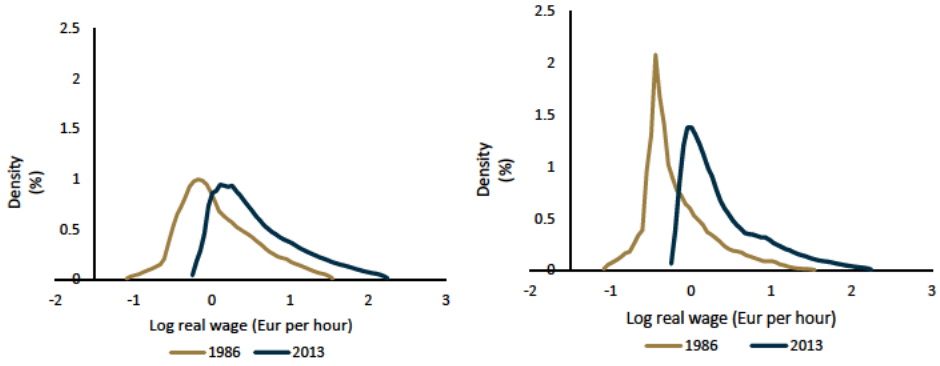
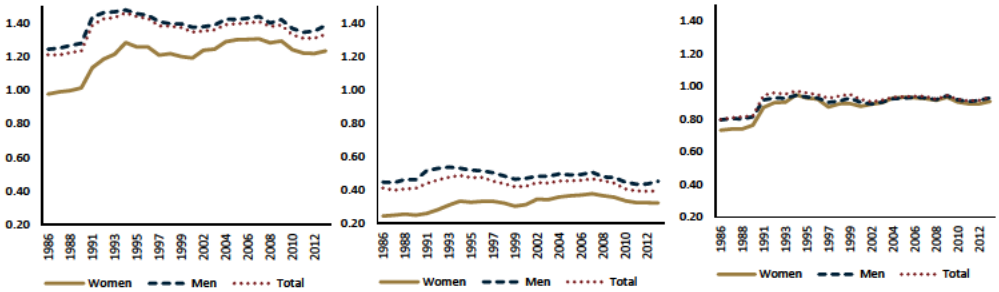
Appendix A: Details on the empirical distribution of the logarithm of hourly wages



(A) Men (B) Women

FIGURE A.1: Distribution of real wages in 1986 and 2013.

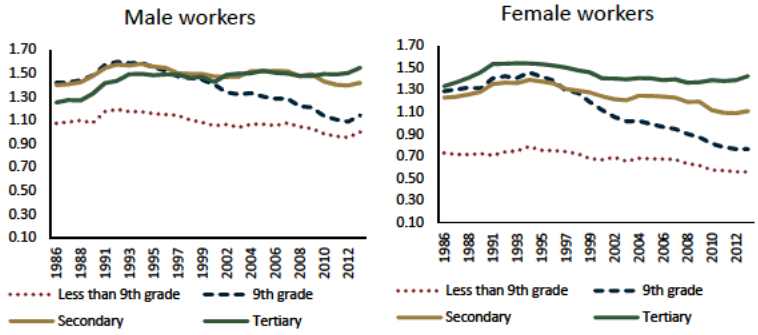
Source: Authors' calculations based on *Quadros de Pessoal*.



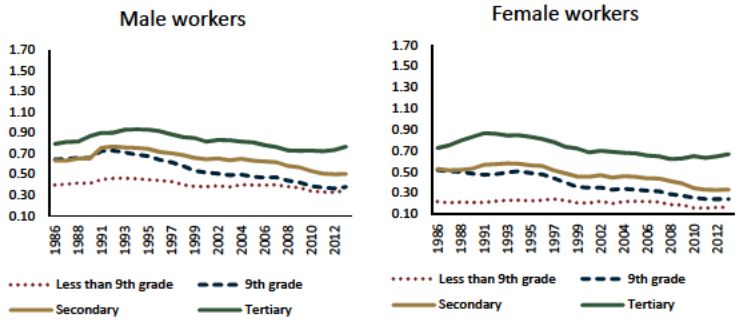
(A) Q90 vs Q10 (B) Q50 vs Q10 (C) Q90 vs Q50

FIGURE A.2: Real wage dispersion.

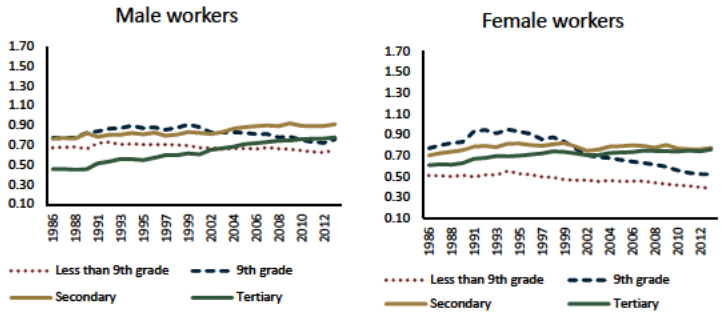
Source: Authors' calculations based on *Quadros de Pessoal*.
Note: Charts depict the difference in the logarithm of real hourly wages at different points of the distribution.



(A) Q90 vs Q10



(B) Q50 vs Q10



(C) Q90 vs Q50

FIGURE A.3: Real wage dispersion by schooling attainment.

Source: Authors' calculations based on *Quadros de Pessoal*.
Note: Charts depict the difference in the logarithm of real hourly wages at different points of the distribution.

Appendix B: Estimation results

	Baseline specification (2)					Specification (2) with additional controls				
	1986	1996	2005	2010	2013	1986	1996	2005	2010	2013
Educ. (years)	0.0608***	0.0719***	0.0730***	0.0715***	0.0706***	0.0478***	0.0580***	0.0640***	0.0638***	0.0637***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Age	0.0580***	0.0458***	0.0413***	0.0404***	0.0423***	0.0489***	0.0406***	0.0382***	0.0363***	0.0374***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Age sqrd.	-0.0006***	-0.0004***	-0.0004***	-0.0004***	-0.0004***	-0.0005***	-0.0004***	-0.0003***	-0.0003***	-0.0003***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sex (male=1)	0.1858***	0.2526***	0.2567***	0.2449***	0.2477***	0.1530***	0.1957***	0.2154***	0.2036***	0.1992***
	(0.0007)	(0.0006)	(0.0006)	(0.0005)	(0.0006)	(0.0007)	(0.0007)	(0.0006)	(0.0006)	(0.0006)
Firm size (log)	0.0778***	0.0832***	0.0715***	0.0497***	0.0446***	0.0590***	0.0621***	0.0539***	0.0335***	0.0303***
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Tenure	0.0078***	0.0117***	0.0166***	0.0165***	0.0164***	0.0097***	0.0122***	0.0174***	0.0162***	0.0159***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Tenure sqrd.	-0.0000***	-0.0002***	-0.0002***	-0.0002***	-0.0001***	-0.0001***	-0.0002***	-0.0003***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
							(0.1064)	(0.0934)		
Intercept	-2.1323***	-1.9018***	-1.7187***	-1.6105***	-1.7051***	-2.0086***	-1.6877***	-1.5613***	-1.4275***	-1.5136***
	(0.0033)	(0.0035)	(0.0034)	(0.0035)	(0.0039)	(0.0042)	(0.0043)	(0.0043)	(0.0043)	(0.0046)
Region controls	N	N	N	N	N	Y	Y	Y	Y	Y
Industry controls	N	N	N	N	N	Y	Y	Y	Y	Y
R-squared	0.54	0.53	0.49	0.45	0.45	0.63	0.59	0.53	0.50	0.49
N	990215	1464732	1981128	2042134	1904805	990215	1464732	1981128	2042134	1904805

TABLE B.1. Wage regressions - OLS.

Source: Authors' calculations based on *Quadros de Pessoal*.
Notes: Coefficients obtained from OLS regressions using specification (2) pooling data for men and women. Standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	Baseline specification (4)					Specification (4) with additional controls				
	1986	1996	2005	2010	2013	1986	1996	2005	2010	2013
9th grade	0.3309***	0.2824***	0.2127***	0.1936***	0.1832***	0.2360***	0.1966***	0.1663***	0.1577***	0.1508***
	(0.0011)	(0.0009)	(0.0007)	(0.0007)	(0.0008)	(0.0009)	(0.0008)	(0.0007)	(0.0007)	(0.0008)
Second. educ.	0.4365***	0.4604***	0.4138***	0.3839***	0.3720***	0.3156***	0.3304***	0.3278***	0.3117***	0.3058***
	(0.0016)	(0.0010)	(0.0008)	(0.0008)	(0.0008)	(0.0012)	(0.0009)	(0.0008)	(0.0008)	(0.0008)
Tertiary educ.	0.7643***	0.9508***	0.9356***	0.8767***	0.8496***	0.6521***	0.8005***	0.8321***	0.7883***	0.7697***
	(0.0026)	(0.0017)	(0.0011)	(0.0010)	(0.0010)	(0.0019)	(0.0014)	(0.0010)	(0.0009)	(0.0009)
Age	0.0569***	0.0437***	0.0397***	0.0401***	0.0425***	0.0471***	0.0381***	0.0360***	0.0356***	0.0370***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Age sqrd.	-0.0006***	-0.0004***	-0.0004***	-0.0004***	-0.0004***	-0.0005***	-0.0004***	-0.0004***	-0.0003***	-0.0004***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sex (male=1)	0.1947***	0.2543***	0.2581***	0.2484***	0.2525***	0.1606***	0.1964***	0.2167***	0.2068***	0.2030***
	(0.0007)	(0.0006)	(0.0005)	(0.0005)	(0.0006)	(0.0007)	(0.0007)	(0.0006)	(0.0006)	(0.0006)
Firm size (log)	0.0784***	0.0841***	0.0713***	0.0500***	0.0450***	0.0584***	0.0620***	0.0532***	0.0333***	0.0303***
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Tenure	0.0068***	0.0123***	0.0179***	0.0173***	0.0169***	0.0087***	0.0127***	0.0187***	0.0170***	0.0164***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Tenure sqrd.	-0.0000	-0.0002***	-0.0003***	-0.0002***	-0.0001***	-0.0001***	-0.0002***	-0.0003***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Intercept	-1.8229***	-1.4761***	-1.2544***	-1.1626***	-1.2639***	-1.7812***	-1.3597***	-1.1697***	-1.0422***	-1.1261***
	(0.0033)	(0.0035)	(0.0034)	(0.0035)	(0.0039)	(0.0042)	(0.0043)	(0.0042)	(0.0043)	(0.0046)
Region controls	N	N	N	N	N	Y	Y	Y	Y	Y
Industry controls	N	N	N	N	N	Y	Y	Y	Y	Y
R-squared	0.52	0.52	0.49	0.46	0.46	0.61	0.59	0.54	0.51	0.50
N	990215	1464732	1981128	2042134	1904805	990215	1464732	1981128	2042134	1904805

TABLE B.2. Wage regressions - OLS.

Source: Authors' calculations based on *Quadros de Pessoal*.
Notes: Coefficients obtained from OLS regressions using specification (4) pooling data for men and women. Standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	1986			1996			2005			2010			2013		
	P10	P50	P90	P10	P50	P90	P10	P50	P90	P10	P50	P90	P10	P50	P90
Educ. (years)	0.0385***	0.0611***	0.0762***	0.0394***	0.0719***	0.0887***	0.0371***	0.0732***	0.0902***	0.0326***	0.0716***	0.0885***	0.0309***	0.0709***	0.0881***
	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
Age	0.0503***	0.0530***	0.0705***	0.0235***	0.0405***	0.0655***	0.0188***	0.0386***	0.0599***	0.0147***	0.0368***	0.0600***	0.0135***	0.0387***	0.0646***
	(0.0002)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)
Age sqrd	-0.0006***	-0.0006***	-0.0007***	-0.0002***	-0.0004***	-0.0006***	-0.0002***	-0.0003***	-0.0005***	-0.0001***	-0.0003***	-0.0005***	-0.0001***	-0.0003***	-0.0006***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sex (male=1)	0.1522***	0.1906***	0.2174***	0.1710***	0.2575***	0.3158***	0.1533***	0.2568***	0.3393***	0.1244***	0.2407***	0.3268***	0.1206***	0.2391***	0.3379***
	(0.0008)	(0.0008)	(0.0015)	(0.0005)	(0.0007)	(0.0014)	(0.0004)	(0.0006)	(0.0012)	(0.0003)	(0.0006)	(0.0012)	(0.0003)	(0.0006)	(0.0012)
Firm size (log)	0.0667***	0.0766***	0.0813***	0.0711***	0.0829***	0.0801***	0.0537***	0.0716***	0.0735***	0.0287***	0.0488***	0.0529***	0.0257***	0.0429***	0.0506***
	(0.0002)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0003)	(0.0001)	(0.0002)	(0.0003)	(0.0001)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0003)
Tenure	0.0073***	0.0074***	0.0084***	0.0116***	0.0136***	0.0038***	0.0129***	0.0167***	0.0106***	0.0112***	0.0167***	0.0112***	0.0128***	0.0170***	0.0088***
	(0.0001)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
Tenure sqrd	-0.0001***	-0.0000***	-0.0000	-0.0002***	-0.0002***	0.0001***	-0.0002***	-0.0002***	-0.0001***	-0.0002***	-0.0002***	-0.0000***	-0.0002***	-0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Intercept	-2.1000***	-2.0584***	-2.1252***	-1.4851***	-1.8398***	-1.9750***	-1.1600***	-1.6994***	-1.8373***	-0.8478***	-1.5666***	-1.7899***	-0.8485***	-1.6566***	-1.9629***
	(0.0041)	(0.0035)	(0.0066)	(0.0019)	(0.0035)	(0.0073)	(0.0016)	(0.0035)	(0.0073)	(0.0015)	(0.0032)	(0.0077)	(0.0015)	(0.0033)	(0.0085)
N	990215	990215	990215	1464732	1464732	1464732	1981128	1981128	1981128	2042134	2042134	2042134	1904805	1904805	1904805

TABLE B.3. Wage regressions - Quantile regressions.

Source: Authors' calculations based on *Quadros de Pessoal*.
Notes: Coefficients obtained from QR using specification (3). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	1986			1996			2005			2010			2013		
	P10	P50	P90	P10	P50	P90	P10	P50	P90	P10	P50	P90	P10	P50	P90
9th grade	0.1995***	0.3219***	0.4409***	0.1359***	0.2636***	0.3751***	0.0996***	0.1904***	0.2861***	0.0862***	0.1747***	0.2580***	0.0813***	0.1653***	0.2534***
	(0.0013)	(0.0014)	(0.0022)	(0.0009)	(0.0011)	(0.0019)	(0.0006)	(0.0008)	(0.0016)	(0.0004)	(0.0007)	(0.0017)	(0.0004)	(0.0007)	(0.0018)
Second. educ.	0.2628***	0.4312***	0.5866***	0.2364***	0.4497***	0.6192***	0.1955***	0.3962***	0.5699***	0.1635***	0.3548***	0.5352***	0.1530***	0.3418***	0.5285***
	(0.0017)	(0.0020)	(0.0027)	(0.0011)	(0.0012)	(0.0021)	(0.0007)	(0.0009)	(0.0017)	(0.0005)	(0.0008)	(0.0018)	(0.0005)	(0.0008)	(0.0018)
Tertiary educ.	0.5473***	0.8431***	0.8663***	0.6331***	1.0206***	1.1082***	0.6006***	0.9837***	1.1092***	0.4940***	0.9108***	1.0676***	0.4502***	0.8800***	1.0503***
	(0.0054)	(0.0029)	(0.0035)	(0.0038)	(0.0021)	(0.0024)	(0.0020)	(0.0013)	(0.0018)	(0.0016)	(0.0011)	(0.0018)	(0.0014)	(0.0010)	(0.0019)
Age	0.0499***	0.0508***	0.0709***	0.0221***	0.0371***	0.0626***	0.0174***	0.0347***	0.0573***	0.0141***	0.0343***	0.0582***	0.0139***	0.0366***	0.0632***
	(0.0002)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0004)
Age sqrd.	-0.0006***	-0.0006***	-0.0008***	-0.0002***	-0.0004***	-0.0006***	-0.0002***	-0.0003***	-0.0005***	-0.0001***	-0.0003***	-0.0005***	-0.0001***	-0.0004***	-0.0006***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sex (male=1)	0.1610***	0.1981***	0.2189***	0.1697***	0.2576***	0.3154***	0.1517***	0.2550***	0.3411***	0.1264***	0.2415***	0.3327***	0.1248***	0.2418***	0.3459***
	(0.0008)	(0.0008)	(0.0015)	(0.0005)	(0.0007)	(0.0014)	(0.0005)	(0.0006)	(0.0012)	(0.0004)	(0.0006)	(0.0012)	(0.0004)	(0.0006)	(0.0012)
Firm size (log.)	0.0653***	0.0768***	0.0811***	0.0697***	0.0834***	0.0818***	0.0525***	0.0699***	0.0749***	0.0279***	0.0467***	0.0544***	0.0255***	0.0403***	0.0515***
	(0.0002)	(0.0002)	(0.0004)	(0.0001)	(0.0002)	(0.0003)	(0.0001)	(0.0002)	(0.0003)	(0.0001)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0003)
Tenure	0.0067***	0.0062***	0.0076***	0.0112***	0.0145***	0.0047***	0.0132***	0.0182***	0.0121***	0.0116***	0.0173***	0.0122***	0.0136***	0.0166***	0.0094***
	(0.0002)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
Tenure sqrd	-0.0001***	0.0000***	0.0000***	-0.0003***	-0.0002***	0.0001***	-0.0002***	-0.0002***	-0.0001***	-0.0002***	-0.0002***	-0.0000***	-0.0002***	-0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Intercept	-1.8962***	-1.7218***	-1.7707***	-1.2250***	-1.3824***	-1.4688***	-0.8965***	-1.1694***	-1.2918***	-0.6226***	-1.0440***	-1.2513***	-0.6578***	-1.1268***	-1.4207***
	(0.0039)	(0.0034)	(0.0067)	(0.0018)	(0.0035)	(0.0071)	(0.0021)	(0.0034)	(0.0076)	(0.0016)	(0.0028)	(0.0079)	(0.0018)	(0.0030)	(0.0085)
N	990215	990215	990215	1464732	1464732	1464732	1981128	1981128	1981128	2042134	2042134	2042134	1904805	1904805	1904805

TABLE B.4. Wage regressions - Quantile regressions.

Source: Authors' calculations based on *Quadros de Pessoal*.
Notes: Coefficients obtained from QR using specification (5). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Impact of uncertainty measures on the Portuguese economy

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April 2017

Abstract
The purpose of this article is to review developments in a number of uncertainty measures for Portugal and gauge their impact on macroeconomic developments in recent years, particularly on GDP, GFCF and private consumption. Our analysis shows that elevated uncertainty had a significant negative impact on economic activity during the financial and sovereign debt crises, while the unwinding in uncertainty associated with the conclusion of the economic and financial assistance programme in 2014 boosted the subsequent recovery.
(JEL: E24, J24, J41)

Introduction

Uncertainty has often been considered a driver of weak developments in advanced economies since the 2008 financial crisis. As a result, the literature on the measurement of uncertainty and the evaluation of the macroeconomic effects of uncertainty has grown in recent years.

Economic uncertainty refers to a situation involving imperfect and/or unknown information about the future of the economy.[1] When deciding on consumption or investment, economic agents must form expectations on relevant future events on the basis of available data. These expectations are affected by uncertainty, to the extent that the likelihood of alternative events is unknown or impossible to gauge with precision. It should be noted that there is always some level of uncertainty in an economy, being an intrinsic

Acknowledgements: The authors thank Miguel Gouveia and the participants in a seminar at Banco de Portugal for helpful comments and suggestions. Any errors and omissions are the sole responsibility of the authors. The opinions expressed in the paper are those of the authors and do not necessarily coincide with those of Banco de Portugal or the Eurosystem.

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1. Economists tend to distinguish between uncertainty and risk. Knight (1921) was probably the first to drew the distinction between risk – possible outcomes to which one can assign probabilities (measured or learned) – and uncertainty – outcomes with unknown probabilities or not knowing all the possible outcomes. While anything is possible (which is the essence of uncertainty) everything is not equally probable (which is the essence of risk). In this article, as in much of the empirical literature, we do not distinguish between the two concepts given that in practice they are difficult to disentangle.

feature of the economic cycle. It is the change in uncertainty levels over time that impacts on the decisions of economic agents.

Economic theory suggests that there are three main transmission channels of uncertainty to economic activity.[2] The first channel is through possible wait-and-see effects. Firms and consumers might decide to postpone spending decisions in order to avoid costly mistakes. Firms may also cut back on hiring when faced with higher uncertainty. A high level of uncertainty gives agents an incentive to delay or cancel decisions involving considerable irreversible costs until uncertainty is reduced and more information becomes available, restraining economic activity. This channel is usually referred to as the real option theory to uncertainty, because the option value of waiting in the face of uncertainty increases. Precautionary savings might also be a channel of transmission. Heightened uncertainty about future income may induce households to reduce current consumption in order to increase savings for the future. Finally, uncertainty may also have an impact on economic activity via higher risk premia. In the presence of heightened uncertainty, agents are likely to demand a higher risk premium, which reduces asset prices and pushes up borrowing costs. A potential reduction in the volume of credit may also occur in periods of high and prolonged uncertainty, as banks have less incentive to provide loans.

The empirical literature on the impact of uncertainty suggests that it tends to be associated to lower short-term growth.[3] For the Portuguese economy, there is little evidence on this link between uncertainty and economic activity.[4] Therefore, the purpose of this article is to present a set of uncertainty measures specific to the Portuguese economy and to assess how uncertainty matters for economic developments in Portugal.

The article is organized as follows. The next section presents and analyses some commonly used proxies of uncertainty applied to the Portuguese economy. In the methodology section we describe the structural Bayesian vector auto regression (BVAR) models used to quantify the impact of shocks to these uncertainty measures on economic activity, investment and private consumption in Portugal. The main results are discussed in the results section. The last section summarizes the main findings of the article.

2. See Haddow *et al.* (2013) and references herein, and IMF (2012).

3. For a overview, see Bloom (2014).

4. Schneider and Giorno (2014) present a comparative analysis of the impact of uncertainty in Greece, Portugal and Ireland using as uncertainty measure stock market volatilities, which limits its comprehensiveness. Gunnemann (2014) develops national economic policy uncertainty indices, based on newspaper news, for nine European countries, including Portugal, and studies their impact on industrial production and unemployment.

Uncertainty indicators

An empirical assessment of the relationship between uncertainty and economic activity requires a quantification of uncertainty. Uncertainty cannot be directly observed but a number of measures have been proposed in the empirical literature, based on different methods and data. These measures can be classified into three main groups, which emphasize distinct aspects of uncertainty. A first group of measures is finance-based, relating mainly to volatility in financial markets. Financial market participants' expectations about the outlook of the economy are reflected in equity prices, bond yields and exchange rates. Thus, low volatility in these markets should be an indication of stable expectations, while high volatility should indicate that financial market participants are more uncertain about future economic developments. Some other measures take into account the prevalence of certain terms related to economic uncertainty in news publications. Finally, a third group of measures focuses on the disagreement of professional analysts´ forecasts for selected macroeconomic aggregates or among survey participants' expectations regarding firm sales or sectoral output. The rationale is that expectations about the future should be more diverse in times of high uncertainty than in times of low uncertainty, when agents should broadly share the same outlook.

Each group of measure has its own pros and cons, they are imperfect and partial ways of assessing economic uncertainty. Measures based on financial markets volatility have the advantage of being timely. However, they can move regardless of changes in uncertainty, including as a result of increasing risk aversion of economic agents, and might be a narrow indicator, failing to capture uncertainty shocks relevant to the broader economy. News-based uncertainty indexes have the advantage of better representing the degree of uncertainty felt by the general population. As phrased by Alexopoulos and Cohen (2009), press coverage is likely to be more important for perceptions of uncertainty on "Main Street", rather than financial volatility which primarily is directly observed on "Wall Street". Caveats to newspaper-based measures relate to accuracy and potential bias. Finally, measures based on the dispersion of forecasts or survey responses can also have a more direct link with the real economy but the problem is that they may not capture only uncertainty but also disagreement. Each forecaster/survey respondent could be extremely certain, but there could still be a high degree of disagreement (and vice versa). In spite of these caveats, the uncertainty proxies proposed are expected to provide a useful guide to the true degree of uncertainty in the economy. In this article we attempt to use uncertainty measures for Portugal from these three groups.

In the first group, we consider two measures built on the methodological concept of the Composite Indicator of Systemic Stress (CISS-EA) from Holló

et al. (2012) who apply basic portfolio theory to the aggregation of market-specific stress indicators into a composite index.[5] One of the indicators is the composite indicator of financial stress for Portugal (acronym **ICSF**) from Braga *et al.* (2014), which takes into account individual indicators of financial stress such as realized asset return volatilities and risk spreads in several relevant domestic financial markets (stock, bond, money, exchange rate and financial intermediaries markets). The other indicator is narrower in scope, measuring only stress in sovereign bond markets in Portugal (**SovCISS-PT**). It integrates measures of credit risk, volatility and liquidity into an overall measure of sovereign systemic stress indicator.[6] The SovCISS-PT is compiled by the ECB.[7]

In the second group of measures, we use three indicators. The first is the well-known index of economic policy uncertainty for Europe (**EPU**) from Baker *et al.* (2016), which is based on searches for keywords in the press, counting each month the number of newspaper articles which simultaneously contain terms having to do with economy, economic policy and uncertainty.[8] While the indicator is for Europe, we will test its relevance for Portugal, which can be expected to be high given Portugal´s small open economy characteristics, its degree of integration (euro area and EU) and its exposure to economic and political developments at the European level. Gunnemann (2014) has compiled a comparable indicator for the Portuguese economy (**EPU-PT**), but an update for recent years is not available. Finally, it is possible to build an alternative indicator for Portugal by computing an EPU trade-weighted indicator (**EPU-TW**), by taking the weighted average of national EPU indices available for six European countries (France, Germany, Italy, Spain, United Kingdom and Ireland), where weights correspond to the share of these countries in Portuguese exports.

Finally, in the third group, we constructed uncertainty survey-based indicators for Portugal in line with the approach of Girardi and Reuter (2017) by exploiting the information of the European Commission Business and

5. The indicators represent a correlation-weighted average of individual stress indicators, with correlation-weights which vary over time. The basic idea is that the overall level of systemic stress increases with a stronger correlation between various stress symptoms, all else being equal.

6. See Garcia-de Andoain and Kremer (2016) for methodological details.

7. Monthly updates of the SovCISS for the euro area as a whole (SovCISS-EA) and individual Euro area countries can be obtained from the ECB´s Statistical Data Ware-house: http://sdw.ecb.europa.eu/browse.do?node=9551138.

8. Some authors have proposed the use of measures of policy-related uncertainty based on the volume of Google searches (see Donadelli (2015) and Bontempi *et al.* (2016)). The idea behind these measures is that internet users manifest their uncertainty by searching for specific words with greater frequency. However, the evidence suggests that these Google-search-based uncertainty metrics are closely related to the standard indexes of economic policy uncertainty developed by Baker *et al.* (2016).

Consumer surveys (European Commission (2017)). The indicators rely on the idea that divergence in the responses may be interpreted as an indication of uncertainty, which is thus measured directly at the level of economic agents making decisions on investment and consumption expenditures.

The first measure (**UNC1**) is based on the dispersion of positive and negative answers to the forward-looking survey questions.[9] Girardi and Reuter (2017) compute an aggregate measure by simply taking the average of all question-specific dispersions standardized so as to have zero mean and unit standard deviation. We refer to this measure as **UNC1A**. We also use an alternative measure (**UNC1B**) for which we compute first an uncertainty index for each sector and for consumers, by averaging the dispersion series in each survey[10], and second, we aggregate these sectoral and consumer indexes into an economy-wide uncertainty indicator by taking a weighted mean which uses the weights of the Economic Sentiment Indicator.

The second measure (**UNC2**) takes advantage of the fact that the surveys contain a number of questions inquiring about expectations and retrospective assessments of some variables. While dispersion in answers to forward-looking questions can be influenced by uncertainty and other factors (namely, heterogeneity and disagreement), dispersion in answers to backward-looking questions should not reflect uncertainty. In practice, the indicator involves scaling the dispersion of answers to the forward-looking questions, as inquired in a given month, by the dispersion of answers to the corresponding backward-looking questions, as inquired some months later, which can be interpreted as a measure of the extent of uncertainty expressed as a share of the "natural" dispersion across the economy. The main downside to uncertainty proxy UNC2 is that, due to its construction on the basis of respondents' retrospective assessments of past developments, the indicator is only available with a significant time lag.

The third measure of uncertainty (**UNC3**) proposed by Girardi and Reuter (2017) is based on the idea that a high degree of uncertainty might also manifest in balance scores developing into very different directions across questions (increased dispersion across questions rather than within questions as in the two previous measures). Thus, this measure is computed by taking the dispersion of changes in balance scores compared to three months ago across all survey questions. In times of certainty, the assessment of changes to most variables can be expected to be more or less commonly shared, i.e. businesses should have a favorable assessment of past and future output, orders, stocks etc. ("everything gets better"), while the opposite should be true

9. For details on the computation of the uncertainty measures based on surveys see Manteu and Serra (2017).

10. We only included in each aggregated index the question-specific standard deviations that were negatively correlated to GDP growth.

in times of uncertainty, when the dispersion of balance scores regarding these questions can be expected to increase.

The individual measures can also be combined in a synthetic indicator, better able to capture the underlying uncertainty process in the economy by smoothing away the noise inherent in any particular measure. The synthetic index of uncertainty for Portugal (**SIU-PT**) aggregates four of the above listed proxies, namely the ICSF, the EPU, UNC1B and UNC3, which were chosen because of their timeliness and to cover the three categories of uncertainty measures. The index is a weighted average of the standardized components, where the weights are 1/3 for the ICSF, 1/3 for the EPU and 1/3 for a simple average of the two survey-based measures UNC1B and UNC3.

Figures 1-5 present all the above described uncertainty proxies for Portugal.[11] As there is no track record of "known" uncertainty levels for the Portuguese economy, with which to compare the evolution of the uncertainty indicators, a graphical inspection can only assess whether that evolution is plausible. We start by checking whether the peaks in the indicators coincide with potentially relevant political/economic events, both domestic and international. The shaded areas in the charts identify the last three recessions in Portugal, with the last two being also observed in the euro area.

At a first glance, the measures appear to capture the major uncertainty-enhancing events of the past fairly well, although to varying degrees. The ICSF and the SovCISS-PT remained at a low level for a prolonged period (from 1999 until 2007), but reacted rather strongly during the global financial crisis in 2008 and the euro area sovereign debt crisis (starting in 2010), hinting at the systemic nature of these crises (Figure 1). The SovCISS-PT points to a bigger and more lasting effect of the sovereign crisis. EPU, EPU-PT and EPU-TW exhibited some spikes at the time of the 9/11 terrorist attacks and the Gulf war in 2003 (Figure 2). These news-based measures rose only moderately during the global financial crisis, but reacted more significantly during the euro area sovereign debt crisis. Economic policy uncertainty indicators are likely better at capturing the rise in uncertainty in this period, as the sovereign debt crisis gave rise to questions as regards the euro area institutional framework. Measures of economic uncertainty based on the dispersion of survey responses show a somewhat different pattern (Figures 3 and 4). They reacted relatively strong to the global financial crisis but much more moderately to the euro area sovereign crisis (except UNC2). Finally, the synthetic indicator of uncertainty, while spiking in all major events, registered the largest peaks during the global financial crisis and the euro area sovereign crisis. The SIU-PT rose by more than two standard deviations from its mean

11. Standardized variables were used, i.e. net of the average and divided by the standard deviation computed over the sample period.

in late 2008 and by one and a half standard deviations in the last quarter of 2011 (Figure 5).

The different nature of the indicators might help explain their diverging performances in the most recent period. The EPU and the EPU-TW started rising in 2015, in the context of the Greek crisis, and spiked strongly in early 2016, likely reflecting first a relatively negative review of the European banking sector as well as the European immigration crisis and, subsequently, the consequences of the UK's referendum. It has remained elevated since, which can be associated to uncertainties regarding Brexit as well latent political risks in view of recent and upcoming elections in several countries. The indicators stood at maximum levels in the end of 2016. Uncertainty, measured by financial stress indicators (ICSF and SovCISS-PT), also rose in the beginning of 2016, but comparatively less, and has since subsided. Regarding the survey-based uncertainty proxies (UNC1 and UNC3), they point to a persistent reduction of uncertainty since mid-2014, an effect likely associated with the conclusion of the Economic and Financial Assistance Programme. At the end of 2016, both measures were substantially below their historical average levels. The synthetic indicator SIU-PT points to some elevation in economic uncertainty in early 2016 and subsequent stabilization in the remaining of the year, at slightly above average levels.

Uncertainty appears to have a countercyclical association with real gross domestic product (GDP). Figures 1-5 show that uncertainty, proxied by the various measures, tends to increase during recession periods and to fall in periods of stable growth. Table 1 shows that all indicators of uncertainty for Portugal display a negative correlation with GDP growth as well as with gross fixed capital formation (GFCF) and private consumption, either expressed in quarter-on-quarter or year-on-year rates.

	GDP		GFCF		Private Consumption	
	yoy rate	qoq rate	yoy rate	qoq rate	yoy rate	qoq rate
ICSF	-0,63	-0,51	-0,53	-0,33	-0,60	-0,50
SovCISS-PT	-0,56	-0,46	-0,56	-0,34	-0,64	-0,53
EPU	-0,47	-0,36	-0,45	-0,20	-0,44	-0,32
EPU-TW	-0,49	-0,39	-0,48	-0,23	-0,45	-0,34
EPU-PT	-0,22	-0,19	-0,30	-0,17	-0,23	-0,21
UNC1A	-0,08	-0,12	-0,15	-0,12	-0,11	-0,11
UNC1B	-0,46	-0,35	-0,39	-0,20	-0,41	-0,28
UNC2	-0,33	-0,34	-0,44	-0,32	-0,39	-0,44
UNC3	-0,14	-0,32	-0,07	-0,12	-0,08	-0,18
SIU-PT	-0,74	-0,64	-0,64	-0,36	-0,68	-0,56

TABLE 1. Correlations between measures of uncertainty and macroeconomic aggregates

Figures 6-9 compare the uncertainty measures constructed for Portugal with similar measures for the euro area, revealing that the recent evolution

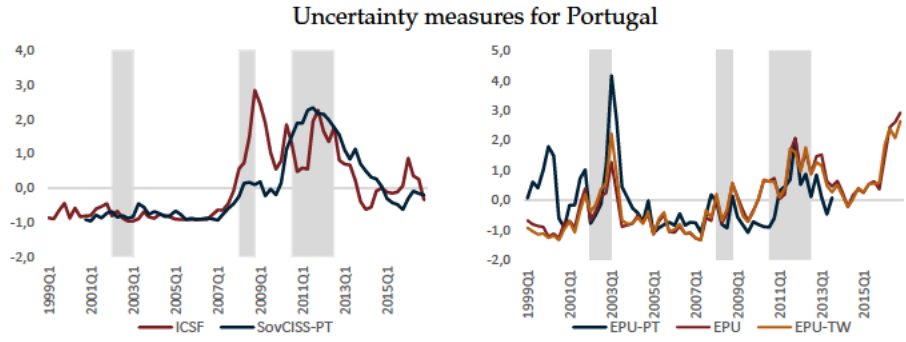

FIGURE 1: Based on financial markets data

FIGURE 2: Based on newspaper data

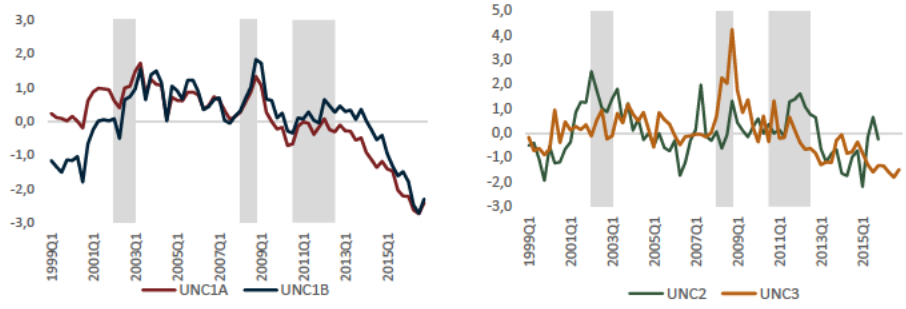

FIGURE 3: Based on survey data

FIGURE 4: Based on survey data

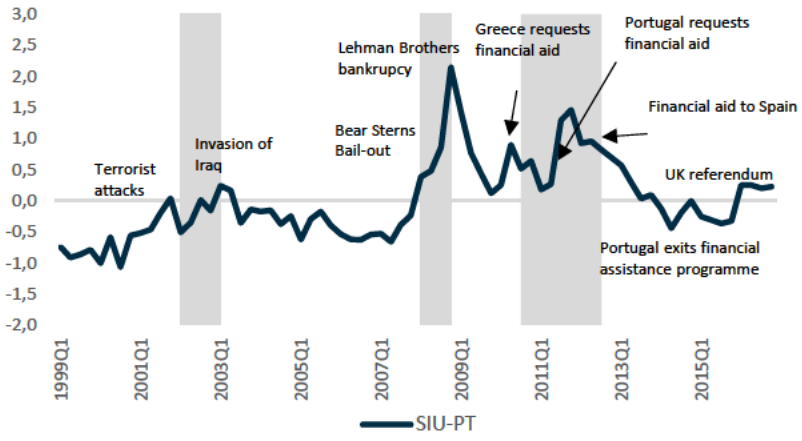

FIGURE 5: Synthetic indicator of uncertainty

of uncertainty in Portugal has been strikingly similar to that in the euro area. The main exceptions concern measures UNC1A and UNC2. The later appears as the only survey-based indicator pointing to higher uncertainty levels in Portugal than in the euro area during the period of the sovereign crisis. The

SovCISS measure for Portugal shows a much bigger rise during the sovereign crisis than during the financial crisis, while the two episodes generated comparable increases in the euro area measure. The deeper and longer impact of the debt crisis in Portugal, as in other vulnerable sovereigns in the euro area, likely explains the much bigger rise in uncertainty (as measured by SovCISS) during this period. The high correlations of the indicators with similar measures for the euro area suggest that global common factors have been the important drivers of uncertainty in Portugal.

Methodology

The connection between the uncertainty indicators presented and economic activity can be best described with models that explore the mutual interdependence between them, without imposing *a priori* a causal relationship. Vector Autoregression (VAR) models are a common used tool for this purpose, in particular when estimated using Bayesian techniques that reduce the overfitting problems of traditional VAR models. Therefore, the importance of uncertainty to macroeconomic developments was estimated on the basis of structural Bayesian Vector Autoregression (BVAR) models, along the lines of Bundesbank (2016) and European Commission (2015).[12] For a formal description of the BVAR model and details on priors and hyperparameters used, refer to Manteu and Serra (2017). The structural decomposition of shocks was based on the Cholesky method, which is standard in the literature (ECB (2016)). The macroeconomic variables considered were those for which the channels of uncertainty transmission are better and more often identified in the literature, namely GDP, GFCF and private consumption (see Haddow *et al.* (2013) and references herein).

The models for each macroeconomic variable were initially estimated in a baseline version that includes a number of regressors that are typically considered in literature. This version was then re-estimated by adding one uncertainty measure at a time, which was placed firstly in the Cholesky ordering, i.e., uncertainty is assumed to affect contemporaneously all other variables in the model. This assumption is also in line with the most common option in the literature. Finally, a third version was estimated including, along with each uncertainty variable, a measure of private sector leveraging, proxied by the relevant stock of credit.

12. Models were estimated using the MATLAB-based toolbox presented in Dieppe *et al.* (2016).

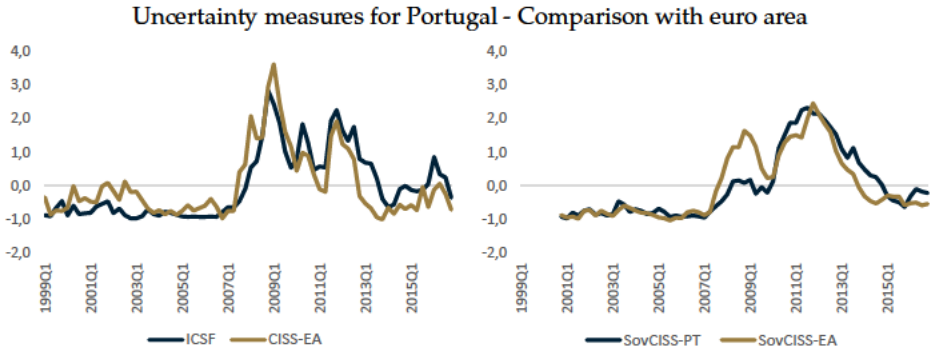

FIGURE 6: ICSF/CISS

FIGURE 7: SovCISS

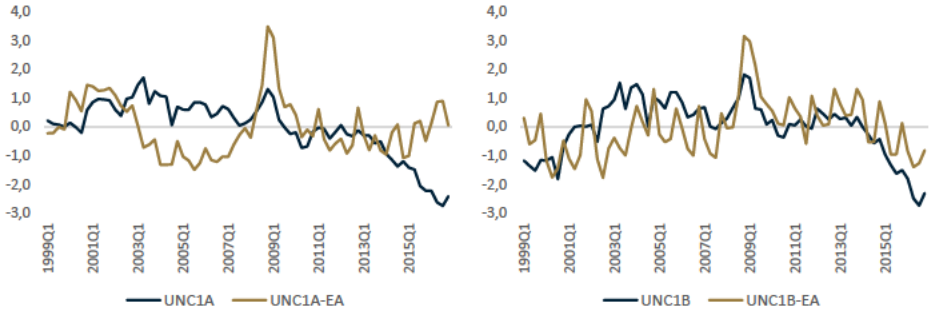

FIGURE 8: UNC1A

FIGURE 9: UNC1B

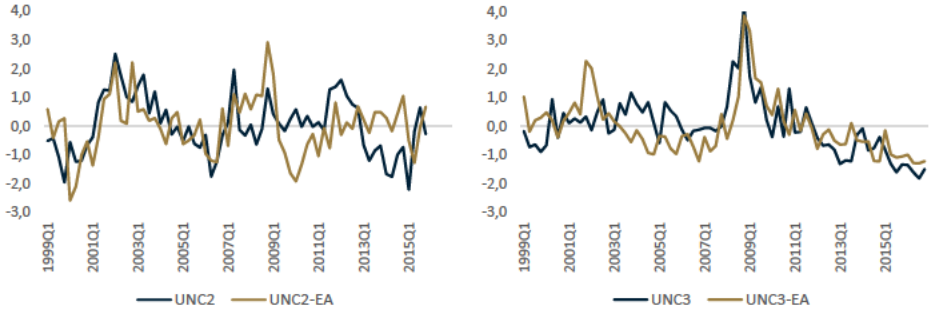

FIGURE 10: UNC2

FIGURE 11: UNC3

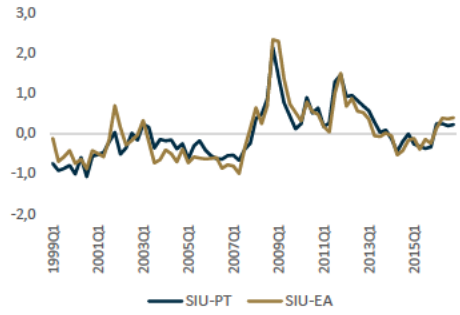

FIGURE 12: Synthetic indicator of uncertainty

Thus, the first baseline model includes as covariates[13] GDP, inflation, employment, the stock of loans to households and non-financial corporations (as proxy for indebtedness levels) and the short-term nominal interest rate. In the case of GFCF, the set of covariates in the model is similar, with the inclusion of GDP and the exclusion of employment and the proxy for household indebtedness as determinants. Finally, the last baseline model includes private consumption, inflation, disposable income, the short-term interest rate and a measure of the stock of total wealth (composed of housing and financial wealth) and the stock of credit to households.[14]

In order to enrich and increase the robustness of the analysis, a set of variants of the models were estimated. All the models were estimated both in levels and in differences, whereas in the latter case a standard BVAR and a mean-adjusted VAR model were considered.[15] In addition, all models are estimated with one up to four lags. Results, available upon request, show that on the basis of the loglikelihood of the model the optimal choice of lags is overwhelmingly one and never more than two, and therefore, for simplicity, all the results presented refer to models with one lag. Another robustness check involved estimation for two subsamples. The first ranges from 1999Q1 to 2007Q4, thus excluding both the great recession and the euro area sovereign debt crises, while the second ranges from 1999Q1 to 2010Q4, therefore excluding just the euro area sovereign debt crisis.[16] This robustness test is relevant given that the estimated impact of uncertainty depends crucially on the presence on the estimation sample of large changes in uncertainty levels, which for the majority of the indicators considered are precisely those associated with the last two recessions mentioned. Therefore, in some cases, estimation on the basis of a sample up to 2008 only will imply a response of macroeconomic variables to uncertainty without the expected sign or strongly non significant. In the case of SovCISS-PT and the UNC2 this holds also when the sample is extended to 2010, given that they generate responses

13. The order according to which the variables are presented here describes the Cholesky ordering of the variables in the model.

14. Some authors, like Girardi and Reuter (2017) or Haddow *et al.* (2013), also include in their estimated VARs a confidence measure given the observation that rises in uncertainty measures tend to coincide with reductions in confidence. Thus, there is the possibility that these measures may be capturing the effect of changes in confidence and not uncertainty shocks. However, the authors report that controlong for changes in confidence does not change results significantly, and therefore this avenue was not pursued.

15. For more details on the methodology behind mean-adjusted VAR, see Jarocinski and Smets (2008) and Dieppe *et al.* (2016).

16. There are exceptions to these estimation samples, and to the samples available for conditional forecasts evaluation, namely for the models which include the SovCISS-PT (available only from 2000Q4 onwards) and the EPU_PT and UNC2 (available only up to 2013Q3 and 2015Q4, respectively).

to the uncertainty shocks which are positive on impact. Therefore results for these indicators are not presented, being available upon request.

Following Banbura *et al.* (2015), the majority of variables are expressed in logs (with the exception of the interest rate, which is in levels), and for the model in differences, the variables are expressed as annualized quarter-on-quarter rates of change. Uncertainty indicators are expressed in levels in both types of models, following a preliminary analysis that shows that the correlations with the year-on-year rates of change of macroeconomic variables are maximized when uncertainty indicators are expressed in levels.[17]

Results

Conditional forecasts

In order to access how uncertainty could have helped explain the path of GDP, GFCF and consumption in the recent past, a conditional forecast analysis was performed with the BVAR. The conditional forecasts are obtained by constraining the path of all the variables to the observed one, with the exception of the macroeconomic aggregate of interest in each case. This allow for an assessment of the counterfactual path for these variables given by the model and to what extent the inclusion of uncertainty and leveraging indicators in the model would aproximate this path from the actual one. This exercise was performed in Ciccarelli and Osbat (2017) to analyze inflation developments and is applied to the impact of uncertainty in European Commission (2015). Therefore, models are estimated for a subsample and an out-of-sample forecasted path for each macroeconomic variable in question is computed on the assumption that the path of all other variables is known. The relative performance of all models is evaluated on the basis of their ability to improve the root-mean squared error (RMSE) of the conditional forecasts for the year-on-year rate of change of the macro variable vis-à-vis the baseline model for the financial and sovereign debt crises and the following recovery.

Table (A.1) in the Appendix displays the relative RMSE of the estimated models for the forecasts of year-on-year rates of change, in the case of the double-dip and sovereign crisis subsamples, respectively. Results for RMSE levels, available in Manteu and Serra (2017), give rise to some preliminary conclusions.

Results show that models in levels are clearly preferred to models in differences, and therefore the remaining analysis will be focused on these results. It is worth mentioning, however, that models in differences indicate

17. Although the models were estimated in levels and in first differences of the variables, the focus of result presentation will be year-on-year rates of change, given the volatility of the some of the variables in quarter-on-quarter terms, namely GFCF.

that at least some uncertainty indicators improve conditional forecasts for all macroeconomic aggregates considered.

In addition, a longer estimation sample originates in general lower RMSE for conditional forecasts of the sovereign crisis and posterior period, reinforcing the theory that a major uncertainty event in the estimation sample is necessary to identify the impact of these indicators on the macroeconomic variables. There is however an exception in the case of GFCF, for which models estimated only up to 2008 perform better.

Results in table (A.1) are rather consistent for both estimation samples used and show that the inclusion of uncertainty variables in the models improves the conditional forecasts in some cases (highlighted with shading), specially in the post-sovereign crisis period. In the case of consumption, however, improvements in forecasts take place mostly over the 2008-2010 period. Gains in forecasting performance happen with the addition of uncertainty indicators to the baseline model in the case of GDP and consumption, while in the case of GFCF relative gains are smaller and are mostly present when leveraging indicators are also included in the model. This conclusion, identical to European Commission (2015), does not mean that uncertainty is not a driver of GFCF, but that it does not appear to have been a major factor accounting for the insufficiency of GDP and the other variables in the model in explaining the drop in investment over the two recessions under analysis. Another possibility is that the relevant uncertainty factors for GFCF decisions are more idiosyncratic than the ones captured by most of the indicators in this article, which appear to capture essentially supranational phenomena. This hypothesis is strengthened by the choice of "best" uncertainty indicators, i.e., those that generate lower RMSE. The financial-based and media-based uncertainty indicators appear to be the most helpful for explaining GDP developments (ICSF and EPU-TW), while in the case of the GFCF and private consumption the preferred indicators are survey-based (UNC1A and UNC3, respectively) (in the case of GFCF, the media-based indicator EPU_PT seems promising, but the available sample is limited). This possibly results from the fact that GFCF and private consumption require more specific information that is contained in the survey indicators, which reflect directly the opinion of managers and consumers.

Results in terms of additional gains in explaining the GDP decline over the last two recessions by including uncertainty indicators seem to be relatively limited, which suggests that there is still a large part of economic developments over this period that can not be explained with this set of models/variables. One possibility for this result is that more large uncertainty episodes are necessary for the model to estimate accurately the impact of uncertainty in the economy. This result is observationally equivalent to the possibility that the impact of uncertainty on macroeconomic developments has increased since the great recession (an hypothesis supported by European Commission (2013)). To assess this possibility, conditional forecasts were

recalculated for the case in which the model coefficients were estimated with the full available sample. Results, available in Manteu and Serra (2017), show that gains in relative RMSE for all macroeconomic aggregates from the inclusion of uncertainty and leverage indicators are larger and more broad based across indicators when the models are estimated with the full sample. As regards the best performing indicators, conclusions to do not change significantly when compared to those obtained with the out-of-sample conditional forecasts, given that the best performing indicators are the same for GDP, and for GFCF and private consumption these are still survey-based indicators, and, in the latter case, also the SIU.

Impulse response functions

This subsection focuses on the quantification of the impact of uncertainty indicators through impulse response functions (IRF) obtained with models estimated with the full sample. Results are presented for models that include both uncertainty and leverage indicators, but are very similar for the models that include only uncertainty indicators.
Figures (**??**) to (B.2) display the IRF of the level of each macroeconomic aggregate (in percentage points) to a standard deviation structural shock associated with uncertainty. These are statistically significant for the majority of indicators, specially over the first half of the impulse response function.

In the case of GDP, the impact of the shocks is similar across most indicators, and also not very different in magnitude from the results obtained by Girardi and Reuter (2017) for the euro area, Meinen and Röhe (2016) for the largest four euro area countries and Gil *et al.* (2017) for Spain. The magnitude of the maximum response to an uncertainty shock is also similar to the one obtained for Portugal by Gunnemann (2014), although in that case economic activity is proxied by industrial production and results are not significant. As regards Schneider and Giorno (2014) results for Portugal, information on the exact size of the shock considered is unavailable, but the cumulative impact on the level of GDP over the financial crisis seems to be much smaller than the one described in the next subsection, possibly because the scope of the uncertainty measure considered is too limited. In the case of GFCF and private consumption, while the ICSF and the media-based indicators generate similar IRF, these are in general much weaker for the survey-based indicators, and in some cases (UNC3) even positive on impact. This feature is also found in Meinen and Röhe (2016) for the response of the GFCF to a dispersion measure of the type of UNC1A. A feature which is common to the three macroeconomic variables is the fact that SIU is the lower envelope of the IRF (excluding the SovCiss-PT). This possibly stems from the fact that being an average of indicators with a different nature, the SIU covers a broader range of uncertainty episodes, capturing more accurately the impact of uncertainty on the business cycle. The use of a composite of uncertainty indicators to evaluate

macroeconomic effects is a common approach in the literature (ECB (2016), Gil *et al.* (2017)).

Historical decomposition

Another way to analyze the impact of uncertainty on business cycle developments is to assess its impact over time through a historical decomposition exercise. Figures (C.1) to (C.6) in the Appendix show results for the indicators and models suggested by the out-of-sample conditional forecast analysis, a choice which is not substantially altered when the model is estimated full sample, as mentioned above. Given the disparity of IRF results between survey-based indicators and the rest in the case of GFCF and private consumption, the composite measure SIU is also reported.

The time profile of uncertainty contributions measured by the SIU is quite similar across macroeconomic aggregates and also to the ICSF in the case of GDP. Uncertainty had a negative impact of between 1 and 2 percentage points (p.p.) on GDP growth from late 2008 up to mid 2012, starting to abate from then onwards. The largest impact of uncertainty in this period is however positive, over 2014, possibly associated with the end of the economic and financial assistance programme for Portugal. Over 2016, the positive impact of uncertainty on GDP started to fade away, turning negative over the second half of year. Several events may have contributed to this path, including the immigration crisis in Europe and a relatively negative review of its banking sector and the period leading to and in the aftermath of the UK referendum on EU participation (so called Brexit).

However, results for GFCF and private consumption are substantially different when assessed with survey-based indicators, which show a much more marginal role for uncertainty. In the case of consumption, uncertainty, evaluated with the UNC3 indicator, has the largest impact during the financial crisis, with virtually no effect during the sovereign debt crisis. This result is hard to reconcile with the economic and financial assistance program measures that had an impact on disposable income and with the increase in unemployment over this period, which is a proxy for uncertainty used in models for consumption (Gil *et al.* (2017)). This analysis suggests that results are more consistent for GDP than for its subcomponents, possibly because these are more susceptible to idiosyncratic shocks not captured by the majority of uncertainty indicators. In fact, these appear to reflect essentially supranational events, as suggested by the similarity between the Portuguese and euro area composite indicators.

Conclusions

This article presented a set of uncertainty indicators for the Portuguese economy, covering several types of approaches to the measurement of this variable. Among these measures, the survey-based indicators were computed for Portugal for the first time. A composite indicator of these measures shows striking similarities to a comparable measure for the euro area. An analysis based on BVAR models for GDP, GFCF and private consumption reinforce previous results in the literature that report a negative impact of uncertainty increases on economic developments. Results suggest that these indicators, either by themselves or along with leverage indicators, help explain the decline in macroeconomic aggregates over the financial and sovereign debt crises and the weakness of the ensuing recovery. However, the magnitude of that impact is very dependent on the type of uncertainty indicator considered. Results for GDP are however very consistent across indicators and indicate a relevant negative impact of uncertainty in the last two recessions and positive impact after the end of the financial assistance programme.

This topic offers several avenues for further research, from the analysis of additional uncertainty measures to further robustness checks in the models considered. Possibly the most interesting one would be the estimation of a threshold VAR. That would allow for asymmetrical responses to uncertainty shocks and for these only to be active above a certain degree, features that the estimation results of this article hint to be relevant.

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Appendix A: Conditional Forecast Results

		Estimation sample up to 2007Q4						Estimation sample up to 2010Q4		
		GDP		GFCF		CONS		GDP	GFCF	CONS
Uncertainty indicator	Model	2008Q1-2010Q4	2011Q1-2016Q4	2008Q1-2010Q4	2011Q1-2016Q4	2008Q1-2010Q4	2011Q1-2016Q4	2011Q1-2016Q4	2011Q1-2016Q4	2011Q1-2016Q4
CIFS	Base									
	Base+Uncert	0.93	0.90	1.49	1.18	1.19	1.11	0.88	1.01	1.08
	Base+Uncert+Loans	1.38	1.39	2.01	1.11	0.83	1.70	1.60	0.95	1.91
EPU	Base									
	Base+Uncert	1.03	0.97	1.01	1.02	1.07	1.15	1.00	1.02	1.09
	Base+Uncert+Loans	1.28	1.50	1.06	0.99	0.68	1.65	1.64	0.99	1.97
EPU_PT	Base									
	Base+Uncert	0.98	1.01	1.01	1.02	1.04	0.89	1.04	1.02	1.03
	Base+Uncert+Loans	1.24	1.83	1.06	0.92	0.62	2.64	2.54	0.98	4.04
UNC1	Base									
	Base+Uncert	1.01	1.06	1.04	1.01	0.99	0.89	1.08	1.00	1.12
	Base+Uncert+Loans	1.32	1.60	1.20	0.93	0.58	1.58	1.25	0.94	1.92
UNC3	Base									
	Base+Uncert	1.01	1.02	1.11	1.02	0.92	0.87	1.08	0.95	0.86
	Base+Uncert+Loans	1.12	1.35	1.24	0.96	0.51	1.48	1.50	0.93	1.85
UNC1-B	Base									
	Base+Uncert	1.01	0.95	1.00	1.01	1.04	0.82	0.96	1.01	0.91
	Base+Uncert+Loans	1.28	1.59	1.06	0.93	0.63	1.47	1.36	0.95	1.88
EPU_Europe_TW	Base									
	Base+Uncert	1.08	1.01	1.02	1.00	1.09	1.01	0.94	1.01	1.02
	Base+Uncert+Loans	1.32	1.55	1.06	0.95	0.67	1.54	1.64	1.00	1.94
SIU	Base									
	Base+Uncert	1.08	1.06	1.00	0.99	0.90	0.88	1.00	1.02	0.90
	Base+Uncert+Loans	1.27	1.48	1.17	0.95	0.58	1.59	1.69	1.00	1.92

TABLE A.1. Relative Root mean squared errors of conditional forecasts

Notes: Values refer to the RMSE computed on the yoy rates of change projection errors. Results are not completely comparable between the EPU_PT and the rest because the RMSE are computed with errors up until 2013Q3.

Appendix B: Impulse response function results

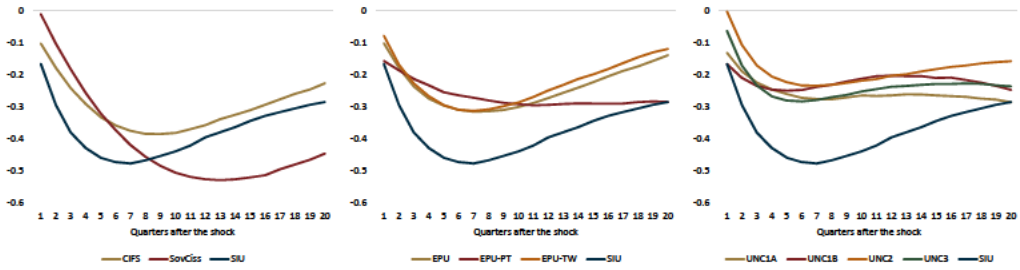

FIGURE B.1: Impulse response functions to an uncertainty shock for GDP

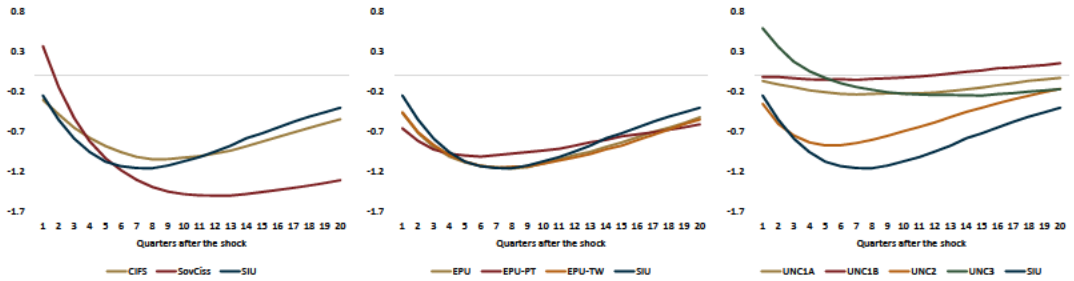

FIGURE B.2: Impulse response functions to an uncertainty shock for GFCF

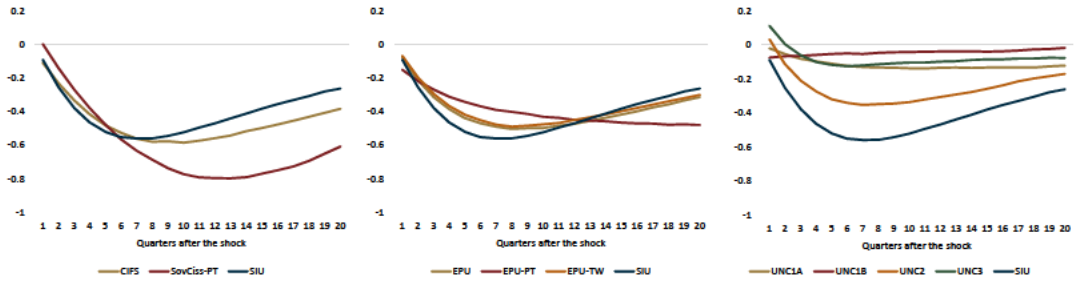

FIGURE B.3: Impulse response functions to an uncertainty shock for Private Consumption

Appendix C: Historical decomposition results

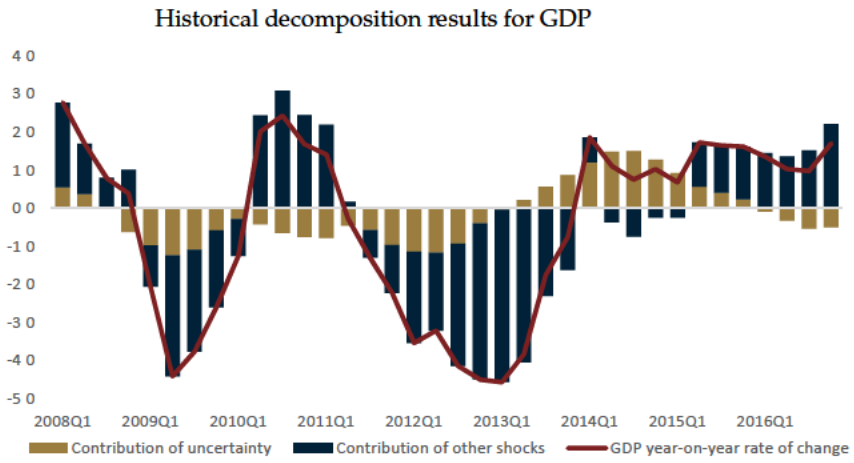

FIGURE C.1: ICSF as uncertainty indicator

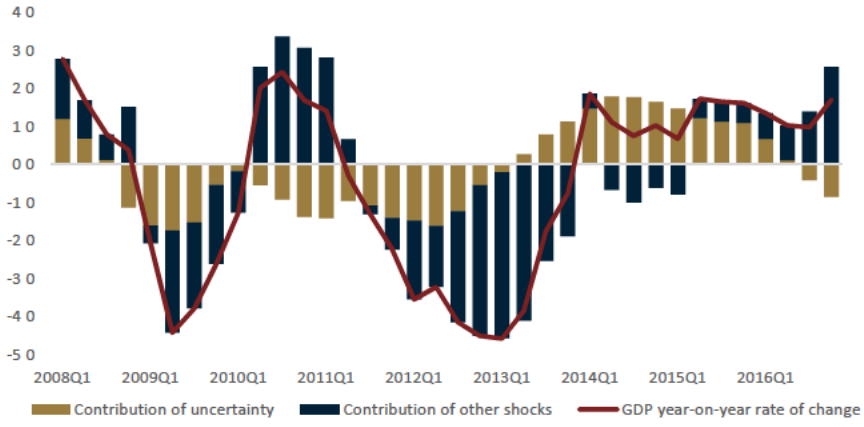

FIGURE C.2: SIU as uncertainty indicator

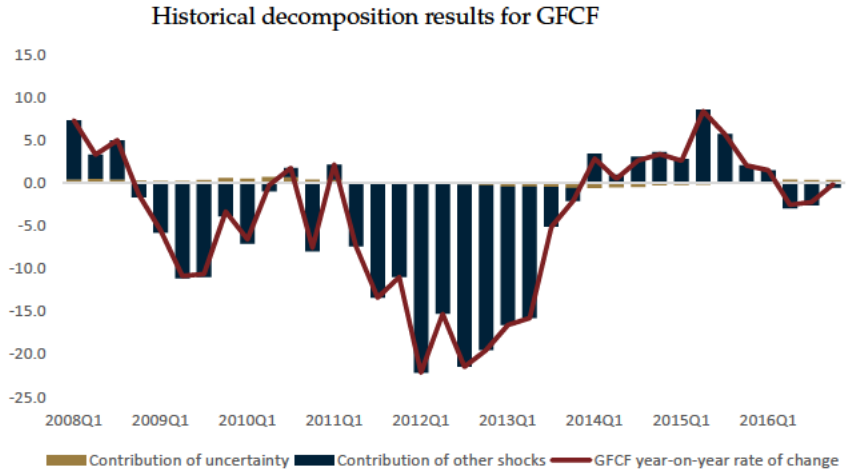

FIGURE C.3: UNC1 as uncertainty indicator

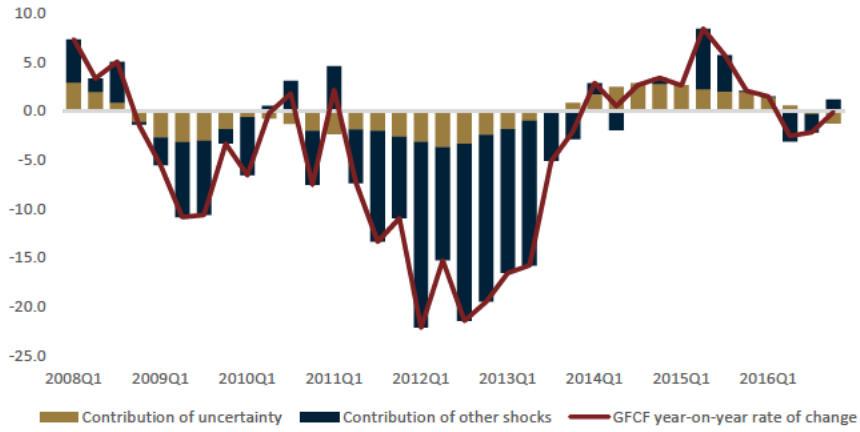

FIGURE C.4: SIU as uncertainty indicator

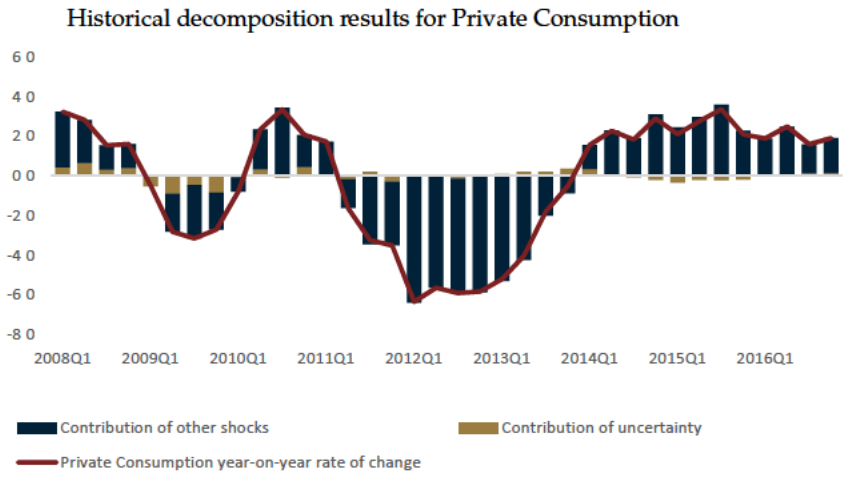

FIGURE C.5: UNC3 as uncertainty indicator

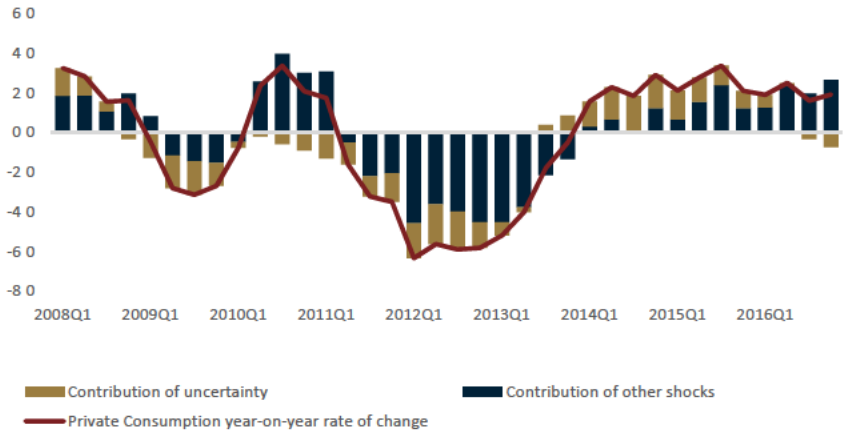

FIGURE C.6: SIU as uncertainty indicator

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

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April 2017

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

Acknowledgements: We would like to thank helpful discussions with Cláudia Braz, Lara Wemans, Luciana Barbosa, Nuno Silva, Pedro Prego and Sónia Costa. Paulo Júlio acknowledges financial support from Fundação para a Ciência e Tecnologia (grant UID/ECO/04007/2013) and FEDER/COMPETE (POCI-01-0145-FEDER-007659). The views expressed in this article are those of the authors and do not necessarily reflect the views of Banco de Portugal. Any errors and mistakes are ours.

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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.

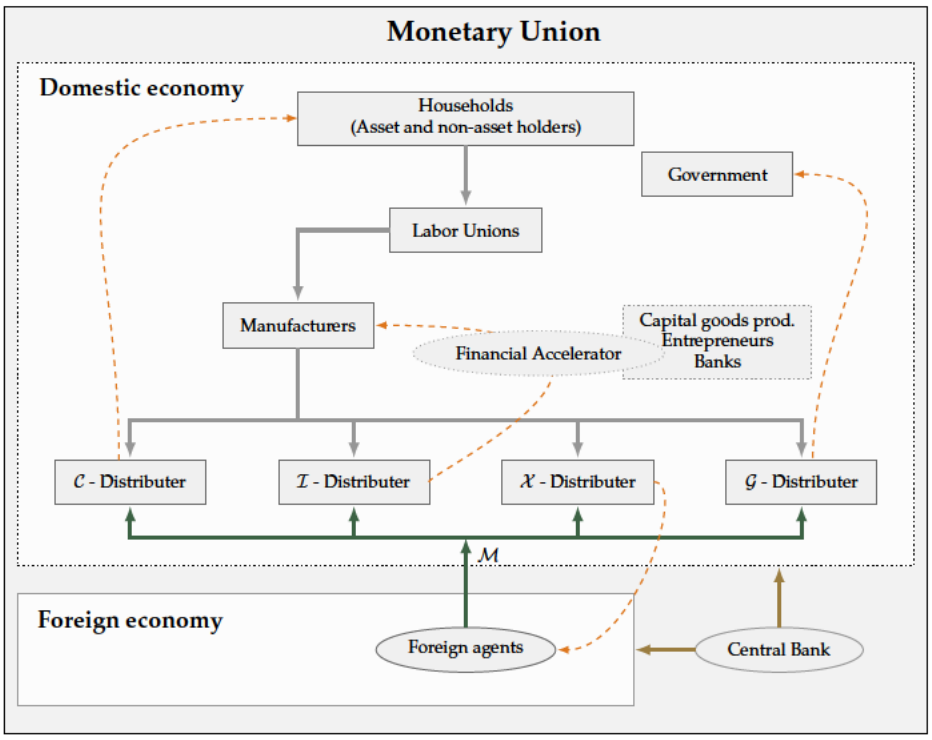

FIGURE 1: A bird's eye view of *PESSOA*.

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

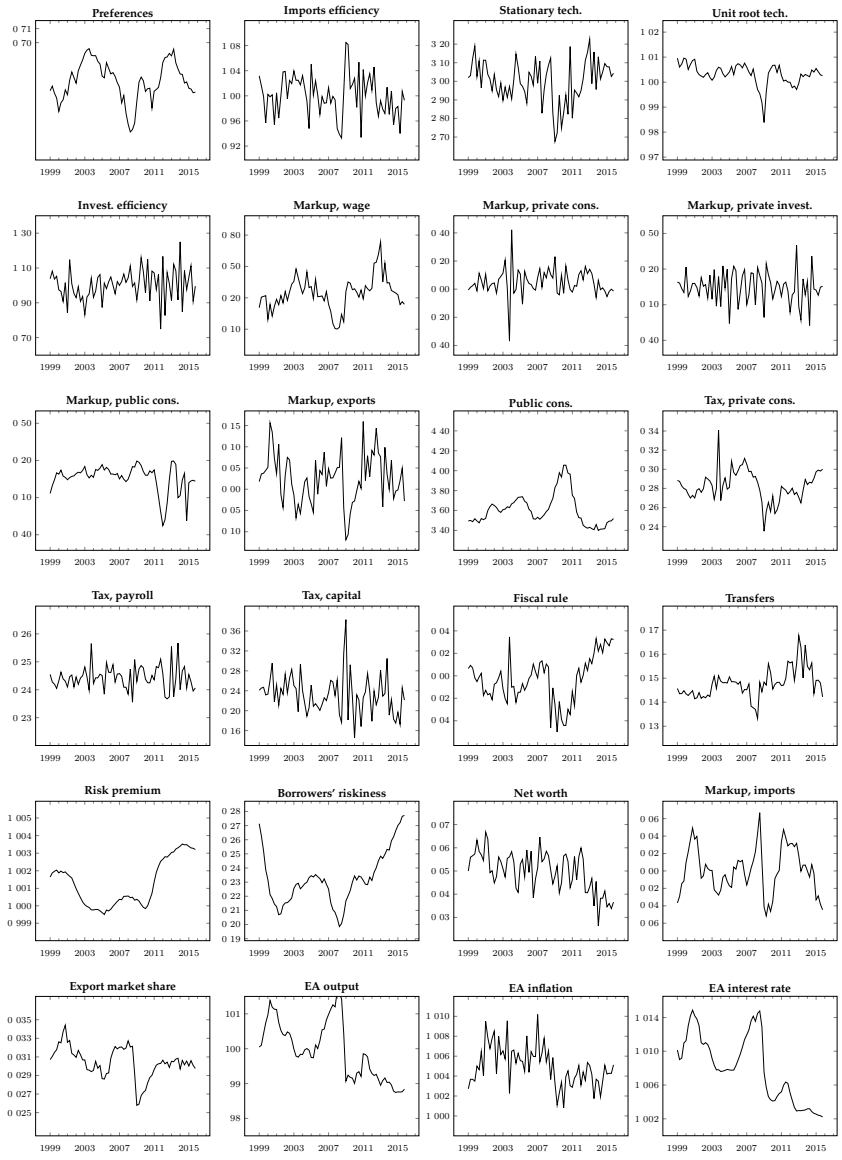

FIGURE 2: Smoothed shock processes.

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.

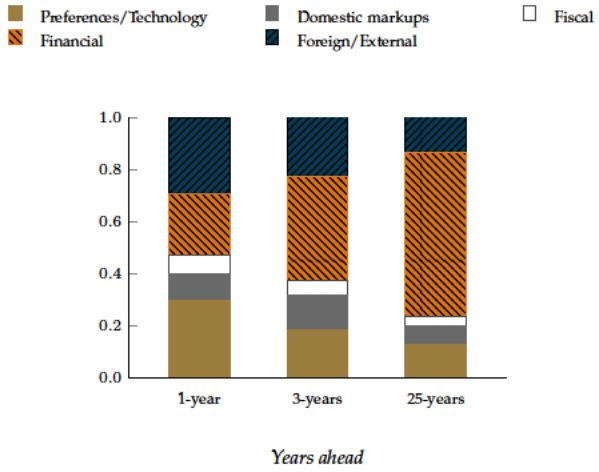

FIGURE 3: Forecast error variance decomposition for GDP.

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.

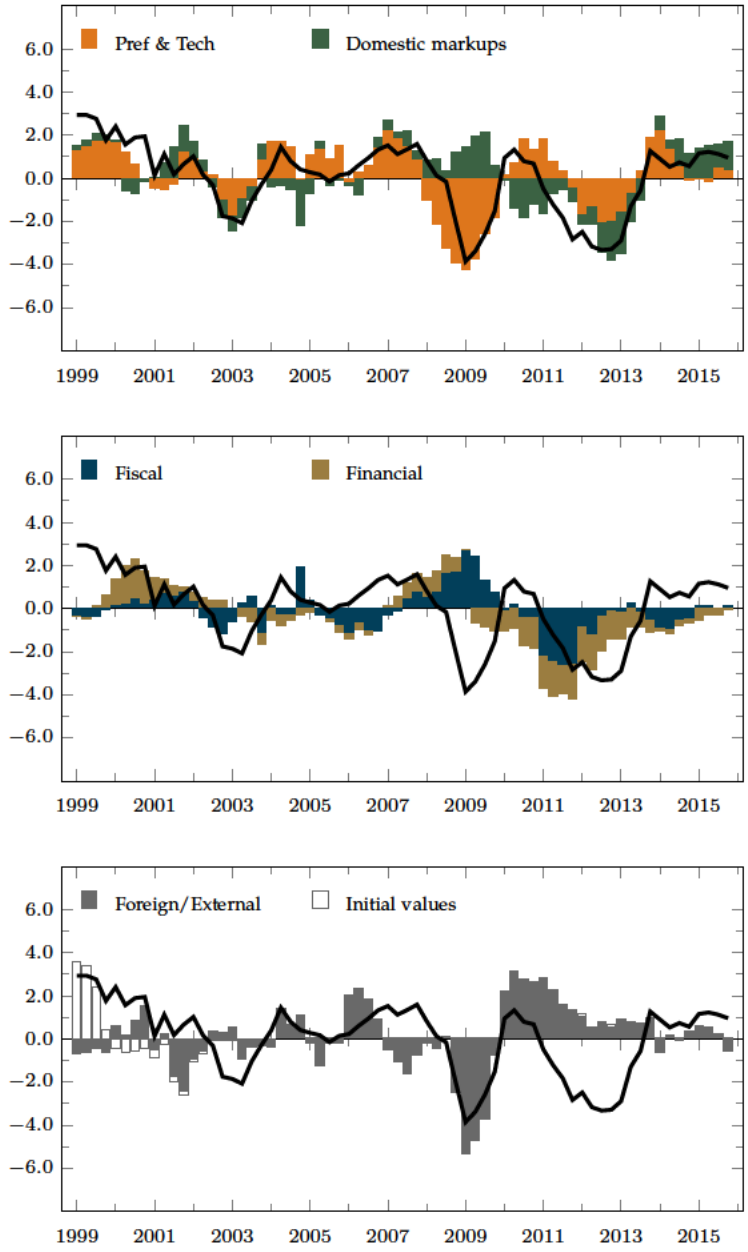

FIGURE 4: Historical decomposition of Portuguese GDP growth.

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.

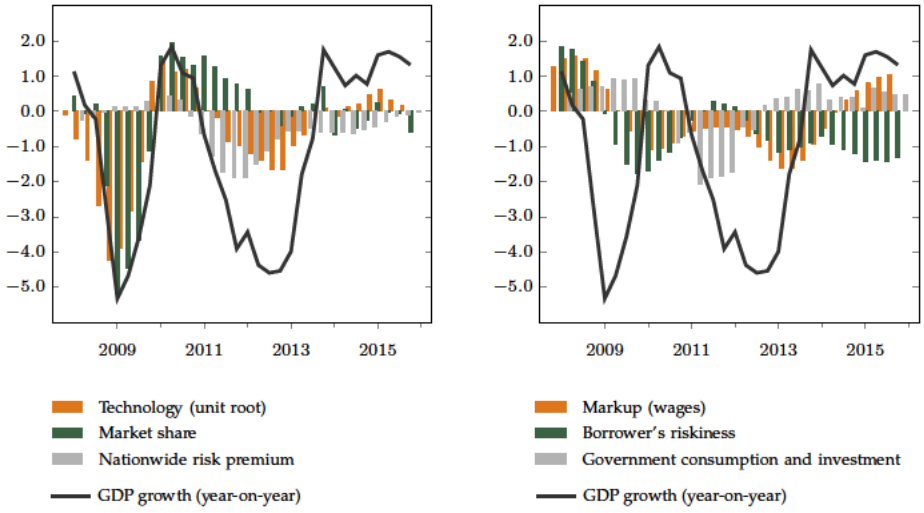

FIGURE 5: Contributions to GDP growth—selected shocks.

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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