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Ageing and Productivity: An Exploratory Analysis of the Portuguese Case

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ABSTRACT
The Portuguese labour force is ageing rapidly, corresponding to an increase in the share of older cohorts in the workforce, and there are no prospects that this situation will slow down. This study carries out an empirical analysis of the impact of workforce ageing on labour productivity in the Portuguese economy considering data for the period 1971-2017. We investigate the main channels through which these demographic changes affect labour productivity, the accumulation of factors of production, physical or human capital, and total factor productivity (TFP), based on a Cobb-Douglas production function. The results from the estimation of our VAR model defined according to the aggregate production function that includes the capital-output ratio, educational attainment, TFP and an indicator of workforce ageing, and the corresponding impulse-response functions analysis do not allow us to identify any impact of the growth rate in the proportion of older workers on the growth rate of labour productivity. For the time being it thus seems that workforce ageing has not posed a serious threat to the Portuguese economy, but this situation could rapidly change in the near future given the dismal demographic forecasts that project that the Portuguese population will decrease from 10.5 millions of people in 2012 to 8.6 millions in 2060 (INE 2014).

Key words: *labour productivity, workforce ageing, transmission mechanisms, Portugal, VAR*

JEL Classification: E23, J11, O30, O47

INTRODUCTION

The Portuguese economy almost stagnated during the 21st century and income levels are diverging from the average income per capita levels of the 28 European Union member states (EU28). Between 1996-2000 Portuguese real GDP grew at an annual average rate of 4.08%, higher than the EU28, 2.92%; however, in the period 2001-2017, which encompasses the 2007-08 economic crisis, the sovereign debt crisis and the subsequent period of economic and financial assistance by the ECB, the European Commission and the IMF (2011-14), this rate decreased to 0.45% against 1.42% for the EU28 (PORDATA). This trend has been mainly explained by decreasing contributions from productivity (Alves, 2017; National Productivity Board, 2019). Portugal's hourly productivity levels are indeed well below those of the EU28 (68%; 2000-2017). Simultaneously, demographic ageing proceeds at a fast pace. Between 1997 and 2017 Portugal recorded the fourth largest increase of the old age dependency ratio (OADR) that stood at 32.5% in 2017 (EU28 - 29.9%), Eurostat (2018). The Portuguese population is getting older and the workforce is no exception. The proportion of the younger age groups of the

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workforce, 15-24 and 25-34 years old, has decreased: in 2000 they represented 27.9% and 29% of the workforce, respectively; while in 2017 they represented 20.5% and 21.6%. On the other hand, the older age groups, 45-54 and 55-64 years old, which in 2000 represented 24.5% and 20.8% of the workforce, respectively, in 2017 increased their participation in the workforce to 28.4% and 25.7% (PORDATA). As Portugal is getting older, is this ageing population bad for productivity and thus growth? This is the research question posed by the present study.

Previous studies have highlighted the economic importance of population ageing, including its impact on economic growth through productivity (Nagarajan, Teixeira & Silva (2016); Feyrer (2007; 2008); Aiyar, Ebeke & Shao (2016); Acemoglu and Restrepo (2017; 2018)). An older workforce presents higher levels of experience and more firm/task/occupation-specific knowledge, which in turn has a positive impact on productivity resulting in faster output growth. Also, as argued by Galenson, (2019) the nature of creativity differs over the lifetime of individuals resulting in different types of innovations and thus productivity improvements but do not disappear in older individuals and can even increase with age. However, productivity may change over the life cycle because physical and cognitive abilities change with age. Over the life cycle and as they get older, workers may suffer a depreciation of their knowledge and lose cognitive and physical abilities and it could also be the case that older workers are less inclined to take risks like becoming entrepreneurs or moving to a different career where they could be more productive; in addition, the difficulties of adapting to new technologies might also increase, reducing their productivity and thus output growth. However, Acemoglu and Restrepo (2017; 2018) pose that as the workforce ages firms are more likely to adopt technology that improves productivity such as robots. The relationship between age and productivity is thus not easy to establish, as evidenced in micro-level studies such as van Ours & Stoeldraijer (2011) and more generally in WHO (2015).

We investigate workforce ageing contribution for productivity dynamics in Portugal over the period 1971-2017. The empirical approach makes use of a VAR model inspired by the Cobb-Douglas aggregate production function to distinguish between the effects of workforce ageing (the proportion of the labour force aged 55-64 years) through factor accumulation, physical and human capital, and total factor productivity. To determine these impacts, we use impulse-response functions (IRFs) analysis and employ the standard Cholesky decomposition. Next we determine the cumulative impacts of workforce ageing on output per worker growth. The data used was retrieved from the Portuguese National Statistics Agency (INE), PORDATA, the PWT and AMECO databases.

The paper proceeds as follows: after the Introduction, the second section contains a brief review of the relevant literature. The next section describes the empirical strategy and the data used. The fourth section presents and discusses the main results and the final section gives some concluding remarks.

LITERATURE OVERVIEW

According to INE, in 2017 Portugal recorded a fertility rate of 1.37 children per woman, well below the replacement rate (2.1 children per woman). At the same time, the old age dependency ratio stands at 32.5 persons aged 65 and over (age when they are generally economically inactive) per 100 persons aged between 15 and 64 (persons of working age). As a result, the Portuguese population is rapidly ageing, a source of concern at the political level and for society as a whole. In this context, understanding the economic mechanisms through which an ageing population affects a country's long run macroeconomic performance becomes a priority in order to design and implement the most effective and timely policies to prevent its potential economic costs. Previous empirical studies on the topic also provide important background for a better understanding of the Portuguese context.

Population ageing slows growth in several ways, the most obvious of which is the fact that there will be less workers and, *ceteris paribus*, workforce shrinking due to demographic change will result in less aggregate output. Nagarajan, Teixeira & Silva (2016) carry out an extensive review of the theoretical literature on population ageing and economic growth, highlighting different mechanisms of transmission, most of which result in slower economic growth. As the population gets older, we observe changes in consumption and savings patterns that can have detrimental effects on growth. On the hand, older people tend to consume more health related services and other goods related to old age, which can result in a higher relative weight of these sectors within the economy. If these are sectors with low potential for productivity improvements, aggregate productivity will slow down and so will national output growth. On the other hand, according to standard life-cycle consumption theory savings decreases in old age, leading to less capital accumulation and thus stifling growth. Another mechanism of transmission is related to government interventions. Population aging affects both public revenues and expenditures. On the one hand, tax revenues decrease as retired workers pay less income taxes; on the other hand, as the number of retired workers increases and the average life expectancy becomes higher, there will be a greater allocation of government resources to spend with the elderly (pensions, health, etc.), which in other demographic contexts could be directed to other purposes, such as public investment, and in this way promote growth. In addition, retired workers have higher educational attainment levels and, therefore, earn higher pensions. The increased spending on the elderly associated with lower tax revenues could result in an increase in the public deficit, leading to higher interest rates, less investment and growth. Also, if those that are still working and firms have to pay higher taxes, this could act as a disincentive to work and as a disincentive for firms to invest. As a result, there could be a fall in productivity and output growth. Finally, the influence of population ageing on growth might happen through productivity, which according to the authors is the mechanism of transmission with the most discrepant arguments and evidence. Some authors argue that workers of different ages are not perfect substitutes and so different signs can emerge in term of the relationship between an ageing workforce and productivity. On the one hand, older workers have higher levels of experience and firm/task/occupation specific knowledge with associated higher levels of productivity. Additionally, in modern knowledge based economies, creativity is an important driver of innovation and in this way productivity. According to Galenson (2019), p.3 “Creativity is not the prerogative of the young, but can occur at any stage in the life cycle. (...) The bold leaps of fearless and iconoclastic young conceptual innovators are one important form of creativity. (...) But there is another, very different type of creativity, in which important new discoveries emerge gradually and incrementally from the extended explorations of older experimental innovators.” On the other hand, over the life cycle workers become less productive because of weakened cognitive and physical abilities. It could also be the case that older workers are often less inclined to take risks like becoming entrepreneurs or moving to a different career where they could be more productive. If the latter effects are stronger than the former, population ageing, if it translates into an increase in the proportion of older workers, will be detrimental to growth, through a reduction in aggregate productivity. However, other authors argue that with modern economies increasingly mechanized/automated, the loss of physical and cognitive abilities by older people will not be relevant for aggregate productivity if firms become more likely to adopt technology that increases productivity, such as an increase in the use of robots in production and automation of tasks, as population gets older (Acemoglu and Restrepo 2017;2018). According to Acemoglu and Restrepo (2017; 2018), there will be an endogenous response of the economy to an ageing workforce. If, as population ages, the supply of workers declines relative to demand, wages will increase. Faced with higher wages firms will have an incentive to invest in technologies that make labour more productive and this in turn promotes growth.

The former discussion seems to imply that the issue is essentially empirical. A few recent studies make an attempt to assess the impact of population/workforce ageing on economic growth, highlighting in most cases the productivity channel. Werding (2008) and Feyrer (2007;2008) have explored the idea that workers from different age groups have different levels of productivity. To identify the impact that the age composition of the workforce may have on output growth per worker and on the growth rate of TFP, Werding (2008) uses data for 106 countries, including 27 OECD economies, from 1960 to 2000, and estimates a model where the dependent variable is the growth of TFP and the main explanatory variables the different age groups. The results suggest the existence of an inverted U relationship between the proportion of workers belonging to different age groups and productivity. Thus, up to the 40-49 years old group productivity is increasing; but from the age of 50 workers' contributions to productivity become less and less important. Feyrer (2007; 2008) also concluded that demographic changes in the workforce have a significant correlation with labour productivity and output growth rates. Thus, differences in the age structure of countries explain their differences in productivity. The same inverted U relationship was found between the proportion of workers belonging to different age groups and their productivity. The econometric models considered as dependent variables either the growth rate of output per worker or the growth rate of TFP. The sample covered 87 countries, also focusing on OECD countries alone (19 OECD countries in Feyrer (2007) and 21 in Feyrer (2008)) with data ranging from 1960 to 1990. The findings for both samples were consistent in showing that a very young or very old age structure is detrimental to the growth rate of output per worker. In both cases the regressions are derived from a Cobb-Douglas production function with physical and human capital in order to identify the most relevant mechanisms of transmission from ageing to growth, input accumulation or productivity. The authors find that the latter is the most important one. Based on the same empirical approach, Aiyar, Ebeke & Shao (2016) focus on the EU member states for the period 1950-2014, confirming also that workforce ageing leads to slower labour productivity growth. They also identified as the main underlying transmission mechanism TFP growth. The authors additionally estimated models to identify policy measures that can alleviate the negative effects of demographic change, concluding that the most important ones are better health conditions, innovation, human capital accumulation, labour market flexibility and a lower tax burden. In an even more recent study, Poplawski-Ribeiro (2019) uses the same methodology to reassess the empirical relationship between workforce ageing and TFP growth focusing on a panel data set composed of at least 32 and at most 73 advanced economies (AEs) and emerging market economies (EMEs) over the period 1985–2014. One of the main contributions of Poplawski-Ribeiro (2019) is the consideration of the age structure of employed workers and not the labour force, measured as the ratio of older employed workers (ages 55–64) to the total number of employed workers. The results show that ageing slowdowns TFP growth particularly in AEs, but also in EMEs.

Maestas, Mullen & Powell (2016), Liu & Westelius (2017) and Daniele, Honiden &. Lembcke (2019) tackle the issue from the perspective of US states, Japanese prefectures and OECD regions, respectively. Maestas, Mullen & Powell (2016) use data on the variation in the rate of population aging across U.S. states over the period 1980-2010 to estimate the economic impact of ageing on state output per capita. The results suggest moderate reductions in economic growth associated with population aging at the state-level, with about 2/3 of the total effect of population aging on the growth of GDP per capita arising from slower productivity growth. Liu & Westelius (2017) use data for 47 Japanese prefectures over the period 1990-2007 to estimate the impact of the shares of 10-year age groups of the working age population (ages 20 to 69) on productivity. The results show that the age distribution of the working age population had a significant impact on total factor productivity, corresponding to a clear inverted U productivity pattern amongst age groups, with the excluded age group 40–49 being the most productive. The evidence found by Daniele, Honiden & Lembcke (2019) for 1802 TL3 regions in 19 OECD countries over the 2006-14 period through the estimation of an empirical model where labour productivity is regressed on the ratio of old (aged 50 or more) to young workers (aged between 20 and 49) points also to a negative relationship, stronger in predominantly urban and intermediate regions. This difference, according to the authors, could be due to the heterogeneous impact of ageing on productivity growth across sectors: tradable services are the sectors in which ageing has the most negative impact on productivity growth and these tend to concentrate in cities.

Different from the previous studies, Acemoglu and Restrepo (2017; 2018) provide evidence that ageing can meaningfully accelerate growth. Data for 49 countries between the early 1990s and 2015 and for the US states reveal a strong positive correlation between the change in the ratio of the population above 50 to those between 20 and 49 and the change in the number of robots (per million of labour hours). Estimates of the impact of ageing on GDP per capita from 1965 to 1990 and 1990 to 2015 reveal a positive association leading the authors to conclude that countries undergoing more rapid population ageing adopted more robots, which resulted in faster productivity and output growth.

For the Portuguese case, according to Albuquerque (2015), the reduction of the working age population relative to the total population has already had an impact on the dynamics of output per worker. The authors observe the period 1999-2014 and perform a decomposition exercise disaggregating the Portuguese real GDP per capita growth rate into four components: demographic, which consists of the working age population relative to total population; employment, which relates the number of workers to the total working age population; working hours, which is the ratio between the number of hours worked and the total number of workers; and productivity per hour, measured as GDP per hour worked. The first component, the demographic one, presented small but steady negative contributions, amounting to around 0.194% on average.

Most of the reviewed studies find a negative association between the age structure of the population/workforce and aggregate productivity but controversies remain, making it important to conduct an empirical study directed only at Portugal to gain a better understanding of the effects of population ageing on productivity in this specific case. As van Ours & Stoeldraijer (2011) and more generally WHO (2015) point out, based on individual data workers' productivity does not seem to fall with age because, for instance, even if there are negative impacts resulting from weakened physical and cognitive abilities these can be compensated for by the life and work experiences of older workers. Other offsetting effects include the type of occupation, the type of tasks involved in the workers' job and the age diversity of working teams.

EMPIRICAL STRATEGY AND DATA

To investigate the impact of workforce ageing on productivity we estimate a VAR model defined according to a standard Cobb-Douglas aggregate production function, with human capital, as in Hall & Jones (1999), Feyrer (2007; 2008) and Aiyar, Ebeke & Shao (2016), highlighting potential differentiated effects of workforce ageing. The approach adopted by Feyrer (2007; 2008) and Aiyar, Ebeke & Shao (2016) is adapted to country specific analysis in the context of a VAR model as suggested by Bação, Gaspar and Simões (2019).

Hall & Jones (1999) assume that output, Y, is produced according to the following production function:

$$Y_t=K_t^{\alpha}(A_tH_t)^{1-\alpha} \tag{1}$$

where K is the stock of physical capital, H is the amount of human capital-augmented labour used in production, A is total factor productivity and α is the capital share.

Output per worker, y, can thus be written as:

$$y_t=k_t^{\alpha}(A_th_t)^{1-\alpha} \tag{2}$$

where k represents the stock of real capital per worker, h is human capital per worker, A is total factor productivity (TFP) and α is the share of capital in output, assuming values between 0 and 1 and usually set at 1/3. The production function described in (2) can be also rewritten as:

$$y_t=(K/Y)_t^{\alpha/(1-\alpha)}A_t h_t \quad (3)$$

where K/Y is the capital output ratio.

Applying logarithms and first differences to both sides of equation (3) allows us to arrive at equation (4), where the Δlog's are the log-growth rates of the variables:

$$\Delta log y_t=[\alpha/(1-\alpha)]\Delta log(K/Y)_t \Delta log A_t+\Delta log h_t \quad (4)$$

This decomposition makes it possible to estimate the impact of workforce ageing on real output per worker considering its influence through the growth rate of the capital-output ratio, the growth rate of human capital per worker and the growth rate of TFP. Thus, it is possible to analyse separately two effects, the effect via factor accumulation (physical and human capital) and the effect via TFP.

For this purpose, a VAR (Autoregressive Vector) model is estimated (based on Bação, Gaspar & Simões 2019) consisting of four endogenous variables ordered[1] as follows: the growth rate of the proportion of older workers; the growth rate of human capital per worker; the growth rate of TFP and the growth rate of the capital-output ratio. The general VAR model of order p is given by equation (5), where X represents the column vector including the four variables described before.

$$X_t=\alpha+\beta_1 X_{t-1}+ \beta_2 X_{t-2}+\ldots+ \beta_p X_{t-p}+\varepsilon_t \quad (5)$$

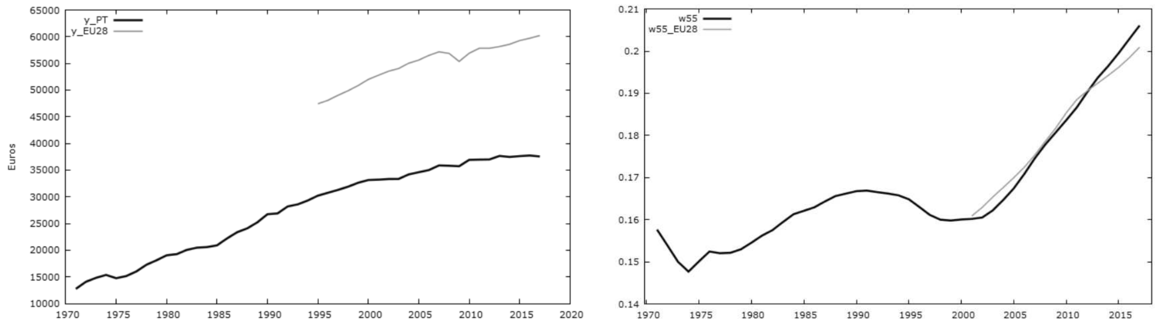
The VAR approach is appropriate since it allows to treat all variables as endogenous. In addition, it allows us to obtain the reaction from each variable to a shock in one of the other variables, in particular we want to analyse how each component of the Cobb-Douglas production function reacts to a shock in the growth rate of the proportion of older workers and, based on these results, we determine the cumulative impact on the growth rate of output per worker.

Output per worker y is measured as the ratio between GDP at constant 2010 prices and the number of workers (or hours worked), both retrieved from AMECO. Workforce ageing is measured as the proportion of workers aged 55-64 in the labour force and was obtained from PORDATA. The capital stock data at constant 2010 prices is also from AMECO. Human capital per worker data was retrieved from the Penn World Table 9.1 and corresponds to a human capital index based on average years of schooling and an assumed rate of return to education, available from 1971 to 2014. To obtain the remaining 3 missing observations, the average growth rate of the former 10 years was calculated and used to obtain the values for the years 2015, 2016 and 2017. TFP was computed according to equation (2), using the time series mentioned above: from AMECO we used the number of employees, real GDP at constant 2010 prices and the capital stock at constant 2010 prices; and from the PWT we used human capital per worker. The growth rate of total factor productivity had thus to be estimated; we did so based on the aggregate production function (equation 2) and setting α, the capital share, to one third, as is customary.

Figure 1 contains data on output per worker and workforce ageing for Portugal and the EU28 over the period 1971-2017. From the inspection of Figure 1, part (i), it is possible to see that Portuguese output per worker is well below that of the EU28 average. In 1995 output per worker in Portugal amounted to €30221.73 while the average EU28 worker produced € 47430.20. In 2017, these values were respectively € 37567.84 and € 60216.24, corresponding to

[1] See the explanation for the ordering adopted in the next section.

an annual growth rate of 1% for Portugal and 1.1% for the EU28. From graph (ii), Figure 1, we can see that the proportion of workers aged 55-64 in the labour force both in Portugal and the EU 28 shows a strong positive trend. In 2001 the figures were quite close, around 16%; in 2017, the values were, respectively, 20.6% and 20.1%.



(i) Outuput per worker ***(ii)* workers aged 55-64 (proportion of the labour force)**

Figure 1. Output per worker and workers aged 55-64 as a proportion of the labour force, Portugal and the EU28, 1971-2017

Source: AMECO, INE, PORDATA.

Figure 2 presents the annual growth rate of the proportion of older workers in Portugal from 1971 until 2017 where it is possible to observe a steady increase since the mid-90s that however seems to be decelerating since more or less the year 2010.

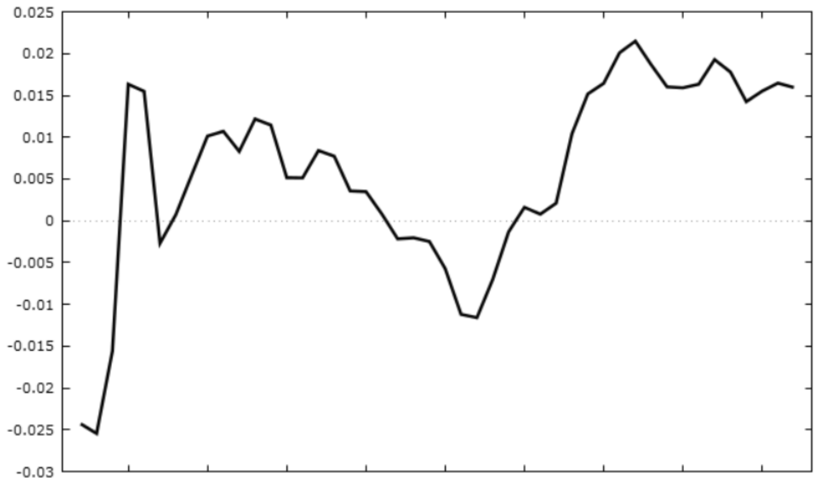
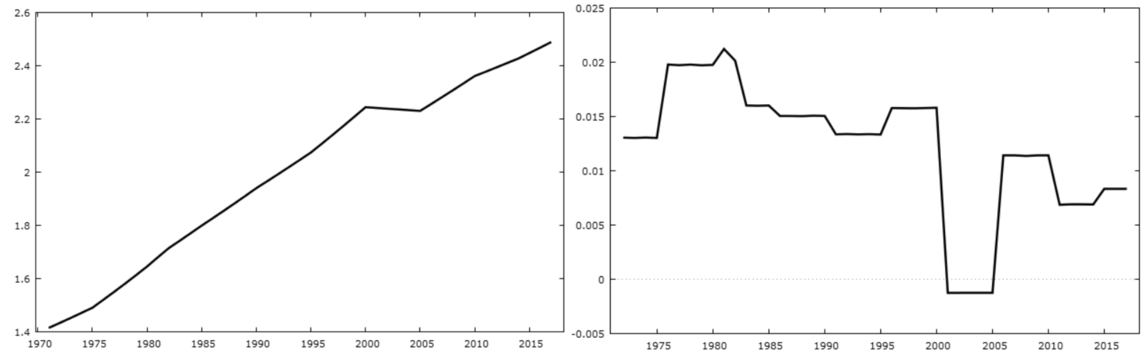


Figure 2. Workers aged 55-64 as a proportion of the labour force, annual growth rate, Portugal, 1971-2017

Source: PORDATA and authors' computations.

In Figure 3 it is possible to observe the behaviour over time of the human capital index for Portugal over the period 1970-2017, both in levels and growth rates. The level of human capital shows a strong positive trend, going from 1.4 in 1971 to 2.5 in 2017. As for its growth rate, it has remained positive for almost the entire period under analysis, however between 2000 and 2005 it recorded negative values, although very close to zero.

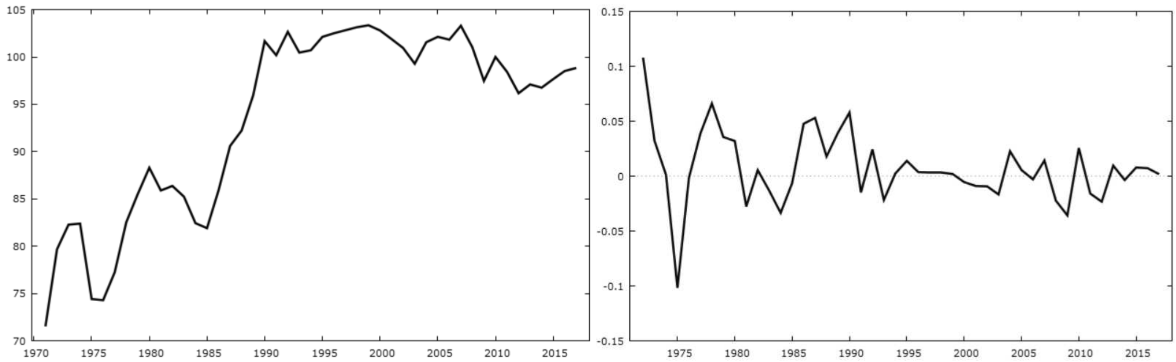


(i) levels ***(ii) annual growth rate***

Figure 3. Human capital per worker, in levels and growth rates, Portugal, 1971-2017

Source: PWT 9.1 and authors' computations.

In Figure 4 (i) it is possible to observe TFP in levels (2010=100) and growth rates. From 1971 to around 1990, the increase was considerable, from a value of 71 to a little over 100 but from then onwards TFP stagnated and shows a tendency to decrease during most of the 21st century. The respective growth rate thus shows a quite irregular behaviour but towards lower values at end of the period.

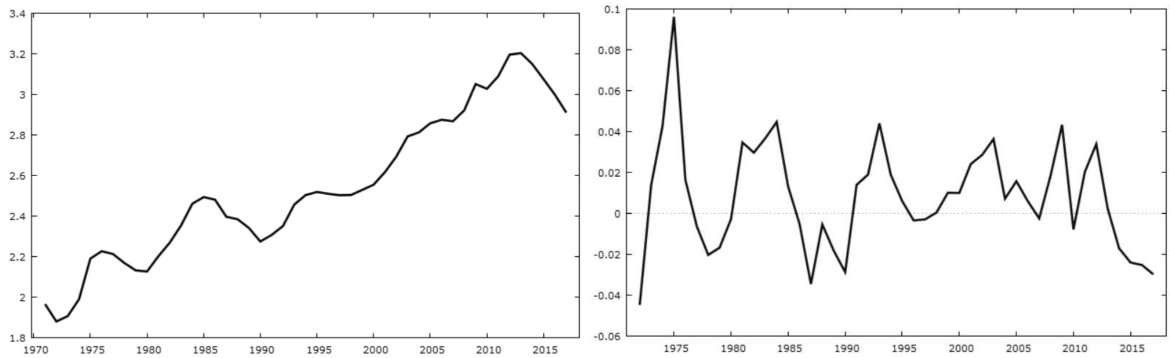


(i) levels ***(ii) annual growth rate***

Figure 4. Total factor productivity, in levels and growth rate, Portugal, 1971-2017

Source: authors' computations.

Finally, Figure 5 presents the capital-output ratio series, in levels and growth rates. This variable, as can be seen from Figure 5 (i) shows a positive trend over the period under analysis that came to a halt in 2012, decreasing ever since. Regarding the growth rate of this variable, it is possible to observe alternating periods of positive and negative growth over the years. In more recent years, in particular since 2013, it recorded negative values in every year.



(i) levels *(ii) annual growth rate*

Figure 5. Capital-output ratio, in levels and growth rate, in Portugal, 1971-2017

Source: authors' computations.

RESULTS

Before estimating the VAR model described in the previous section it is necessary to test for the stationarity of the variables included in order to avoid the spurious regressions problem. Table 1 contains the results of four different unit root and stationarity tests (KPSS and ADF, with and without trend). The values in bold indicate stationarity and, as can be observed, the growth rates of output per worker and the growth rate of the proportion of older workers are stationary. Human capital per worker, TFP and the capital-output ratio are also stationary in first differences. Lastly, the log growth rates of output per hour worked (YH) and PTF per hour worked (AH) are also stationary according to the four tests. Given these results we will use the variables in first differences in our VAR model to avoid spurious regressions. Also, since according to the results in Table 1 the variables Δlogy and Δlogw55 are only stationary with a trend, we also include a trend when estimating the VAR model.

Table 1. Unit root and stationarity tests results (p-values)

	KPSS trend	ADF trend	KPSS	ADF
y	< .01	0.998	< .01	0.099
Δlog y	**> .10**	**2.1e-5**	< .01	0.97
w55	0.01	1	< .01	1
Δlog w55	0.097	**0.049**	0.042	0.111
h	< .01	0.901	< .01	0.256
Δlog h	**> .10**	0.395	< .01	0.726
A	< .01	0.71	< .01	0.14
Δlog A	**> .10**	0.1023	**> .10**	**1.04e-05**
KY	**> .10**	0.056	< .01	0.232
Δlog KY	**> .10**	**0.011**	**> .10**	**0.0016**
YH	0.028	0.339	< .01	0.858
Δlog YH	**> .10**	**0.004**	**> .10**	**0.0005**
AH	**> .10**	0.145	**> .10**	0.064
Δlog AH	**> .10**	**0.0009**	**> .10**	**0.0001**

Source: authors.

The order of the VAR model was selected by setting a maximum order of two; this choice comes from dividing the result of the formula suggested by Schwert (1989) for univariate AR models by the number of variables included in our model (four). The formula is thus:

$$lmax = int([12(T/100)^{0.25}]/4) \quad (6)$$

where int(.) is the integer part of the argument and T is the number of observations. The rationale for adjusting Schwert's formula in this way is that the same number of lags of each variable will be present in each equation of the VAR model; therefore, the four variables will be consuming degrees of freedom in every equation of the VAR model – the division by four takes this into account (see Bação, Gaspar & Simões 2019). For both versions of the VAR model the information criteria and the likelihood ratio test points to one lag - see Table 2.

Table 2. Number of lags to include in the VAR model

Lags	loglik	AIC	BIC	HQC
1	608.167	-26.553*	-25.580*	-26.192*
2	622.507	-26.478	-24.856	-25.876

Source: authors.

Table 3 presents the estimated coefficients for the lagged growth rate of the proportion of older workers (Δlog w55) in the equations for the other variables in the VAR model. In model 1, TFP was computed taking into account the number of workers (A). In model 2, TFP was computed taking into account hours worked (AH). Most of the estimates are not statistically significant. The exceptions are the coefficients in the equation of TFP adjusted for hours worked and the equation of the capital-output ratio (model 2). In the first case, the sign is positive indicating that faster growth of the older workers group benefits economic growth via TFP. Contrarily, the impact on the growth rate of the capital-output ratio is negative. The same signs apply in model 1, although the coefficients are not statistically significant. In any case, the magnitude of the estimated coefficients is large and could assign to growth rate of the proportion of older workers an important role in the evolution of productivity and the capital-output ratio. For the growth rate of human capital per worker, the influence is positive in both models, although never statistically significant.

Table 3. Coefficients of the lagged growth rate of the proportion of older workers (Δlog w55) in the other equations of the VAR (T = 45)

		Coefficient	std. error	t-ratio	p-value
Model 1	**Δlog h**	0.0678	0.0549	1.236	0.2240
	Δlog A	0.4907	0.4567	1.075	0.2892
	Δlog KY	−0.5556	0.3463	−1.604	0.1167
Model 2	**Δlog h**	0.0758	0.0542	1.399	0.1698
	Δlog AH	1.385**	0.5291	2.617	0.0126
	Δlog KY	−0.6766*	0.3551	−1.905	0.0641

Note: ***; **; * indicate statistical significance at the level of 1, 5 and 10%, respectively.

Source: authors' computations.

In a VAR model the correct way to assess the importance of ageing is by analysing the impulse-response functions. The difficulty is that this requires an assumption about the structure of the relationship between the variables in the model. Here we employ the standard Cholesky decomposition, which imposes a recursive structure on the shocks that change the variables so that the first variable in the VAR model reacts contemporaneously only to a shock to itself; the second variable reacts contemporaneously to a shock in itself and in the previous variable; the third reacts contemporaneously to a shock to itself and to the previous two variables and, finally, the last variable in the model reacts contemporaneously to shocks to all the four variables in the VAR model.

The growth rate of the proportion of workers aged 55-64 will be the first variable that appears in the VAR model since we believe that this is the variable that takes more time to adjust to shocks due to the fact that it is related to individual decisions made at least 15 years before on whether or not to have children. In this way we do not expect it to be influenced by shocks to the other variables, i.e. it is the most rigid variable. The growth rate of human capital per worker is also related with individual decisions regarding education, work experience, training opportunities provided in the workplace, public spending on education, etc. so it makes sense to be one of the model's variables that takes more time to adjust and thus we place it in the second place in terms of the ordering of the variables in the VAR model. Productivity might depend to a great extent on age and knowledge (education, work experience, etc.), thus the growth rate of TFP will be the third variable to be included in the model so that it may react contemporaneously to its own shocks and to shocks to the proportion of older workers and to human capital. Finally, the growth rate of the capital-output ratio is the last variable to appear in the VAR model as this is the least rigid and thus adjusts most rapidly. This variable corresponds to the amount of physical capital available per unit of output, so if overall productivity changes, which depends on age and human capital, the amount of capital needed to produce each one unit of output also changes. Also, since we consider the capital-output ratio and, according to the production function, output depends on the other variables included in the VAR, we expect it to adjust more rapidly. Therefore, we will assume that the capital-output ratio will react contemporaneously to all the structural shocks in the other variables of the model. The estimated impulse-response functions and the 90% confidence intervals (grey lines) are shown in Figure 6 based on the results from Table 3 for VAR model 1, i.e. without adjusting for hours worked. Given the IRFs and the responses of the variables *Δlogh*, *ΔlogA* and *Δlog(K/Y),* it is possible to determine the impact of a shock to *Δlogw55* on the growth rate of output per worker using equation (4).

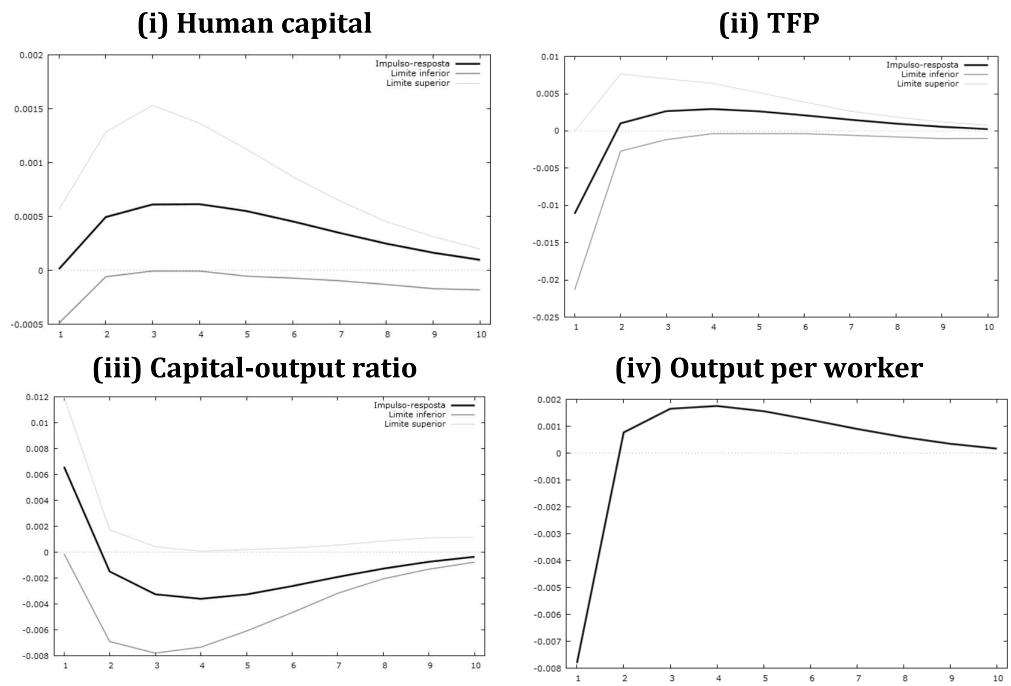


Figure 6. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of older workers (Δlogw55) based on VAR model 1 from Table 3

Source: authors.

The impulse-response functions are also not significantly different from zero (the confidence interval never excludes zero). Nevertheless, the prevailing effect is negative: an increase in the proportion of older workers would appear to decrease TFP in a more intense way than the contemporaneous positive effect it has on human capital per worker and the capital-output ratio. Consequently, the estimated impact of a temporary increase in the proportion of older workers would immediately shift down the growth rate of output per worker, as shown in Figure 6, part (iv). The shift corresponding to a one-standard-deviation temporary shock in the Δlogw55 would amount to about -0.0078 percentage points of the GDP per worker growth rate. However, in the following years the variable records positive values, reaching its maximum value after four years with the value of 0.0018, as expected, since the VAR model is stationary and so the long-term effect tends to zero.

We also carried out the impulse response analysis considering output and TFP adjusted for hours worked using the results for VAR model 2 presented in Table 3. The estimated impulse-response functions and the 90% confidence intervals (grey lines) are shown in Figure 7. The behaviour of the IRFs of the different variables is similar to that of the previous model and again the results are not significantly different from zero (the confidence interval never excludes zero). A temporary shock of a standard deviation to Δlogw55 as a negative immediate impact on ΔlogYH. In the following years the variable records positive values, reaching its maximum after three years (0.006) and approaching zero from then onwards as expected in a stationary VAR model.

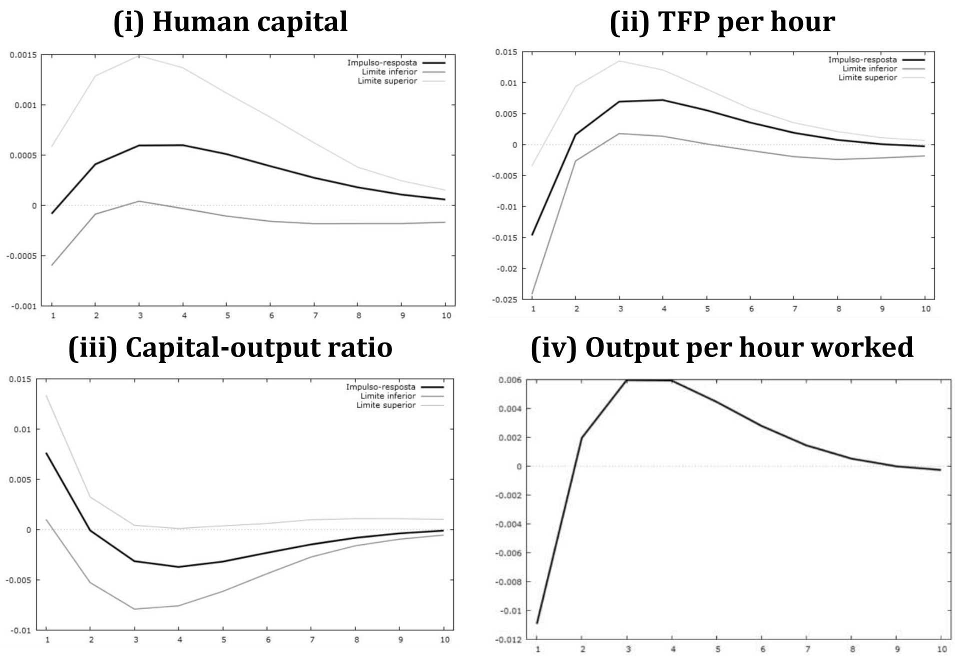


Figure 7. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of older workers (Δlogw55) based on VAR model 2 from Table 3

Source: authors.

Overall, the results from the previous IRFs analyses do not confirm the fears that the ageing of the Portuguese workforce has resulted in substantial losses in terms of output growth at the national level. In fact, the results do not endorse any impact. From the reviewed arguments put foreword to explain a potential relationship between population ageing and economic growth, it seems that for the Portuguese economy, so far, the productivity decline associated with weakened basic capacities (physical and cognitive) to do things as workers get older and the fact that they become less willing to take risks such as moving to a new job or start a new business is being compensated by the positive productivity impact of their higher levels of experience, more firm/occupation/task-specific knowledge and higher creativity or by the fact that Portuguese firms are reacting to labour shortages by introducing new technologies that increase labour productivity, as defended by Acemoglu and Restrepo (2017; 2018).

Finally, in order to get a broader view of the impact of demographics on productivity we extended the baseline VAR model to include other demographic variables corresponding to the different groups representing the age structure of the labour force (w45 - proportion of workers between 45 and 54 years old; w35 - proportion of workers between 35 and 44 years old; w25 - proportion of workers between 25 and 34 years old). We leave out the proportion of younger workers, i.e. the 15-24 age group (w15), since the sum of the different age structure variables corresponds to 100% of the labour force. Additionally, we include the total dependency ratio (ID), i.e. the ratio between the number of people between 0 and 14 years old and the number of people aged 65 and over relative to the working age population (15-64 years old).

Table 4. Coefficients of the lagged growth rate of the proportion of different age groups (Δlogw55; Δlogw45; Δlogw35; Δlogw25) and of the dependency ratio (ΔlogID) in the other equations of the VAR

Model 1								
	Δlogw55				**Δlogw45**			
	Coef.	**Std. error**	**t-ratio**	**p-value**	**Coef.**	**Std. error**	**t-ratio**	**p-value**
Δlogh	0.093	0.0617	1.510	0.1400	0.099	0.080	1.236	0.2246
ΔlogA	0.085	0.4815	0.1765	0.8609	−1.269**	0.6243	−2.032	0.0498
ΔlogKY	−0.349	0.3688	−0.9472	0.3501	0.677	0.4782	1.415	0.1659
	Δlogw35				**Δlogw25**			
	Coef.	**Std. error**	**t-ratio**	**p-value**	**Coef.**	**Std. error**	**t-ratio**	**p-value**
Δlogh	−0.018	0.0636	−0.2796	0.7814	−0.032	0.0564	−0.5651	0.5756
ΔlogA	0.851*	0.4966	1.714	0.0953	0.186	0.4399	0.4239	0.6742
ΔlogKY	−0.583	0.3804	−1.532	0.1346	−0.295	0.337	−0.8750	0.3875
	Δlog ID							
	Coef.	**Std. error**	**t-ratio**	**p-value**				
Δlogh	-0.081	0.1149	−0.7088	0.4831				
ΔlogA	2**	0.8971	2.229	0.0323				
ΔlogKY	-1.41**	0.687089	−2.045	0.0484				
Model 2								
	Δlogw55				**Δlogw45**			
	Coef.	**Std. error**	**t-ratio**	**p-value**	**Coef.**	**Std. error**	**t-ratio**	**p-value**
Δlogh	0.101	0.0614	1.648	0.1084	0.101	0.0861	1.171	0.2495
ΔlogAH	1.187 **	0.5701	2.082	0.0447	−0.231	0.7996	−0.2889	0.7743
ΔlogKY	−0.477	0.3742	−1.274	0.2110	0.549	0.5249	1.047	0.3024
	Δlogw35				**Δlogw25**			
	Coef.	**Std. error**	**t-ratio**	**p-value**	**Coef.**	**Std. error**	**t-ratio**	**p-value**
Δlogh	−0.016	0.0640	−0.2431	0.8094	−0.027	0.0605	−0.4424	0.6609
ΔlogAH	1.181 *	0.5940	1.988	0.0546	0.184	0.5621	0.3272	0.7454
ΔlogKY	−0.613	0.390	−1.572	0.1251	−0.435	0.3690	−1.179	0.2462

	Δlog ID							
	Coef.	**Std. error**	**t-ratio**	**p-value**				
Δlogh	-0.072	0.1161	−0.6211	0.5385				
ΔlogAH	1.511	1.0782	1.402	0.1698				
ΔlogKY	-1.47**	0.7078	−2.079	0.0451				

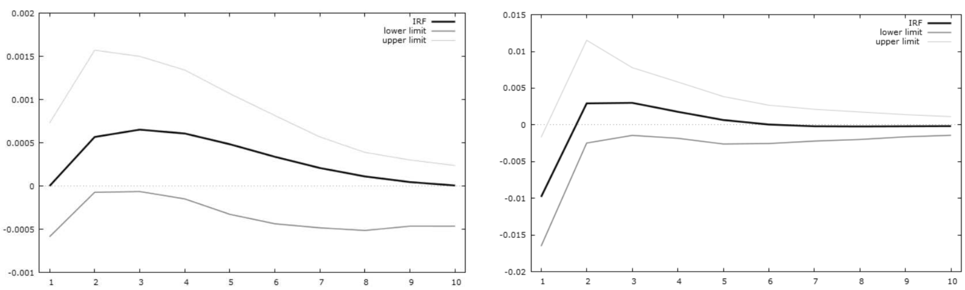
Note: ***; **; * indicate statistical significance at the level of 1, 5 and 10%, respectively.

Source: authors.

From the inspection of the results in Table 4 it is possible to see that, in what concerns the proportion of older workers, they remain basically unchanged. The lagged growth rate of the proportion of workers aged 55-64 is only statistically significant in the equation of the growth rate of TFP per hour worked, again with a positive sign. As for the other age groups, the vast majority of the estimated coefficients are not statistically significant. Exceptions include: the proportion of workers aged 45-54 that show a negative impact on TFP (model 1) and the proportion of workers aged 35-44 that reveal a positive and statistically significant coefficient in the equations of both TFP and TFP per hour worked. The remaining statistically significant coefficients refer to the dependency ratio, which shows a positive impact on the equation of the growth rate of TFP (model 1) and a negative impact on the equation of the growth rate of the capital-output ratio.

The estimated impulse-response functions and the 90% confidence intervals (grey lines) based on the results from Table 4 for VAR models 1 and 2 are shown in Figures 8 and 9, respectively. The behaviour of the IRFs of the different variables is similar to that of the previous model and again the results are also not significantly different from zero (the confidence intervals never exclude zero). The results from these IRFs also do not confirm the fears that the ageing of the Portuguese workforce has resulted in substantial losses in terms of output per worker growth at the national level. The IRFs for the remaining age groups and the dependency ration can be found in the Appendix, figures A.1 to A.8. Again the results are also not significantly different from zero (the confidence interval never excludes zero) rendering the age structure of the workforce and the overall population no role in the explanation of the dynamics of labour productivity in the Portuguese economy.

(i) Human capital **(ii) TFP**



(iii) Capital-output ratio **(iv) Output per worker**

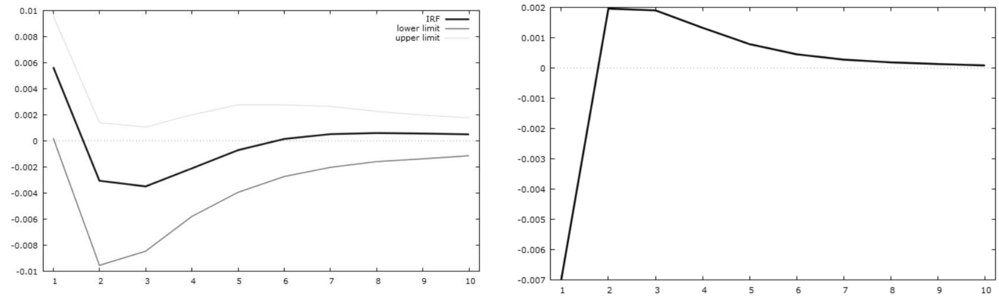
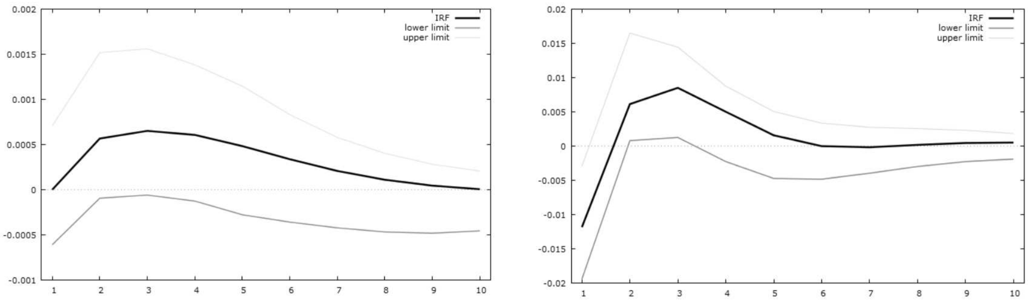


Figure 8. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of older workers (Δlogw55) based on VAR model 1 from Table 4

Source: authors.

(i) Human capital **(ii) TFP per hour**



(iii) Capital-output ratio **(iv) Output per hour worked**

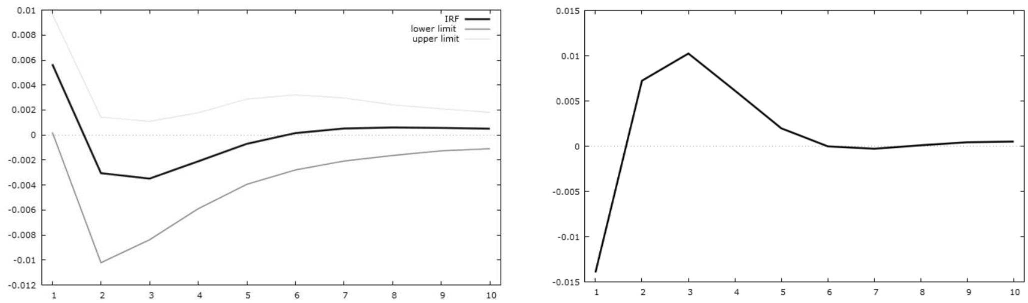


Figure 9. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of older workers (Δlogw55) based on VAR model 2 from Table 4

Source: authors.

CONCLUSION

Population ageing, in particular of the workforce, is an issue that Europe, and especially Portugal, have to face in a serious manner if they want to implement timely policies that can help avoid its potential economic costs. With ever-lower fertility rates and an ever-increasing average life expectancy, the old age dependency ratio and the proportion of older workers (aged 55-64) are increasing steadily, with potential important economic implications in the short and the long run.

We investigated the contribution of workforce ageing for productivity dynamics in Portugal over the period 1971-2017. The empirical approach makes use of a VAR model inspired by the Cobb-Douglas aggregate production function to distinguish between the effects of workforce ageing (the proportion of the labour force aged 55-64 years) through factor accumulation, physical and human capital, and total factor productivity. To determine these impacts, we used impulse-response functions (IRF) and employ the standard Cholesky decomposition. Next we determined the cumulative impact of workforce ageing on output per worker.

The results indicate that using workforce ageing in first differences (not levels) fits the data better, so ageing affects the level of output per worker (temporary growth effect). Yet, workforce ageing is generally not statistically significant in the equations of the other variables in the VAR model. The IRFs are also not significantly different from zero, but the performance of our VAR model may be affected by some series behaviour (e.g. the capital stock decline in recent years), requiring more investigation in the future.

The fact that no significant impact on productivity was found might be an indication that older workers' negative productivity impact due to the depreciation of knowledge and physical/cognitive capabilities is being exactly offset by the positive impact from their higher levels of experience, more firm/task/occupation-specific knowledge and higher creativity. Policies such as broadening access to better health services, workforce training and lifelong learning can reduce the adverse impact so that it does not surpass the positive effect. Yet, the rapid pace of technological development can make experience less relevant and a negative impact can emerge in the data. However, as argued by Acemoglu and Restrepo (2017) as the workforce ages firms are more likely to adopt technology that improves productivity such as robots and a positive impact on TFP could emerge. For the time being it thus seems that workforce ageing has not posed a serious threat to the Portuguese economy, but this situation could rapidly change in the near future given the dismal demographic forecasts that project that the Portuguese population will decrease from 10.5 millions of people in 2012, to 8.6 millions in 2060 (INE 2014).

This paper suggested a methodology (based on Bação et al. 2019; Hall & Jones, 1999; Feyrer 2007, 2008; Aiyar et al. 2016) to quantify and identify the mechanisms of transmission from population ageing to macroeconomic performance in country-specific situations. This is important for a more effective policy design that helps fight potential negative economic performance impacts of ageing. It is important to emphasize that each country is unique in terms of its characteristics and both the effects and the type of measures may differ from country to country. In any case, future comparative analyses with other 'younger' countries in a panel data context could help identifying productivity gains from slowing population ageing.

From a macroeconomic performance perspective our findings thus do not confirm the pessimistic predictions concerning the negative impact of ageing on productivity and long run macroeconomic performance. Our analysis, however, does not provide a definite answer to workforce ageing impacts on productivity growth in Portugal. We used a VAR model defined according to a Cobb-Douglas production function to identify the impact of ageing on output per worker through factor accumulation and productivity. Alternative approaches include considering different types of production functions and/or alternative modelling approaches such as an ARDL model with output per worker growth as the dependent variable and additional explanatory variables. Our aim was to implement the most robust analysis of the research question posed in this study, "Is workforce ageing a threat to productivity and in this way economic growth?" but there are issues intrinsic to the data that may constitute important limitations. First, carrying out time series econometric analysis with a short data coverage might hamper the robustness of the results. Second, the specific behaviour of some of the series used in the analysis, such as the physical or human capital series, may have a detrimental impact on the performance of our simple VAR model.

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APPENDIX

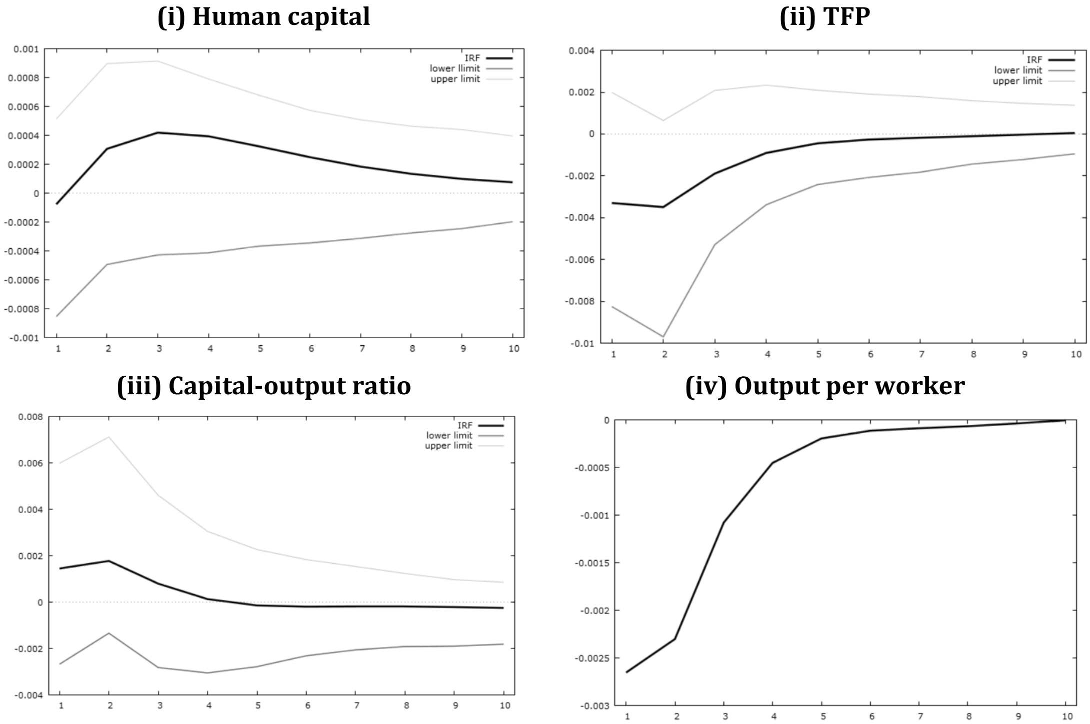

Figure A.1. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of workers aged 45-54 (Δlogw45) based on VAR model 1 from Table 4

Source: authors.

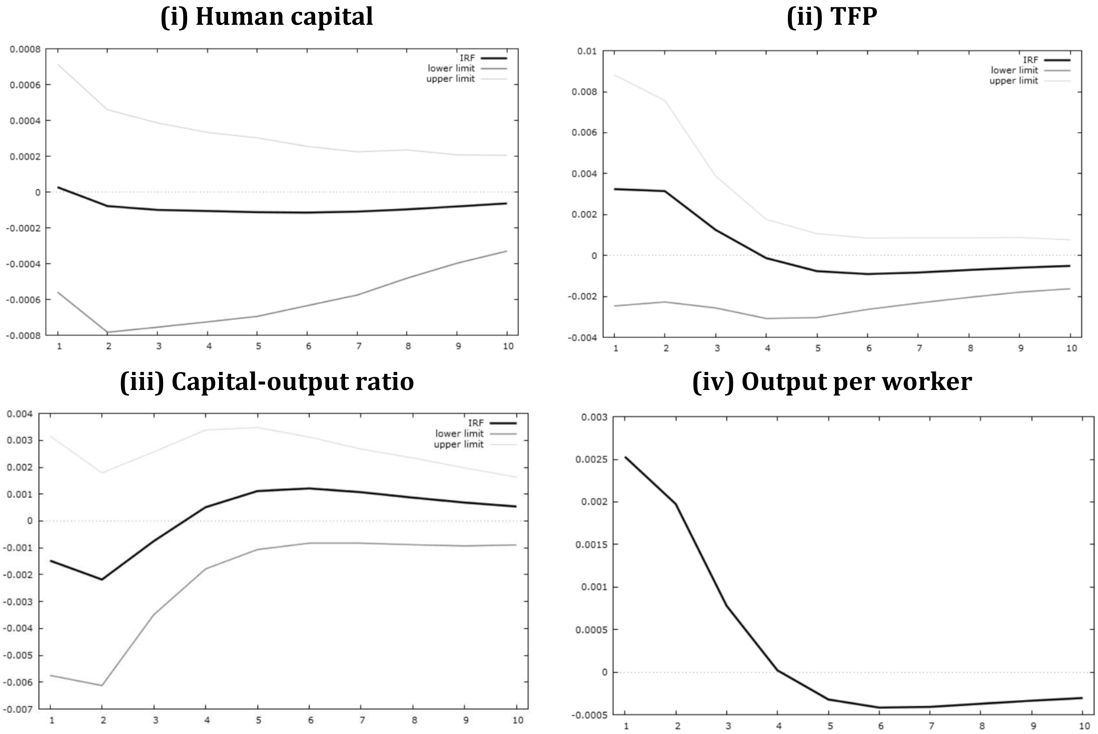

Figure A.2. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of workers aged 35-44 (Δlogw35) based on VAR model 1 from Table 4

Source: authors.

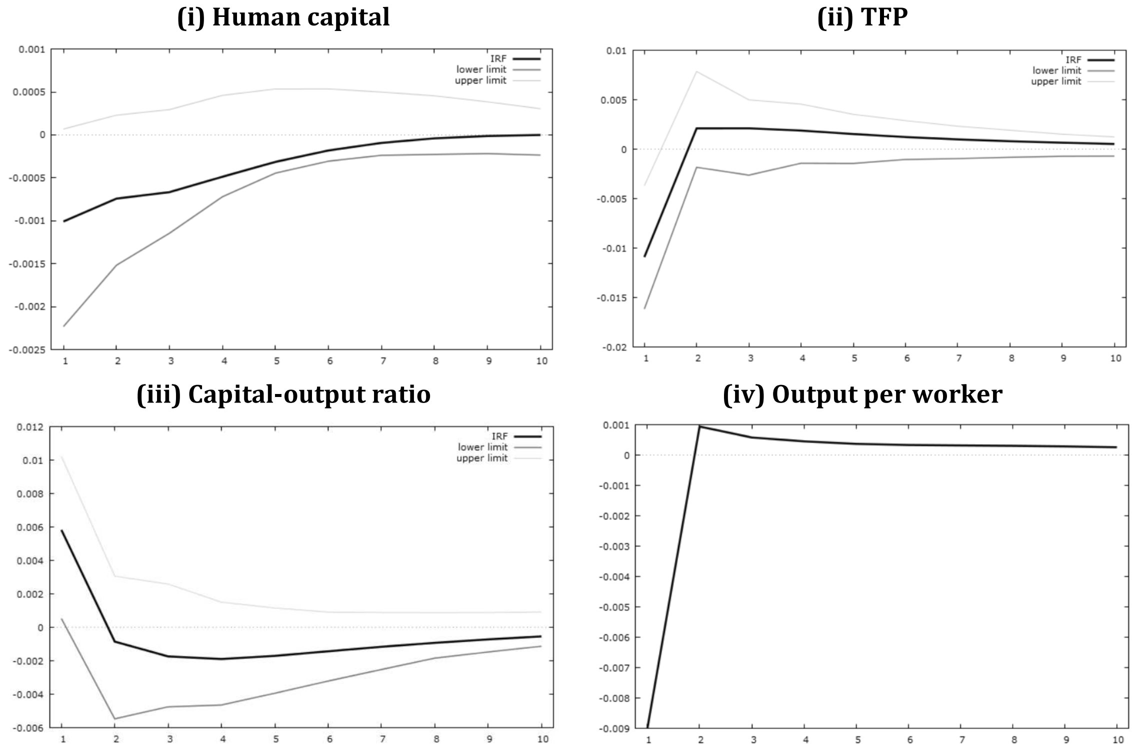

Figure A.3. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of workers aged 25-34 (Δlogw25) based on VAR model 1 from Table 4

Source: authors.

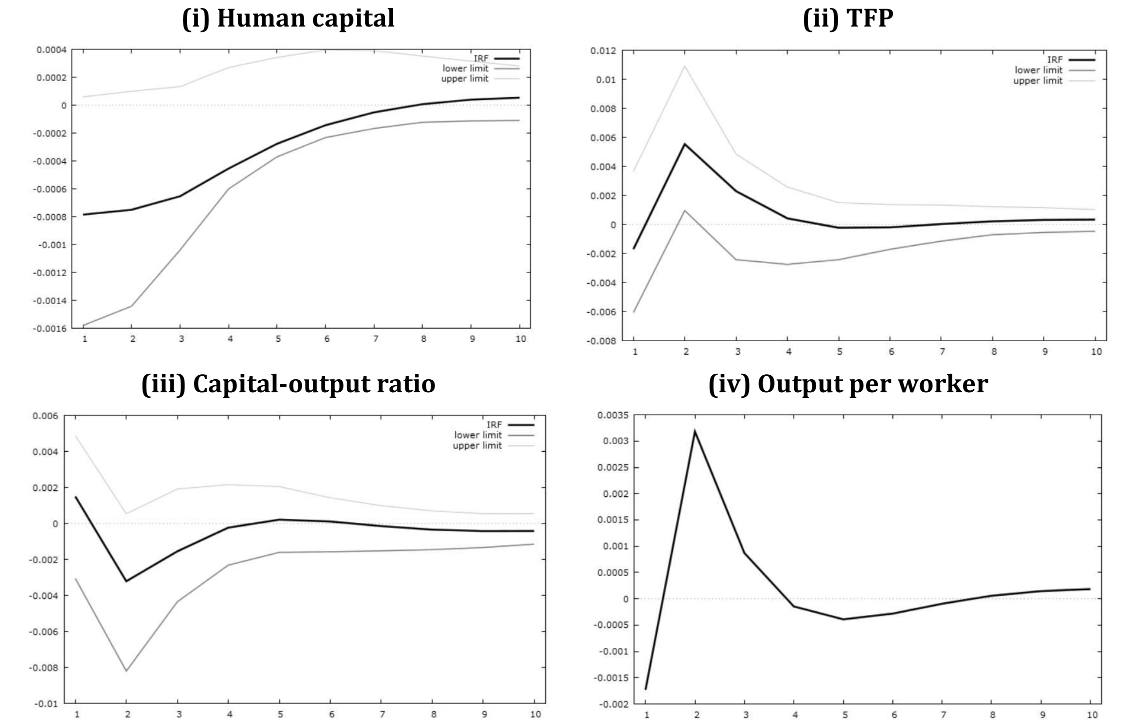

Figure A.4. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the dependency ratio (ΔlogID) based on VAR model 1 from Table 4

Source: authors.

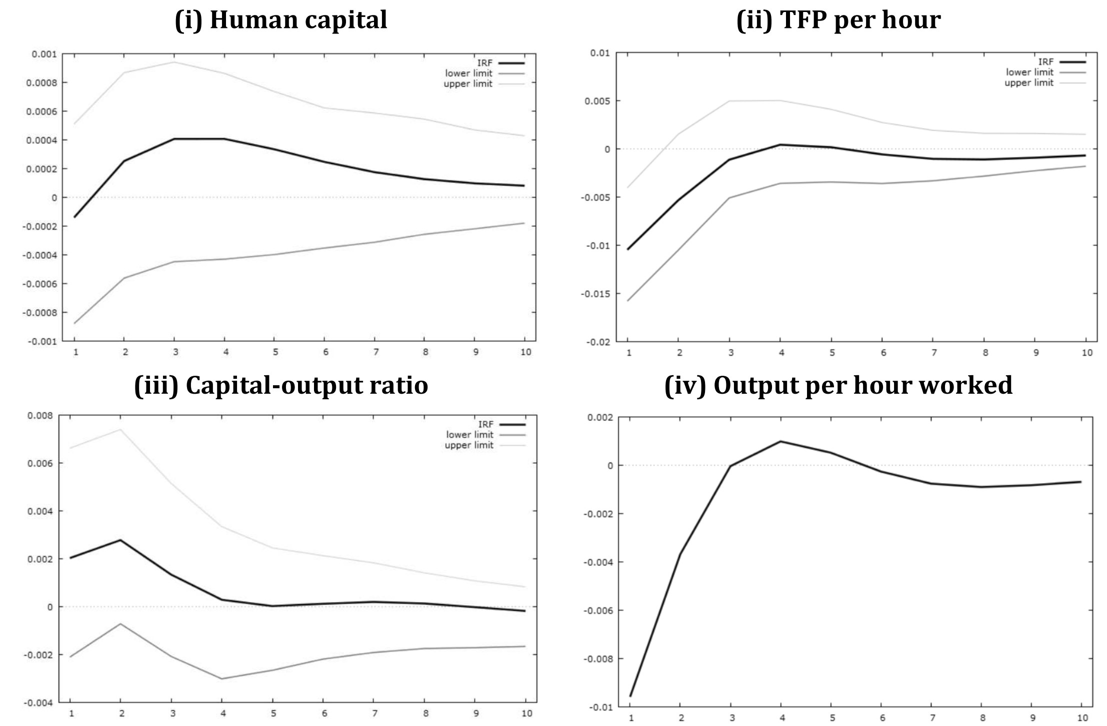

Figure A.5. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of workers aged 45-54 (Δlogw45) based on VAR model 2 from Table 4

Source: authors.

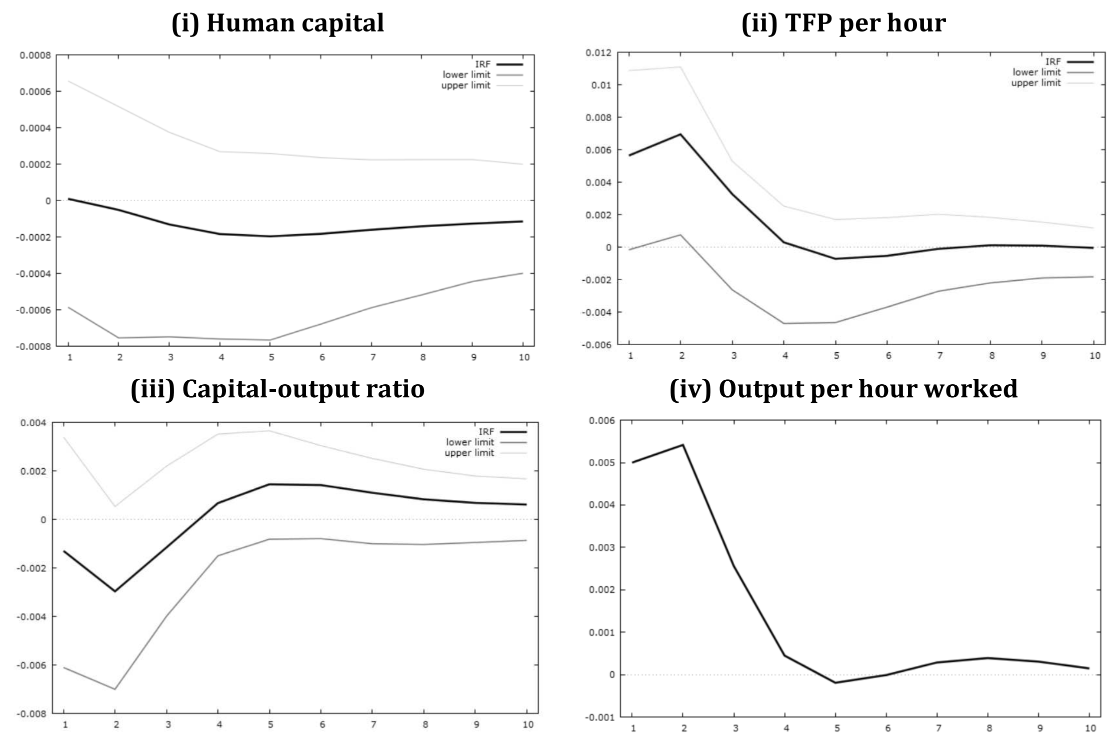

Figure A.6. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of workers aged 35-44 (Δlogw35) based on VAR model 2 from Table 4

Source: authors.

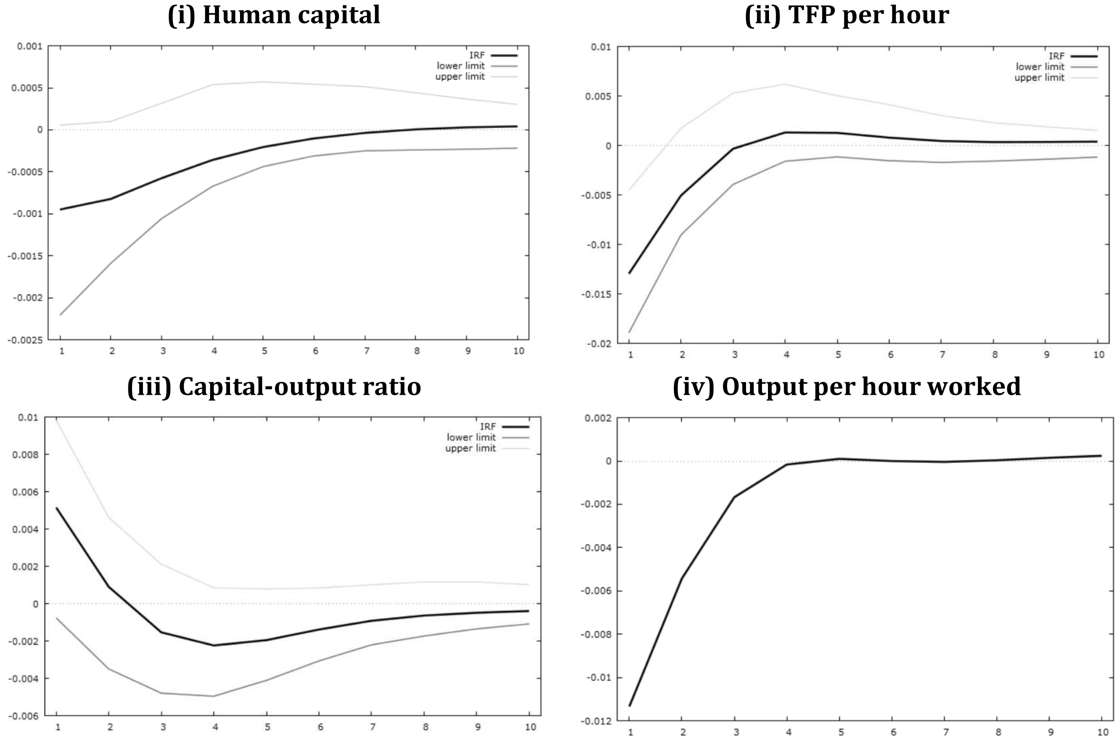

Figure A.7. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the proportion of workers aged 25-34 (Δlogw25) based on VAR model 2 from Table 4

Source: authors.

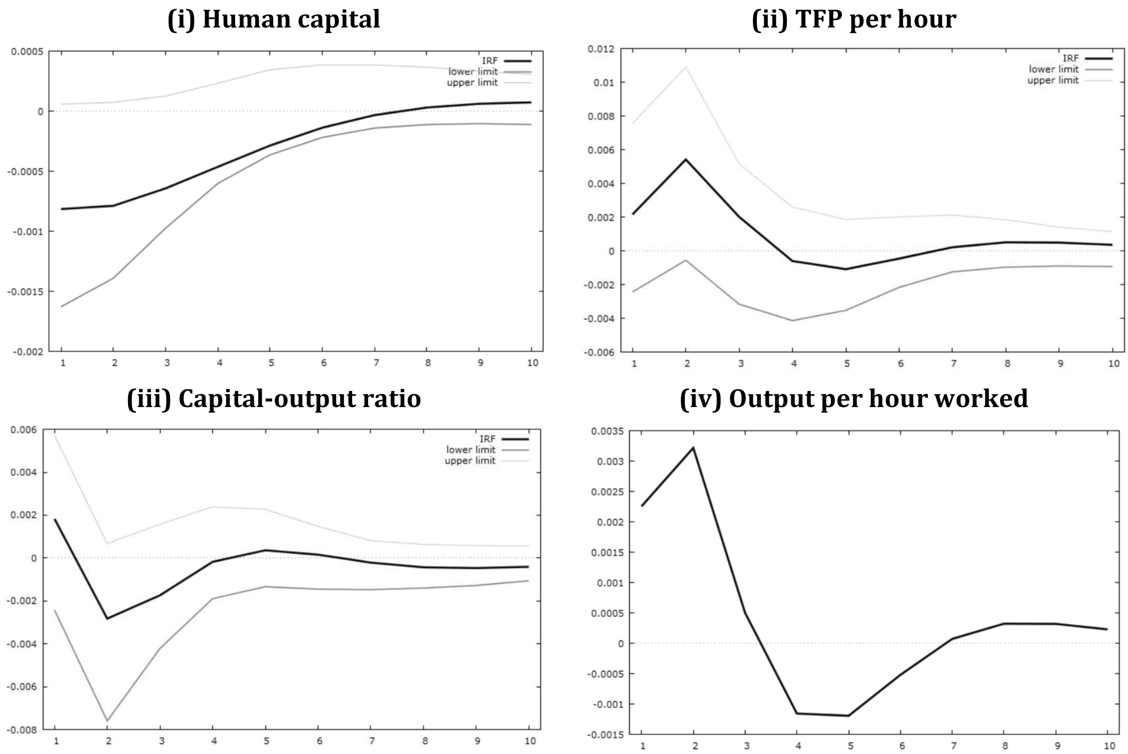

Figure A.8. Impulse-response functions of log-diffs (percent) to a temporary change in the growth rate of the dependency ratio (ΔlogID) based on VAR model 2 from Table 4

Source: authors.

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