Agriculture in Portugal: linkages with industry and services

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Abstract

We estimate a trivariate VAR model for the period 1970-2006 to investigate the existence of long-run relationships and causality among the three main sectors in Portugal in terms of value added and productivity. Agricultural value added is found to be both weakly and strongly exogenous so it exerted no influence in the other sectors expansion nor was it influenced by their growth. The results with labour productivity show that productivity gains in services and industry feedback into productivity growth in agriculture, although the link is weaker in the industry case. The definition of balanced policy strategies across sectors in Portugal should take these results into consideration.

Keywords: agriculture, industry, services, sectoral linkages, Portugal

JEL classification: Q19; O13; O14; O40

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1. Introduction

The importance of agriculture in the Portuguese economy has substantially decreased in terms of output and employment, as in all the developed countries. From the late 1950's onwards, Portugal initiated a path of sustained economic growth and impressive changes in the structure of production and employment, moving from an agrarian society into an industrial and services based economy. According to the OECD STAN Indicators for Portugal, the value added share of agriculture declined from 15.7% in 1977 to 2.82 % in 2006[4], and in terms of employment agriculture represented 28.45% of the total in 1977 and 11.82% in 2006[5]. In spite of the loss of importance of agriculture in the economy, in recent years, especially after the 2007-08 financial crisis, policy makers in Portugal have designed national policies to enhance the agricultural sector and in this way promote growth, employment, and rural development, viewing this sector as instrumental in improving the future growth prospects of the Portuguese economy. The agricultural sector seems to have the potential to play an important role in the achievement of national (and European) objectives such as food security, employment, growth and regional and social cohesion, affecting many persons and wide areas of the country, avoiding the desertification of an important part of its area by guaranteeing good living conditions in the rural areas.

In order to benefit the most from the policies aimed at the expansion of the agricultural sector it is important to understand how this sector relates to the other two main sectors of activity that dominate the Portuguese economy, industry and services. The identification of the linkages between agriculture, industry, and services can then be used to examine the impact of sectoral policies adopted by Portugal and to identify the optimal policy mix for the different sectors in the economy. Understanding these linkages involves its empirical

[4] Industry's value added share was 28.86% in 1977 and 24.27% in 2006, while services contributed to 55.75% of the value added in the total economy in 1977, and 72.97% in 2006.

[5] Despite its decline from 1977 until 2006, this share was still one of the highest in the EU15, similar to that of Greece but much higher than that of Spain or Ireland, and even higher than that of many of the new member states.

analysis, that is, they should be empirically established given the possible different signs for the relation and directions of causality suggested by theoretical predictions.

In fact, from an economic development and growth point of view, agriculture can be an important source of growth by assisting the expansion of the other sectors, traditionally viewed as the drivers of economic growth, especially manufacturing, through the transfer of resources, and providing a market for non-agricultural goods and services. On the other hand, agriculture can also benefit from technological improvements in industry and services that spill over to agriculture and cause it to grow. Additionally, non-agricultural sectors growth provides a market for the surplus labour that some authors consider as characterizing agriculture, thus increasing value added per worker in the agricultural sector. On the other hand, some industry and services sub-sectors are more labour-intensive and will thus compete with the other sectors for labour, resulting in negative sectoral linkages.

The aim of this paper is to investigate the interrelations between the three main sectors of activity, agriculture, industry and services, in the Portuguese economy in order to get some insights as to whether agriculture has benefitted from and/or contributed to the expansion of the industry and services sector. For this purpose we assess the existence of long-run relationships and causality among the three main sectors in the economy in terms of value added and productivity using a vector autoregression (VAR) model for the period 1970-2006. By using a VAR model that relates the value added (or labour productivity) of the three sectors we allow all variables to be potentially endogenous, capture the short and long run responses to shocks and test for the presence of causality. Given the varied theoretical predictions on sectoral linkages this seems the most suitable approach.

This paper adds to the literature in two aspects. First, to the best of our knowledge, the empirical application represents the first attempt to test for causality between agriculture and non-agricultural sectors in the Portuguese economy in terms of value added and productivity; and second, we extend previous analyses by focusing on a currently developed country but still undergoing a structural change process towards industrialization and tertiarization at the beginning of the period under analysis. In spite of the loss of importance of agriculture in the economy, the period covered in this analysis spans three decades over which the structural transformation of the Portuguese economy proceeded.

The remainder of the paper is organized as follows. In section 2 we review some empirical evidence on the linkages between the three major sectors of activity, agriculture, industry and services. In section 3 we describe the data and methodology. Section 4 presents and discusses the results in terms of value added and section 5 does the same for labour productivity. Section 6 contains the main conclusions.

2. A review of some relevant empirical literature

As a country entails a path of sustained economic growth, such as the one Portugal experienced from the 1950's onwards, registering unprecedented economic growth rates until the 1970's, this process is usually accompanied by changes in the structure of production and employment. The standard structural change pattern is a shift of employment from agriculture to industry and services, accompanied by a declining share of agriculture in output and a rise in the output shares of industry and services, with the latter dominating, and Portugal is no exception (see e.g. Duarte and Restuccia (2007)).

Economists have long been interested in the relationship between structural change and economic growth and the ways in which the different sectors interact in the process (see e.g. Silva and Teixeira (2008)). Yet, the direction of causality between changes in sectoral composition and growth and the associated linkages between agriculture, industry and services cannot be assumed to be unique and should thus be established empirically. The specific role of agriculture in the process of economic development and growth and the possible ways through which this sector interacts with non-agricultural sectors during this process is well summarized in Yao (2000), Gemmell *et al.* (2000), Kanwar (2000), and Tiffin and Irz (2006), among others.

According to Gemmell *et al.* (2000), output growth in the different sectors can be either mutually reinforcing or mutually inhibiting. Earlier development theories stressed the positive relationship from agriculture's output growth to industry's output growth, with the former providing the latter with agricultural goods and raw materials, surplus labour and demand for manufactured goods, both as inputs and as consumption goods for farmers (see e.g. Lewis (1954); Hirschman (1958), Fei and Ranis (1964), and Kuznets (1964), cited in Yao (2000), and Tiffin and Irz (2006)). Yao (2000) refers to the first as the product contribution of agriculture, the second as the factor contribution, and the third as the market contribution. However, reverse linkages are also possible, with industry providing the necessary inputs to the expansion of the agricultural sector (e.g. machinery, fertilizers, etc.) and increasing demand for agricultural goods, but also in some cases competing with it for inputs if aggregate resources are relatively fixed. As far as the services sector is concerned, the expansion of certain services sub-sectors (transport and communications, storage, financial services, etc.) can allow the other sectors to take advantage of the benefits of economies of scale, and thus make positive linkages to the rest of the economy. On the other hand, some industry and services sub-sectors (construction, hotels and restaurants, etc.) are more labour-intensive and will thus compete with the other sectors for labour, resulting in negative sectoral linkages.

Gemmell *et al.* (2000) also point out the productivity sectoral linkages, arguing that, at least in the long run, increases in productivity in one sector tend to spill over to the other sectors. For instance, industry and services provide agriculture with modern inputs, technology, and improved managerial skills that allow this sector to modernize its production techniques and thus increase its productivity. Andreoni (2011) analyses the contribution of manufacturing to technological change in agriculture stressing the importance of inter-sectoral learning to "acquire and adapt biological-chemical innovations such as new seeds, fertilizers, pesticides and mechanical technologies such as agroprocessing machines, tractors, water pumps." (Andreoni (2011), p.2).

Empirical work done so far investigates these linkages mainly in developing economies, where agriculture is usually still an important production sector in terms of output and employment. For instance, Yao (1994; 1996; 2000) focus on China; Gemmell *et al.* (2000) study the case of Malaysia; Kanwar (2000) and Chaudhuri and Rao (2004) investigate sectoral linkages in India; Fiess and Verner (2001) focus on the economy of Ecuador; and Blunch and Verner (2006) examine three African countries. In what follows we review in more detail these studies that cover countries from almost all continents. The majority of the papers aim at determining the existence of a long run relationship between the different sectors of the economy and establishing the direction of causality, varying in the exact sectors considered and the variable through which they are linked.

Yao (1994; 1996; 2000) divide the economy of China in five sectors, agriculture, industry, transportation, construction and services, and examine the inter-sectoral linkages based on a VAR model and time-series data for sectoral GDP indices over the period 1952–92. The main conclusion from the three studies is that, based on the finding of weak exogeneity of agriculture, this sector was the major driving force for the growth of all the other sectors, but non-agricultural sectors growth had little effect on agricultural GDP. In Yao (1996) however, it is shown that this result only applies to the period 1952-78. After 1979, important economic reforms occurred that affected the organization and trading of agricultural goods, so that this sectors' GDP becomes endogenous and agriculture is shown to have a strong and positive effect on all the other sectors; industry has a negative effect; and the effects of transportation, construction and services on other sectors are mostly positive.

The Malaysian economy is divided into three broad sectors, agriculture, manufacturing, and services by Gemmell *et al.* (2000), who examine two types of sectoral linkages, in terms of output, and in terms of productivity. Output data refers to sectoral GDP at constant prices over the period 1965-91. Productivity is measured as real GDP over employment for the period 1970-91. The authors use a trivariate VAR model to test for the short and long run sectoral relationships and determine the direction of causality. Results suggest that in the long run agricultural output reacts positively to manufacturing growth but the converse is not true, and in the short run the link is negative. A boost on the services sector has a negative effect on agriculture in both the short and the long run. As for productivity, the findings show that labour productivity in agriculture does not cause labour productivity elsewhere in the economy, but labour productivity in manufacturing and services cause productivity growth in the agricultural sector.

In Kanwar (2000), the focus is on the possibility that poor infrastructure development of the Indian economy, whose adequacy and availability is crucial for the expansion of both the agricultural and industrial sectors, might be masking the true relationship between these two sectors. In order to overcome this problem and identify the true sectoral relationships, the authors test for the existence of cointegration between five Indian sectors: agriculture, manufacturing industry, construction, infrastructure, and services using a multivariate VAR model. The sectors are linked through real GDP at factor cost over the period 1950-1/1992-3. The main conclusion of this study is that due to block exogeneity of agriculture, infrastructure, and services sectors, it is possible to argue that these sectors significantly affected the expansion of output in the manufacturing and construction sectors in the Indian economy, but the reverse did not apply. Chaudhuri and Rao (2004) concentrate on the links between agriculture and industry in India in terms of output over a more recent period 1960-2000, including also in the analysis price deflators and public expenditure. The authors conclude in this case for a positive bidirectional causality between the two sectors.

Fiess and Verner (2001) analyze sectoral growth in Ecuador using quarterly data for real GDP from 1965 to 1998 and applying multivariate cointegration analysis and find significant long-run relationships between the agricultural, industrial and service sectors. Their findings point to a large degree of interdependence in sectoral growth, identifying the agricultural sector as a major driving force of sectoral growth, but there appears to be a general tendency for more stability in this relationship from the 1990s onwards. The authors also disaggregate the three sectors into intrasectoral components to uncover relationships that contribute to a better understanding of the inter and the intra-sectoral dynamics. Their main finding is that the agricultural sector cointegrates with manufacturing, commerce, transport and public services.

Blunch and Verner (2006) examine agriculture, industry and services sector growth in Côte d'Ivoire, Ghana, and Zimbabwe in terms of real GDP over the period 1965-97 applying cointegration techniques and impulse response analysis to determine the existence of long-run relations among the growth of sectors. Overall their results point to a large degree of interdependence in long-run sectoral growth. The most robust findings across the three countries are the positive long run relationship and short run dynamics between the agricultural and industrial sectors. As for the service sector it also seems to be important because it is found to be weakly exogenous in all three cases, implying that this sector is important in terms of promoting economic growth. The results with an alternative specification with industry disaggregated into four sub-sectors (manufacturing, construction, gas and water, and mining) confirms the previous findings.

Tiffin and Irz (2006), on the other hand, analyze directly the relationship between agricultural real value added per worker and real GDP per capita testing for causality between the two variables in a sample of 85 developed and developing countries with data starting in the 1960s or the 1970s depending on the country considered. The main findings point to unidirectional causality from agricultural value added to real GDP per capita in developing countries, while the direction of causality in developed countries is unclear. As far as the results for the developed countries are concerned, twelve of them are excluded from the causality analysis because they are found to be not integrated, Portugal included, suggesting that there is thus no long run relationship between agricultural value added and GDP. In Finland there is evidence of bi-directional causality, and in Australia, Canada, the Netherlands, the U.K., and the U.S.A, causality runs from agricultural value added to real GDP per capita. Among the latter five countries, only the U.K. is not a major exporter of agricultural goods. The authors go on to conclude that "with the possible exception of countries with highly competitive agricultures, the farm sector does not drive the growth process in developed countries." (p. 86).

The literature review carried out in this section shows that the results concerning sectoral linkages and the importance of agriculture for economic growth vary from country to country, from one time period to another in the same country, and also depend on sectors definitions and of the variables used in the analysis to capture inter-sectoral linkages. All these point to the need of, when empirically establishing the relationship between the different sectors, make a careful and cautious interpretation of the results in terms of policy implications.

3. Data and methodology

3.1 Data

We adopt the following sectoral definitions: agriculture comprises agriculture, hunting, forestry, and fishing; industry comprises mining and quarrying, manufacturing, public utilities (electricity, gas and water supply), and construction; and services includes wholesale and retail trade; hotels and restaurants; transport, storage and communication;

finance, insurance, real estate, and business services; and community, social, and personal services.

Annual data from 1970 to 2006 were obtained from the EU KLEMS database (see O'Mahony and Timmer (2009)). Sectoral output is measured as gross value added at 1995 prices. Sectoral employment corresponds to the number of employees. Sectoral labour productivity was obtained dividing gross value added by the number employees.

The three series, real gross value added (GVA), number of employees and labour productivity, for each sector are depicted in log-levels in Figures 1-3. Figure 1 shows an increase over the whole sample period of GVA, at a faster rhythm in the services sector, especially after Portugal joined the EU in 1986. Agriculture value added increased at a very slow pace, especially towards the end of the period. In terms of the number of employees, Figure 2 confirms the expected structural change pattern with employment steadily decreasing in agriculture, releasing workers to the industrial and services sector until the beginning of the 1980s. From then onwards, there are also labour transfers from industry to services. Figure 3 shows that labour productivity increased in the three sectors since 1970, however we must emphasize that agriculture productivity shows a boom when compared with the other two series, a situation that could be explained by the fact that this sector's value added increased at a slow pace while employment decreased at a fast pace[6].

[6] If we compute labour productivity relative to the number of persons engaged, the behavior of the series does not change significantly, although labour productivity in agriculture becomes lower than that of industry and services in all years under analysis.

Figure 1:

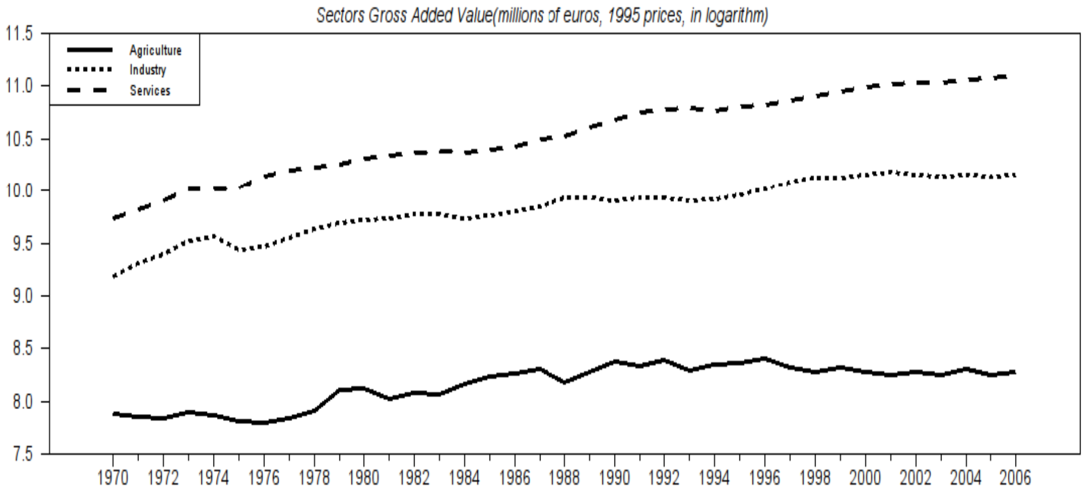


Figure 2:

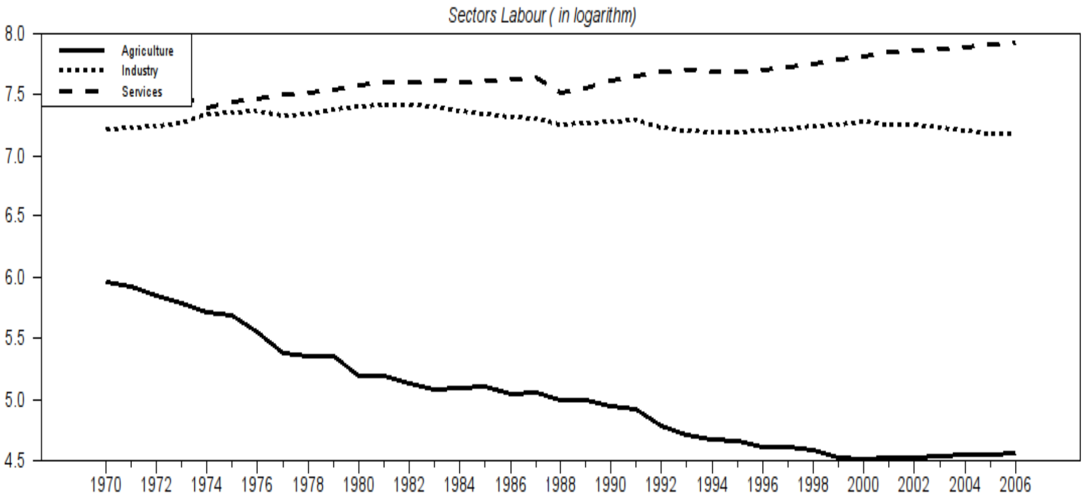
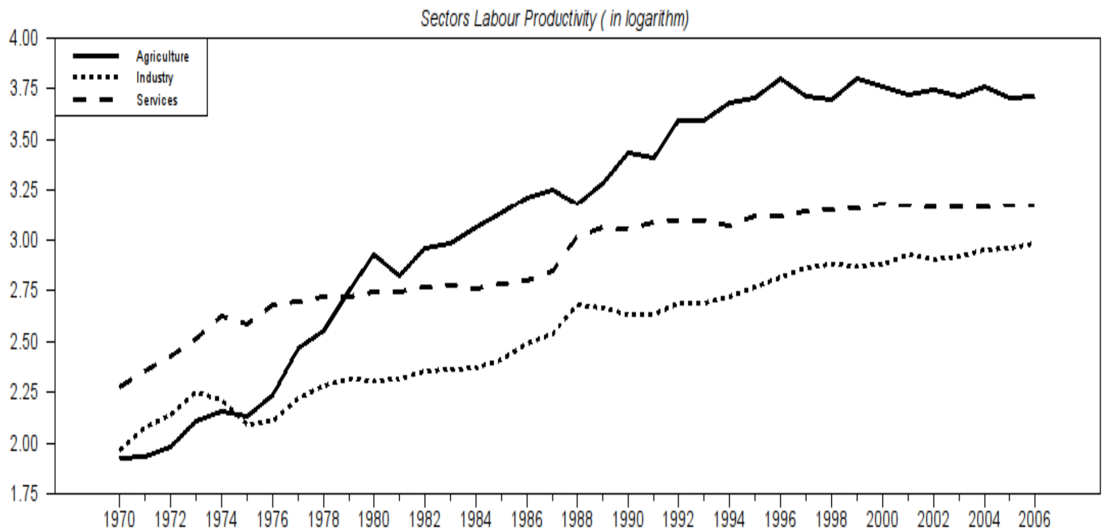


Figure 3:



Before a VAR model is estimated, the data must be tested for orders of integration. All the time series were tested for unit roots after log-transformation. Based on the augmented Dickey-Fuller (ADF) unit root test, considering three lags[7], all series appear *I(1)* in levels and *I(0)* in first differences. See Tables A1 and A2 in the appendix for a summary of the results of the unit root tests.

3.2. Methodology

Since the variables are non-stationary estimating the relationship using the Ordinary Least Squares (OLS) method does not allow for valid statistical inferences and the estimated coefficients do not translate the true relationship between the variables that is we might be in the presence of spurious regressions. But since non-stationary variables might be cointegrated in the sense that they form a stable long-run relationship, we use a vector autoregressive (VAR) model and the Johansen and Juselius (1992) approach to explore

[7] The series for the services sector are stationary in first differences with five lags.

possible cointegration relationships in the data. We interpret cointegration as evidence for interdependence between the different sectors.

In a VAR model all variables are considered as potentially endogenous and are specified as linear functions of $\mathcal{p}$ of their own lags, $\mathcal{p}$ lags of the other variables in the system, and also additional exogenous and deterministic variables, such as an intercept and a time trend.

Let $\mathbf{y_t}$ denote the column vector that contains the three sector series (value added or productivity) at time *t*. We can specify the VAR($\mathcal{p}$) model as:

$$\boldsymbol{y_t} = \boldsymbol{\Phi_1 y_{t-1}} + \boldsymbol{\Phi_2 y_{t-2}} + \ldots + \boldsymbol{\Phi_{\mathcal{p}} y_{t-\mathcal{p}}} + \boldsymbol{\mu} + \boldsymbol{\varepsilon_t} \qquad (1)$$

with $\boldsymbol{\varepsilon_t} \sim i.i.d.\ N(\boldsymbol{0}, \boldsymbol{\Omega})$ a white-noise disturbance vector (n×1). $\boldsymbol{y}$ is a column vector (n×1) of all endogenous variables, $\boldsymbol{\mu}$ a (n×1) vector of constants, $t = 1, \ldots T$ is the number of observations, and $\mathcal{p}$ is the number of lags. In a VAR framework the precise relationship between the variables is determined by data interaction.

The VAR($\mathcal{p}$) system defined in equation 1 can be reparametrized as, following Johansen and Juselius (1992),

$$\Delta \boldsymbol{y}_t = \sum_{i=1}^{\mathcal{p}-1} \boldsymbol{\Gamma}_{\mathrm{i}} \boldsymbol{\Delta y}_{t-i} + \boldsymbol{\Pi y}_{t-\mathcal{p}} + \boldsymbol{\mu} + \boldsymbol{\varepsilon_t} \qquad (2)$$

where $\boldsymbol{\Gamma}_{\mathrm{i}}$ and $\boldsymbol{\Pi}$ are the parameter matrices and $\Delta \boldsymbol{y}$ is a vector of first differences of *y*. The first element in the right hand side of equation (2), $\sum_{i=1}^{\mathcal{p}-1} \boldsymbol{\Gamma}_{\mathrm{i}} \boldsymbol{\Delta y}_{t-i}$, captures the short-run relationships between sectors, while the long-run effects are captured by the second term, $\boldsymbol{\Pi y}_{t-\mathcal{p}}$. The matrix $\boldsymbol{\Pi}$ is a matrix of order *k*×*k*, where *k* is the number of endogenous variables. If the rank *r* of matrix $\boldsymbol{\Pi}$ is less than *k* (*r*<*k*), the vector of endogenous variables will be integrated of order 1, ***I(1)***, or higher. However, the matrix $\boldsymbol{\Pi}$ can be expressed in terms of the outer product of two matrixes of order *k*×*r*, so the coefficients of $\boldsymbol{\Pi}$ can be factored out as $\boldsymbol{\alpha\beta}'$, where $\boldsymbol{\alpha}$ is a matrix of equilibrium coefficients and also captures the speed of adjustment to a shock in the long-run, and $\boldsymbol{\beta}'$ is a cointegrating matrix that quantifies the long-run relationships between sectors.

When the variables in the VAR model are at least *I(1)*, there is the possibility of existence of at least one cointegrating relationship. Estimating the model without restrictions is subject to the risk of the regressions involving non-stationary variables. In this case, we have to determine the number of *r* possible cointegrating vectors and estimate equation (2) restricting **Π** to the *r* cointegrated variables.

For testing the rank of **Π** we use two tests proposed by Johansen (1995), the trace statistic and the maximum eigenvalue statistic. Testing the null hypothesis of reduced rank *r* by trace statistic we have $q_{ts} = -T \sum_{i=r+1}^{n} \ln(1-\lambda_i)$, and by the maximum eigenvalue statistic we have $q_{l\max} = -T \ln(1-\lambda_r)$, with λ the estimated eigenvalues.

4. Results with real value added

The first step in the analysis of inter-sectoral linkages in terms of value added is to test for the optimal lag order of the VAR model. In order to specify the order of the VAR we use several order-selection criteria: the Akaike criterion (AIC), the Schwarz Bayesian criterion (BIC) and the Hannan-Quinn criterion (HQC). The results concerning the selection of the optimal lag order with the different criteria are presented in Table A3.a. All order-selection criteria applied show that the correct order to be considered in the estimation of the VAR model is one, so we estimate a VAR(1) model with three variables, real value added of the agricultural, industrial and services sectors.

The next step is to guarantee that the formulated VAR(1) is correctly specified, that is, the residuals have the right properties in terms of normality, ARCH and serial correlation. According to the results of the diagnostic tests presented in Table A4.a, the VAR(1) model seems to be in accordance with the model specification criteria. In particular, at the 5% significance level there are no non-normality/autocorrelation/heteroscedasticity problems[8].

We then tested for co-integration in the VAR(1) model. The eigenvalues from the estimation of the **Π** matrix in equation 2 and test statistics are presented in Table 1. The findings reveal the existence of one co-integrating relationship in sectoral value added. According to Table 1, both the Johansen tests for cointegration rank with restriction in the constant lead to the rejection of the null hypothesis of no-cointegrating vector at the 5% level of significance, since the assumption of one cointegrating relationship is strongly accepted at the 5% level of significance by both the trace and the maximum eigenvalue statistics.

Table 1: Johansen tests for cointegration rank (real value added)

Rank	*Eigenvalue*	*Trace Statistic*		*Maximum-eigenvalue Statistic*	
		Trace	*Trace-95%*	*λ-max*	*λ-max-95%*
0	0.68843	55.703	34.91	41.981	22.00
1	0.24752	13.722	19.96	10.238	15.67
2	0.09226	3.4846	9.42	3.4846	9.24

Considering the existence of one cointegrating vector and one lag, the cointegrating matrix and the corresponding adjustment matrix are presented in the Table 2[9]. Since there is only one cointegrating vector, we will focus only on the first column of matrix **β** (respectively first line of **β´**). The cointegration matrix shows that in the long run agriculture is positively related to industry and negatively related to services.

[8] However, the LM test for the residuals of the equation for the industry sector reject the null hypothesis, as the p-value is less than 0.01. In any case, according to Johansen and Juselius (1992) this is not a problem.
[9] The results of the residuals analysis for the VECM in the value added model are presented in a table A5.a in the appendix.

Table 2: Cointegrating and adjustment matrix (real value added)

	Cointegrating matrix			*Adjustment matrix*		
	β_1	β_2	β_3	α_1	α_2	α_3
Agriculture	0.90086	4.1507	8.9882	0.01004	-0.01245	-0.01889
Industry	-2.3174	-17.835	4.0502	0.03369	0.01638	-0.00341
Services	0.19791	9.6676	-5.8833	0.04044	-0.00289	0.00146

Additionally, given that the co-integrating rank is restricted to one it is possible to carry out relevant tests since the estimated parameters follow standard distributions. For the adjustment matrix α, the main test of interest is that of weak exogeneity of a particular variable with respect to β. This test is carried out by restricting the adjustment coefficients of the variable in question to zero, and amounts to testing whether the variable in question adjusts to deviations from equilibrium. If all the α coefficients of a particular variable can be restricted to zero, then we may condition on this variable in the subsequent analysis. That is, we may remove it from the left-hand side of the equation and it becomes exogenous to the remaining system. If this is the case, this particular variable drives the system of equations.

In fact, a close examination of the adjustment matrix $\boldsymbol{\alpha}$ shows that agriculture may be weakly exogenous, as the element of the agricultural sector is lower than those of the other sectors. To test this hypothesis we compute a LR test considering as the null hypothesis that agriculture is weakly exogenous. If the LR test fails to reject the null we can conclude that agricultural growth can cause the growth of the industrial and services sectors. As expected, the LR test confirmed the closer inspection of the adjustment matrix above. With $\chi^2(1) = 0.7418$ (p-value = 0.3891) the null hypothesis is accepted, confirming that agriculture is weakly exogenous. Carrying out the same test for industry and services, the null hypothesis is rejected at the 1% level of significance for both sectors, with χ^2 (1) = 15.0254 (p-value = 0.0001) and χ^2 (1) = 30.9835 (p-value = 0.0000), respectively. These results indicate that agriculture is the only exogenous variable, so growth in value added of the industrial and services sectors does not cause growth in agricultural value added in Portugal.

Given that agriculture is weakly exogenous, it is important to determine whether it is also strongly exogenous. In other words, it is relevant to determine if agriculture is part of the cointegrating space. If agriculture is strongly exogenous, we can conclude that the other sectors, industry and services, are not influenced by changes in the agricultural sector. Assuming agriculture is weakly exogenous (α_{11}= 0), we impose the restriction that the coefficient of agriculture in the cointegrating vector is zero (β_{11}= 0). With χ^2 (2) = 1.6547 (p-value = 0.4372), the LR test leads us to accept the null, and confirms that changes in industry and services value added are not related with changes in agricultural value added.

Granger-causality tests corroborate the above result, as shown in Table 3. Based on the estimation of the VAR(1) model we apply Wald tests to analyze whether the lags of two variables (industry and services) can Granger-cause changes in agriculture, and also whether agricultural does not Granger-cause changes in the services and industry sectors value added. From the inspection of the results for the agriculture equation we can see that both industry and services do not Granger-cause agricultural change, since the χ^2 is, respectively, 0.3433 and 0.0025 for industry and services. Similarly, the Granger causality Wald tests indicate that agriculture does not Granger-cause growth in the industry and services sectors since the null hypotheses cannot be rejected.

Table 3: Granger causality - Wald tests (real value added)

Equation	*Excluded*	χ^2	*p-values*
Agriculture	Industry	0.3433	0.558
	Services	0.0025	0.960
Industry	Agriculture	1.1279	0.288
Services		0.6375	0.425

These results suggest that, in the long-run, only the services and industry sectors adjust to disequilibrium between the three sectors of the Portuguese economy. Although the relationship between agriculture, industry and services is, respectively, positive and negative, cointegration analysis shows that in the long-run agriculture has no influence on the expansion of the other sectors. In addition to not having any effect on growth of other sectors, agriculture in Portugal also receives no influence from changes in value added in the industry and services sectors.

The existence of a weak cointegration relationship between value added of agriculture and the other sectors presents no great surprise since the weight of agriculture in the Portuguese economy, as in other developed countries, is very low, which in turn does not produce a major influence on the other sectors. On the other hand, the evolution of agriculture in Portugal has been mainly determined by the Common Agricultural Policy (CAP), which leaves little room for the influence of the evolution of the economy.

5. Results with labour productivity

In this section, we analyse inter-sectoral linkages in terms of productivity. The steps followed in this analysis are the same as those for the analysis with value added. Again, the results from the different order-selection criteria point to a lag order of one (see Table A3.b), so our model is specified as a VAR(1) with three labour productivity variables, one for each sector. The various model evaluation diagnostic tests for the residuals are presented in Table A4.b. All the statistics indicate that the residuals in the VAR(1) model pass the normality, AR and ARCH tests, except for the residuals from the services equation, which fail the Jarque Bera Normality test. This is not as serious for the analysis as would be failing the ARCH test (Johansen, 1995).

The next step is to test for co-integration in the VAR(1) model in terms of labour productivity. The eigenvalues from the estimation of the $\mathbf{\Pi}$ matrix in equation 2 and test statistics are presented in Table 4. At the 5% significance level both trace and eigenvalue tests lead us to accept a single cointegration vector.

Table 4: Johansen tests for cointegration rank (labour productivity)

Rank	Eigenvalue	*Trace Statistic*		*Maximum-eigenvalue Statistic*	
		Trace	*Trace-95%*	*λ-max*	*λ-max-95%*
0	0.4292	30.99	29.38	21.19	21.13
1	0.1895	10.80	15.34	7.57	14.26
2	0.0860	3.24	3.84	3.24	3.84

We also tested for weak exogeneity for all variables ($H_0: \alpha_{i1} = 0, i = 1,2,3$). The results show that, on the one hand, services productivity is weakly exogenous since the LM test for the services productivity statistic, $\chi^2(1) = 1.0377 \text{ (p} - \text{value } = 0.4372)$, is lower than the critical value, $\chi^2_{5\%}(1) = 3.84$. This means that agriculture and industry productivity cannot explain services productivity, but the latter can explain both agriculture and industry productivity. One the other hand, agriculture productivity and industry productivity have test statistics higher than the critical values (at a significance level of 5%), respectively $\chi^2(1) = 7.9378 \text{ (p} - \text{value } = 0.0048)$ and $\chi^2(1) = 7.0099 \text{ (p} - \text{value } = 0.0081)$, so for these two variables we reject the null hypothesis of weak exogeneity, which means that agriculture and industry can be explained inside the model.

As we have just one cointegration vector, to analyze the cointegration relationship we will focus on the first column of cointegrating matrix (β_1) in table 5. Since the labour productivity of agriculture is endogenous also it corresponding coefficient of adjustment matrix is higher than others sectors, we normalize the cointegration relation to agriculture. The cointegration relation is given by the following condition[10]:

$$ap = 0.258ip + 2.573s \qquad (3)$$

According to the cointegration relation present in equation (3), a 100% change in industry productivity (*ip*) implies a change of $0.258 \times \frac{ip}{ap}$ in agricultural productivity (*ap*) or, which the same, if industry productivity increases by 1 unit, productivity in agriculture a

[10] The results of the residuals analysis for the VECM in the labour productivity model are presented in Table A5.b in the appendix.

will increase by 0.258 units. Using the same analysis, a 100% change in services productivity (sp) implies a change of $2.573 \times \frac{sp}{ap}$ in productivity in agriculture that is if services productivity increases by 1 unit, the productivity in agriculture will increase by 2.573 units. These results thus suggest that in long-run productivity in agriculture suffers a greater positive influence from services productivity than from industry productivity.

Table 5: Cointegrating and adjustment matrix (labour productivity)

	Cointegrating matrix			*Adjustment matrix*		
	β_1	β_2	β_3	α_1	α_2	α_3
Agriculture	-29.117	-8.1231	11.667	0.01059	-0.00332	0.00333
Industry	7.5207	81.820	-82.103	-0.00240	-0.00027	0.00111
Services	74.919	-59.506	18.124	-0.00129	0.00229	0.00098

In order to shed additional light on the relationship of the variables in our model we also perform a variance decomposition analysis, based on the previous results from the VEC model. The variance decomposition indicates how much of the forecast error variance of each variable can be explained by exogenous shocks to the variables in the same model with innovations to an individual variable having the possibility to affect both own changes and changes in the other variables. Variance decomposition is one of the most important tools in VAR analysis since it allows us to identify the main influences in the explanation of the variance of each variable under consideration.

The results of the variance decomposition analysis applying the Cholesky method are presented in Table 6, where we have three sets of columns, one for each sector, containing the variance decomposition of each sector (%) after an innovation in labour productivity in that sector and in the other two sectors considered, from the first to the 25^{th} step (years in a forecast) after the shock. The first set of columns contains the variance decomposition of agricultural productivity after, respectively, an innovation in agricultural, industrial and services labour productivity. After 25 steps we can see that the forecast error of agricultural productivity explained by its own shock is 19.48%, by an industry productivity shock 23.43% and 57.08% by a services productivity shock. In the second set of columns we have the industrial productivity variance decomposition, according to which 49.983% of industry's productivity forecast error is explained by a shock to agriculture productivity, 34.916% by a shock to industry productivity, and 15.101% by a shock to services productivity. Finally, according to the third set of columns, 1.991% of services' productivity forecast errors is explained by agriculture, 21.746% by a shock to industry productivity and 76.263% by a shock to services productivity. According to the results of the variance decomposition analysis, we can say that agricultural productivity forecast error is mostly explained by services productivity shocks, agricultural productivity shocks play an important role in the explanation of industrial productivity forecast errors, and services productivity forecast error is not influenced to a great extent by shocks to the other sectors.

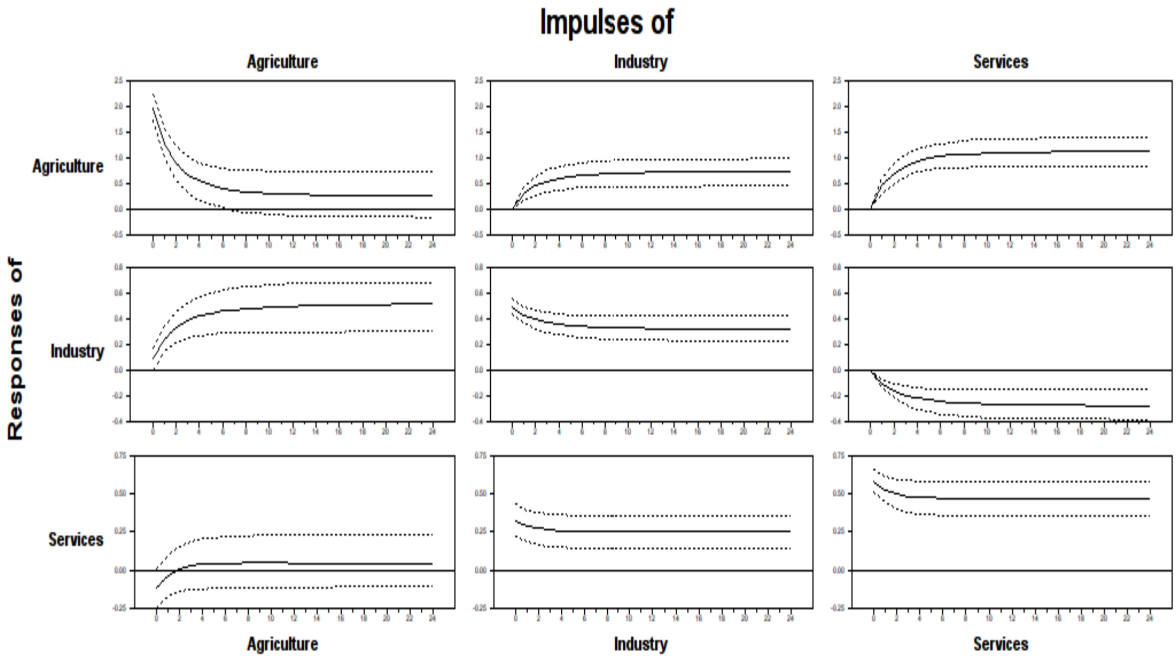
Table 6: Variance decomposition (%) analysis (labour productivity)

	Agriculture			*Industry*			*Services*		
Step	*Ap*	*Ip*	*sp*	*Ap*	*ip*	*Sp*	*ap*	*ip*	*Sp*
1	100.00	0.000	0.000	2.616	97.384	0.000	3.016	22.876	74.108
2	94.626	1.563	3.810	12.461	85.336	2.202	1.832	22.897	75.271
...									
24	20.052	23.259	56.690	49.826	35.132	15.042	1.978	21.757	76.265
25	19.488	23.423	57.089	49.983	34.916	15.101	1.991	21.746	76.263

Notes: *Ap* – agricultural producitivity; *Ip* – industry's producitivity; *Sp* – services' producitivty.

Based on the previous results from the VEC model, the inter-sectoral relationships can also be quantified by means of impulse response analysis, which traces the accumulated dynamic response of a hypothetical one-unit increase of each variable. Figure 4 provides the impulse-response analysis from the VECM model for the inter-sectoral productivity relations in the Portuguese economy. Based on the analysis of the different charts, we can conclude that, after some steps, the response of each variable to the shock tends to a certain value, which means that the results are stable. A unit shock in agricultural productivity generates a positive response from all sectors; however, the response from services productivity is very small, immediately after the shock services productivity decreases but after two periods this variable increases. A unit shock in industry productivity generates also positive responses in all the other sectors. Finally, a unit shock in services productivity generates a positive response from agriculture, but the response from industry is negative

Figure 4: Impulse-response analysis for the VECM model with labour productivity



6. Conclusions

This paper explored the experience of Portugal since 1970 in terms of the economic size/value added and productivity of the three broad sectors of activity, agriculture, industry, and services to investigate the existence of sectoral interdependences by using cointegration and causality data analysis techniques.

The results from the cointegration analysis of inter-sectoral linkages in terms of value added show that in the long-run agriculture has no influence on the expansion of the other sectors. In addition, agriculture in Portugal also receives no influence from the expansion in industry and services. These results present no great surprise since the weight of agriculture in the Portuguese economy, as in other developed countries, is very low, which in turn does not allow it to exert a major influence on the other sectors. On the other hand, the dominance of the services sector reduces the importance of sectoral linkages in the economy since this sector utilizes agricultural products to a less extent than industry. Moreover, industry moved from agro-based industries towards machinery or construction activities. Additionally, the evolution of agriculture in Portugal has been mainly determined by the Common Agricultural Policy (CAP), which leaves little room for the influence of the evolution of the economy on this particular sector.

When focusing on inter-sectoral linkages in terms of productivity the results point to a positive influence of both industry and services in agricultural productivity, although the latter influence is stronger. These findings confirm the theoretical predictions of the importance of industrialization and tertiarization for agriculture by providing high-tech inputs such as machinery and fertilizers and improving transport, communications, storage or financial services in this sector that allow agriculture to benefit from scale economies and become more efficient.

Identifying the direction of causality and inter-sectoral linkages can help policy makers to achieve a better understanding of the economic growth process in Portugal and to formulate more effective and balanced inter-sectoral growth policies, namely in what concerns agriculture. The aim of this paper was not however to identify economic growth determinants. In any case, the recent resurgence of interest in the agricultural sector by the Portuguese public decision makers should take into consideration the productivity inter-sectoral linkages, namely between services and agriculture, and also try to change the past use of CAP instruments so that it does not act as a barrier to explore inter-sectoral linkages that can boost economic growth in Portugal.

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Appendix

Table A1.a: Variables in levels in the real value added model

Augmented Dickey-Fuller test for unit root

	Test Statistic	Interpolated Dickey-Fuller 1%	5%	10%	MacKinnon p-value
Agriculture	-0.764	-4.306	-3.568	-3.221	0.9686
Industry	-1.849	-4.306	-3.568	-3.221	0.6807
Services	-1.521	-4.306	-3.568	-3.221	0.8217

Table A1.b: Variables in levels in the labour productivity model

Augmented Dickey-Fuller test for unit root

	Test Statistic	Interpolated Dickey-Fuller 1%	5%	10%	MacKinnon p-value
Agriculture	-0.619	-4.306	-3.568	-3.221	0.9779
Industry	-3.552	-4.306	-3.568	-3.221	0.0342
Services	-1.926	-4.306	-3.568	-3.221	0.6411

Table A2.a: Variables in first differences in the real value added model

Augmented Dickey-Fuller test for unit root

	Test Statistic	Interpolated Dickey-Fuller 1%	5%	10%	MacKinnon p-value
Agriculture	-4.496	-4.316	-3.572	-3.223	0.0015
Industry	-5.403	-4.316	-3.572	-3.223	0.0000
Services	-4.015	-4.334	-3.580	-3.228	0.0084

Table A2.b: Variables in first differences in the labour productivity model (1 lag)

Augmented Dickey-Fuller test for unit root

	Test Statistic	Interpolated Dickey-Fuller 1%	5%	10%	MacKinnon p-value
Agriculture	-4.545	-4.297	-3.564	-3.218	0.0013
Industry	-4.931	-4.297	-3.564	-3.218	0.0003
Services	-3.634	-4.297	-3.564	-3.218	0.0271

Table A3.a: Order selection criteria in the real value added model

Lag	*LL*	*LR*	*p-value*	*AIC*	*HQC*	*BIC*
0	70.9788			-4.11993	-4.07415	-3.98388
1	179.567	217.18*	0.000	-10.1556*	-9.97247*	-9.61138*
2	187.103	15.072	0.089	-10.0668	-9.74641	-9.11452
3	192.147	10.089	0.343	-9.8271	-9.36934	-8.46664

Table A3.b: Order selection criteria in the labour productivity model

Lag	*LL*	*LR*	*p-value*	*AIC*	*HQC*	*BIC*
0	240.843			-13.9908	-13.9449	-13.8561
1	353.355	225.02	0.000	-20.0797*	-19.896*	-19.541*
2	360.602	14.494	0.106	-19.9766	-19.6551	-19.0338
3	369.093	16.981	0.049	-19.9466	-19.4873	-18.5998

Table A4.a: Analysis of the Residuals' Statistics for the VAR equations in the real value added model

Equation	*Mean*	*SD*	*Normality analysis*			*ARCH*	*AC*
			Ex. Kurtosis	Skewness	Normality-test		
Agriculture	0.000	0.064	-0.657	0.181	0.843	1.316	0.033
Industry	0.000	0.039	2.764	-1.158	15.027	0.245	7.107
Services	0.000	0.028	0.059	-0.136	0.773	0.763	1.803

Note: The normality test reports the LM statistic from the Jarque-Bera test, and the p-values are 0.65600, 0.00055, 0.67959, respectively. The ARCH-test tests the null hypothesis that no ARCH effect is present. The respective p-values are 0.251235, 0.620392, 0.382309. The autocorrelation test (AC) reports the Ljung-Box test and the p-values are 0.8561, 0.0686, 0.1793.

Table A4.b: Analysis of Residuals' Statistics for the VAR equation in the labour productivity model

Equation	*Mean*	*SD*	*Normality analysis*			*ARCH*	*AC*
			Ex. Kurtosis	Skewness	Normality-test		
Agriculture	0.000	1.797	0.474	0.144	0.461	0.021	4.151
Industry	0.000	0.466	1.629	0.577	5.981	0.600	1.838
Services	0.000	0.599	8.306	2.267	134.34	0.172	1.271

Note: The normality test reports the LM statistic from the Jarque-Bera test, and the p-values are 0.793, 0.050 and 0.000, respectively. The ARCH-test tests the null hypothesis that no ARCH effect is present. The respective p-values are 0.885, 0.443 and 0.680. The autocorrelation test (AC) reports the Ljung-Box test and the p-values are 0.125, 0.398 and 0.529.

Table A5.a : Analysis of Residuals' Statistics of the VECM in the real value added model

Equation	*Mean*	*SD*	*Normality analysis*			*ARCH*	*AC*
			Ex. Kurtosis	Skewness	Normality		
Agriculture	0.000	0.068	0.008	0.144	0.598	0.275	0.977
Industry	0.000	0.042	3.569	-1.239	0.791	0.419	2.669
Services	0.000	0.029	0.047	-0.151	0.628	0.159	2.098

Note: The normality test reports the LM statistic from the Jarque-Bera test, and the p-values are 0.74174, 0.67322, 0.73045, respectively. The ARCH-test tests the null hypothesis that no ARCH effect is present. The respective p-values are 0.599971, 0.517639, 0.689831. The autocorrelation test (AC) reports the Ljung-Box test and the p-values are 0.3230, 0.1023, 0.1475.

Table A5.b : Analysis of Residuals' Statistics of the VECM in the labour productivity model

Equation	*Mean*	*SD*	*Normality analysis*			*ARCH*	*AC*
			Ex. Kurtosis	Skewness	Normality		
Agriculture	0.000	0.019	-0.473	0.378	1.344	0.043	1.137
Industry	0.000	0.005	1.169	0.599	15.203	0.502	0.105
Services	0.000	0.007	5.650	2.051	3.999	0.097	2.080

Note: The normality test reports the LM statistic from the Jarque-Bera test, and the p-values are 0.5106, 0.0005 and 0.1354, respectively. The ARCH-test tests the null hypothesis that no ARCH effect is present. The respective p-values are 0.8349, 0.4785 and 0.7551. The autocorrelation test (AC) reports the Ljung-Box test and the p-values are 0.2862, 0.7453 and 0.1493.