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Revue d’Études en Agriculture et Environnement / Volume 95 / Issue 04 / December 2014, pp 437 - 471
DOI: 10.4074/S1966960714014027, Published online: 09 February 2015

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Abstract *– We investigate the links between agriculture and non-agricultural sectors in Portugal by assessing the existence of long-run relationships and causality among the three main sectors of activity in terms of value added and labour productivity using a VAR model for the period 1970-2006. 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. Portuguese decision makers believe that restoring agricultural production plays an important role in overcoming the country's current difficulties. However, they need to pay more attention to the potential synergies between agricultural and non-agricultural sectors, and provide agriculture with the necessary technological and organizational capabilities to benefit from industry and services expansion. Our results indicate that this does not seem to have happened in the past, a situation that should be improved in order to restore agricultural production and promote overall growth.*

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

Agriculture au Portugal : liens avec l'industrie et les services

Résumé – Nous étudions les liens entre l'agriculture et les secteurs non-agricoles au Portugal par l'évaluation de l' existence de relations de causalité et à long terme entre les trois principaux secteurs d'activité en termes de valeur ajoutée et de la productivité du travail en utilisant un modèle VAR pour la période 1970-2006. La valeur ajoutée agricole se trouve être à la fois faiblement et fortement exogène de sorte qu'elle n'a exercé aucune influence dans l'expansion des autres secteurs et elle n'était pas influencée par leur croissance. Les résultats obtenus avec la productivité du travail montrent que les gains de productivité dans les services et l'industrie ont une influence positive sur la productivité dans l'agriculture, bien que le lien soit plus faible dans le cas de l'industrie. Les décideurs portugais estiment que le rétablissement de la production agricole joue un rôle important pour surmonter les difficultés actuelles du pays. Cependant, ils doivent porter plus d'attention aux potentielles synergies entre les secteurs agricoles et non agricoles, et fournir à l'agriculture les capacités technologiques et organisationnelles nécessaires pour bénéficier de l'expansion de l'industrie et des services. Nos résultats indiquent que cela ne semble pas avoir été le cas dans le passé, une situation qui doit être améliorée afin de rétablir la production agricole et de promouvoir la croissance globale.

Mots-clés : agriculture, industrie, services, liens sectoriels, Portugal, VAR

JEL Classification: Q19, O13, O14, O40

1. Introduction

The relative importance of agriculture in the Portuguese economy has substantially decreased in terms of output and employment, as in all the developed countries (Almeida *et al.*, 2009; Memedovic and Iapadre, 2009; Mcmillan and Rodrik, 2011; Santos and Simões, 2013). From the late 1950s 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 (Lains, 2003; Duarte and Restuccia, 2007; Santos Pereira and Lains, 2010). 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[1], and in terms of employment agriculture represented 28.45% of the total in 1977 and 11.82% in 2006[2]. Additionally, this decline in relative terms was also accompanied by a very slow expansion of the economic size of agriculture in terms of real value added, which increased only slightly between 1977 and 2006 (it grew at an annual average growth rate of only 1%) and over the sub-period 1990-2006 it even stagnated/slightly decreased.

In spite of the loss of importance of agriculture in the economy and an overall neglect as a strategic sector, in more recent years, especially after the 2007-08 financial crisis, policy makers in Portugal have designed national policies, within the available EU instruments, 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 has 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 (European Commission, 2009). Portuguese decision makers believe that restoring agricultural production can play an important role in fostering post crisis economic recovery, not only by helping workers to find new job opportunities and thus accelerate the recovery and restructuring process of the Portuguese economy, but also by contributing to recover, sustain and even accelerate pre-crisis economic growth rates fostering the success of Portugal in a globalized economic environment from a longer-run perspective and thus help the country to achieve sustained economic growth. Restoring agricultural production calls for a series of policies directly aimed at the sector, in the framework of the Common

[1] 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.

[2] 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.

Agricultural Policy (CAP), but it lies also on a better understanding of the relationship between agriculture, industry and services in the Portuguese economy over recent years. By tackling the problem from a structural change and inter-sectoral linkages angle, more effectiveness and efficiency can be rendered to the CAP instruments, and Portuguese industrial policy in general, in terms of restoring agricultural production.

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. As far as agriculture is concerned, since before joining the EU as a full member in 1986, Portugal has based its policies towards the agricultural sector on the CAP's guidelines and objectives (promote an increase in the mean size of property; reduction of the population employed in agriculture; higher incomes for farmers; ongoing modernization; and productive specialization, see Freire and Parkhurst, 2002) and mechanisms for intervention (supporting products prices, imposing quotas and buying surpluses, see European Commission, 2011). These remained basically unchanged since the 1960s, and were tailored to the interests and structural characteristics of northern Europe's high-scale agriculture[3], until the recent 1992 reform (that started the reduction in supports to prices and introduced direct payments to farmers) and especially the Agenda 2000 and the 2003 Fischler (that ended payments related to a specific type of production) reforms. The emphasis of the CAP on increasing productivity and specialization implied profound social and structural transformations[4] that together with a relative lack of support for the structural change pillar resulted in depopulation and abandonment of agricultural activities in many Portuguese regions, although in the centre and south of Portugal some modern agricultural enterprises have established successfully and benefitted significantly from the CAP, with products such as grain, cattle, wood, olives, and wine growing in importance and demonstrating vitality in their market-orientated agriculture (Freire and Parkhurst, 2002). The change of focus of the CAP to sustainable agriculture and rural development from the Agenda 2000 reform onward seems to have the potential to restore agricultural production in Portugal making CAPS's instruments more adaptable to the specific conditions of the country, although it is still too soon to make an assessment[5]. In fact, in 2013 a new CAP reform

[3] According to Freire and Parkhurst (2002), p. 7, until the early 1980s: "The CAP dedicated 90% of the budget to guaranteeing prices for producers of grain, beef, dairy products and oils, which effectively granted a considerable advantage to northern agriculture."

[4] That could not be easily accommodated given the ecological and social specificities of Portugal relative to northern Europe.

[5] And they also do not reflect in our analysis since our data ends in 2006, thus soon after the 2003 Fischler reform was approved. This reform was approved in 2003 but has been gradually implemented only since 2005 (European Commission, 2011).

was approved to come in place as from January 1st 2014 that puts an even greater emphasis on synergies between agriculture and other activities, such as the leisure industry, renewable energies, artisanal production or small-scale production in order to support an environmentally friendly agriculture able to compete in the free market. Additionally, it grants each member state more ability to intervene in the preservation of its territory and associated activities.

The profile of economic specialization of Portugal has been historically characterized by a large proportion of low-skilled and low-tech activities, a feature that is common to all three sectors. As far the productive specialization is concerned, EU accession resulted in a stronger specialization in the traditional manufacturing industries such as textiles until the late 1990s, when the opening up of world markets to countries like China and India, the enlargement of the EU to the East, and the participation of Portugal in the Economic and Monetary Union (EMU) from its start lead to an increased specialization in the non-tradable sector (financial services, construction, energy distribution, retail trade, among others). These structural characteristics suggest that the country is in urgent need to modernize its productive structure, a process that could have been aided in the past by industrial policy[6] measures targeting structural change of the productive fabric, even within the more limited framework for this policy imposed by European integration (Pelkmans, 2006). Apart from the CAP directly aimed at the agricultural sector, industrial policy in Portugal has been mainly directed towards the manufacturing sector and grounded on the attraction of foreign direct investment projects such as the automative industry and associated components, with the Renault project of the 1980s as a benchmark, and the establishment of a Ford-Volkswagen plant in the mid-1990s. More recently (mid 2000s) renewable energies and electrical mobility projects have been targeted by various intervention mechanisms and used as flagships of industrial policy in Portugal. In any case, the overall EU framework changed the focus, since the early 1990s, to horizontal policy aimed at modernizing through technological improvement of all activities and sectors. Portugal has put in place many innovation policy instruments (tax credits; tax incentives for R&D; public procurement; *etc.*) that can be used by any firm, although in practice they have not been evenly distributed across industries (Mamede *et al.*, 2014). For instance, between 2006 and 2008 manufacturing industry was the major beneficiary of these measures, and within it pulp and paper, chemical and pharmaceutical, and electronic products industries, although food industries were also a relevant beneficiary. The broad picture that emerges from this brief overview of industrial policy in Portugal points to important efforts in this domain towards the production of more sophisticated and

[6] Considering industrial policy as the set of instruments that aim at stimulating specific economic activities and promote structural change, including not only policies targeted at manufacturing but also at nontraditional agriculture and services (see Rodrik, 2008, p. 3).

tradable products (goods and services), but it also transpires a lack of concern for developing synergies between projects in the three major sectors of activity, which can hamper the desired outcomes from the renewed and increased interventions in the agricultural sector.

Understanding the broad sectoral linkages can help avoid past mistakes and involves its empirical analysis, that is, they should be empirically established given the possible different signs for the relation. 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. But 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 (see *e.g.* Yao, 2000; Gemmell *et al.*, 2000; Kanwar, 2000 and Tiffin and Irz, 2006).

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 labour productivity using a vector auto-regression (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, we 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.

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 labour productivity, extending previous analyses aimed at developing countries 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 and the agricultural sector became under the influence of the CAP's mechanisms of intervention since a little before Portugal's full integration in the EU in 1986.

As stated previously, following the recent global economic crisis, many Portuguese politicians are seeking to identify and promote what they believe will be their countries' most likely to succeed economic activities and it is within this context that agriculture has regained a new improved status in terms of industrial policy in Portugal. Nevertheless, it is in our opinion essential to take a step back and look at these policies within a broader perspective by providing a macro statistical description of inter-sectoral interdependencies. By identifying these sectoral patterns of behaviour over time for a recent period in the Portuguese economic history and establishing some stylised facts of structural change from the perspective of inter-sectoral relations we contribute to avoid past mistakes and/or enhance positive features from the recent past. We hope also to pave the way to more disaggregated studies that enable a better and deeper understanding of the agriculture-industry-services synergies and thus help to define more accurate policy interventions. Our contribution is thus essentially descriptive in nature not aiming at providing an explanation for the existence of inter-sectoral linkages, but by taking stock of these interdependencies using a rigorous methodological approach it can help a country to benefit the most from its industrial policy. This can be accomplished either by taking more advantage of the potential synergies identified later on by the empirical analysis or, if no interdependency is found, by correcting these past mistakes and putting into place potential ones. Similar analyses can be carried out for other European Periphery countries that share common productive structures with Portugal, especially as far as agriculture is concerned, such as Greece, Italy and Spain, and help to gain some further understanding of whether the CAP failed to sufficiently promote agriculture in these countries due to lack of concern for inter-sectoral linkages (Freire and Parkhurst, 2002). Additionally, Central and Eastern European Countries (CEECs) that experienced quite rapid structural change and a sharp drop in the economic importance of agriculture relative to their level of development on their (rapid) way to full EU integration could also benefit from the identification of inter-sectoral linkages (see *e.g.* Evangelos, 2010).

The remainder of the paper is organized as follows. In section 2 we introduce a simple theoretical framework and 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. Literature overview

2.1. A simple framework

As a country engages on a path of sustained economic growth, such as the one Portugal experienced from the 1950s onwards, registering unprecedented economic growth rates until the 1970s, 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 Irzm, 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 agro-processing machines, tractors, water pumps." (Andreoni, 2011, p. 2). The productivity linkages analysis thus allows us to examine a potential mechanism of transmission for output linkages, the transfer of technology (see *e.g.* Hall and Jones, 1999, on the importance of TFP for output growth)[7].

Gemmell *et al.* (2000) present a model in which the economy is divided into three sectors, agriculture (a), manufacturing (m), and services (s), to empirically examine the linkages between sectors, adapting and extending the Feder (1983) model on the importance of exports for economic growth to provide some theoretical guidance on the circumstances under which interactions among the three sectors are likely to be mutually enhancing or inhibiting. Equations (1)-(3) describe the production functions of the three sectors[8].

$$A = \alpha_a L_a + \beta_a K_a + \gamma_a^m M + \gamma_a^s S \tag{1}$$

$$M = \alpha_m L_m + \beta_m K_m + \alpha_m^{\gamma} A + \gamma_m^s S \tag{2}$$

$$S = \alpha_s L_s + \beta_s K_s + \gamma_s^a A + \gamma_s^m M \tag{3}$$

where A, M and S represent output in agriculture, manufacturing, and services, respectively; with L_i and K_i (i = a,m,s) the quantities of labour and capital, respectively, employed in each sector i; marginal products are measured by α_i and β_i; and spillovers/linkages between sectors by γ_i.

Considering that aggregate output Y equals A + M + S, and assuming that the marginal productivity differences between sectors are given by:

$$\frac{\alpha_i}{\alpha_a} = \frac{\beta_i}{\beta_a} = 1 + \delta_i \quad i = m, s \tag{4}$$

and that the marginal productivity of labour and capital in agriculture is proportional to average productivity in the economy as a whole:

$$\alpha_a = \alpha \frac{Y}{L} \text{ and } \beta_a = \beta \frac{Y}{K} \tag{5}$$

[7] Although in practice, as we explain later on, the proxy used for this purpose is not conceptually the most appropriate to capture this link. Ideally, we should use total factor productivity (TFP) data but this kind of information is not available at the sectoral level for Portugal. Instead, we use labour productivity.

[8] The presentation of the model carried out in this paper is a summary of that provided in Gemmell *et al.* (2000). We refer the interested reader to the original paper for a more complete derivation and interpretation of the model.

the authors show that agricultural output can be written as a function of output in the other two sectors, with:

$$A = \left[\frac{(1+\delta_m)\left[\alpha + \beta + \gamma_a^m + \frac{\gamma_s^m}{1+\delta_s}\right] - 1}{(1+\delta_m)\left[1 - (\alpha+\beta) - \frac{\gamma_s^a}{1+\delta_s}\right] - \gamma_m^a} \right] M + \left[\frac{(1+\delta_m)\left[\alpha + \beta + \gamma_a^s - \frac{1}{1+\delta_s}\right] + \gamma_m^s}{(1+\delta_m)\left[1 - (\alpha+\beta) - \frac{\gamma_s^a}{1+\delta_s}\right] - \gamma_m^a} \right] S \tag{6}$$

Equation (6) implies that an expansion of either manufacturing or services can have positive or negative net effects on agriculture depending on the size of sector marginal productivity differentials (δ_i) with higher productivity in manufacturing/services reducing agricultural output if the externalities effects are less than one due to competition for resources, and inter-sectoral externalities (γ_i) that have always positive effects.

As far as sectoral labour productivity linkages are concerned, Gemmell *et al.* (2000) show that the impact of an increase in manufacturing and services productivity on agriculture productivity depends essentially on the size of sectoral productivity differentials. For instance, if manufacturing/services productivity is assumed to be always higher than agricultural productivity, then increases in manufacturing and services productivity will have the same effect on agricultural productivity as those of an expansion in manufacturing and services output on agricultural output. In any case, productivity-enhancing advances in industrial and services technologies tend to spill over to agriculture, unless the necessary absorptive capacity is not available, and thus a positive effect from an increase in productivity in either of the two sectors upon agricultural productivity is expected, at least in the long-run (see *e.g.* Dowrick and Gemmell, 1991; Krüger, 2008; Andreoni, 2011).

For the purposes of our analysis, this model provides a simple framework that allows us to define an empirical model to identify sectoral patterns of behaviour over time in the Portuguese economy and thus provide a statistical description of inter-sectoral linkages, establishing some stylised facts on this issue for the country under analysis over a relatively recent period. We do not aim at providing an explanation for the existence of dynamic interactions between sectors during the growth process nor of their underlying determinants such as factor accumulation or technological progress. We leave these issues for future research.

2.2. Previous empirical results

Empirical work done so far investigates sectoral linkages mainly in developing economies, where agriculture is usually still an important production sector in terms of output and employment. For instance, Yao (1994); Yao (1996); Yao (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 developing countries from different continents. The majority of the papers aims 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. Table 1 provides a summary of these studies that examined the presence of a causal link between the development of the different sectors. A general conclusion from Table 1 is that the results concerning the existence of a long-run relationship and the identification of the direction of the causal relationship between sectors obtained from any particular country time series analysis cannot be readily generalized or extended to other countries to make inference.

The economy of China is divided into five sectors, agriculture, industry, transportation, construction and services, by Yao (1994, 1996, 2000) that examines 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 also be affected by the other sectors, with a positive influence in the case of services and construction, and a negative one in the case of industry. The consideration of historically and economically meaningful structural breaks thus seems to make a difference to the results found.

Gemmell *et al.* (2000) contend that the direction of causality between agriculture and non-agricultural sectors cannot be assessed from cross-country regression techniques since they only allow to capture correlation, not causality, and propose to investigate the issue of inter-sectoral linkages within a time series context for the Malaysian economy, that they divide into three broad sectors, agriculture, manufacturing, and services for this purpose. The authors examine two types of sectoral linkages, in terms of output, and in terms of productivity, and 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

Table 1. **Summary of selected time series empirical studies on sectoral linkages**

						Main results	
Authors	**Countries**	**Period**	**Sectors**	**Variables**	**Methodology**	**Cointegration**	**Direction of causality**
Yao (1994)	China	1952–92	Agriculture Industry Transportation Construction Services	Sectoral GDP indices	VAR-Cointegration	Cointegrated	Agriculture→ Industry; Transportation; Construction; Services
Yao (1996)	China	1952–78 1979–92	Agriculture Industry Transportation Construction Services	Sectoral GDP indices	VAR-Cointegration VECM	Cointegrated	1952–78: same as Yao (1994). 1979–92: Agriculture→Industry; Transportation; Construction; Services; Industry→(-) Agriculture; Transportation; Construction; Services→(+)Agriculture
Yao (2000)	China	1952–96	Agriculture Industry Transportation Construction Services	Sectoral GDP indices	VAR-Cointegration VECM	Cointegrated	Agriculture→ Industry; Transportation; Construction; Services
Gemmell *et al.* (2000)	Malaysia	1965–91 1970–91	Agriculture Manufacturing Services	Sectoral output Sectoral labour productivity	VAR-Cointegration	Cointegrated	Manufacturing output→(+)Agricultural output Services output→(-) Agricultural output Manufacturing/Services productivity→(+)Agricultural productivity

(Continued)

Table 1. **Summary of selected time series empirical studies on sectoral linkages (Continued)**

						Main results	
Authors	**Countries**	**Period**	**Sectors**	**Variables**	**Methodology**	**Cointegration**	**Direction of causality**
Kanwar (2000)	India	1950/1–1992/3	Agriculture Manufacturing Infrastructure Services	Sectoral real GDP	VAR-Cointegration	Cointegrated	Agriculture; Infrastructure; Services→Manufacturing. Agriculture; Infrastructure; Services→Construction
Chaudhuri and Rao (2004)	India	1960–2000	Agriculture Industry	Sectoral output Price deflators Public expenditure	VAR-Cointegration VECM	Cointegrated	Agriculture→Industry Industry→Agriculture
Fiess and Verner (2001)	Ecuador	1965–98 Quarterly data,	Agriculture Industry Services	Sectoral GDP	VAR-Cointegration	Cointegrated only after 1990	Agriculture→Industry/Services Industry→Agriculture/Services Services→Agriculture/Industry
Blunch and Verner (2006)	Côte d'Ivoire Ghana Zimbabwe	1965–97	Agriculture Industry Services	Sectoral real GDP	VAR-Cointegration Impulse response analysis	Cointegrated	Agriculture→Industry
Tiffin and Irz (2006)	85 developed and developing countries	1960–…	Agriculture	Agricultural real value added *per* worker Real GDP *per* capita	Causality analysis	---	Developing countries: Agricultural value added →real GDP *per capita* Direction of causality in developed countries is unclear

Notes: The symbol → represents the direction of causality found between sectors.

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. Owing to data constraints, the estimation period used is not very long, when a meaningful time series analysis requires long series in order to properly account for the persistent dynamics. The authors are aware of this problem but are forced to restrict the maximum number of lags to two in order to preserve degrees of freedom.

Poor infrastructure development, whose adequacy and availability is crucial for the expansion of both the agricultural and industrial sectors, might mask the true relationship between these two sectors. Kanwar (2000) investigates this possibility for the Indian economy trying to overcome this problem and identify the true sectoral relationships by testing for the existence of co-integration between real GDP of five Indian sectors: agriculture, manufacturing industry, construction, infrastructure, and services using a multivariate VAR model. 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.

Using quarterly data for real GDP from 1965 to 1998 and applying multivariate co-integration analysis, Fiess and Verner (2001) analyse sectoral growth in Ecuador 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 intrasectoral dynamics. Their main finding is that the agricultural sector co-integrates with manufacturing, commerce, transport and public services. A drawback that can be pointed out to this study is the fact that it uses quarterly data to increase the sample size and preserve degrees of freedom when a sufficiently long time span is still required to make inference on the long-run results.

Another study that points to a large degree of interdependence in long-run sectoral growth is that of Blunch and Verner (2006), which 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 co-integration techniques and impulse response analysis. 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 where industry is disaggregated into four sub-sectors (manufacturing, construction, gas and water, and mining) confirm the previous findings.

Somewhat differently, Tiffin and Irz (2006) analyse 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 UK, and the USA, causality runs from agricultural value added to real GDP *per capita*. Among the latter five countries, only the UK 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 empirical literature review carried out in this section shows that the results concerning sectoral linkages and the importance of agriculture for economic growth is context specific, varying from country to country, from one time period to another in the same country, and also depending on sectors definitions and of the variables used in the analysis to capture inter-sectoral linkages. When empirically establishing the relationship between the different sectors in the Portuguese economy, all these point to the need to make careful and cautious interpretations of the results in terms of policy implications, also bearing in mind that the results obtained from single country time series analysis cannot be readily generalized to other countries to make inference on sectoral linkages and limit policy formulation to the particular country under investigation.

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[9]. 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 rate in the services sector, especially after Portugal joined the EU in 1986. Agriculture value added increased at a very slow pace (registering an annual average growth rate of 1%), and towards the end of the period under analysis it even stagnated/slightly declined. 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, with agricultural productivity showing a boom when compared with the other two series from the mid-70s to the mid-90s, a situation explained by the fact that this sector's value added increased at a slow pace while employment decreased at a fast pace, and the fact that we are not including the self-employed in our workers measure[10]. Conceptually, we should be using sectoral total factor productivity

[9] The number of employees variable in the EU KLEMS database does not include the self-employed, which are quantitatively important in agriculture. However, primary information about the number of self-employed is less complete than data about employees and thus estimated in the EU KLEMS database, which can introduce measurement error issues. Additionally, both the number of persons engaged (that includes the self-employed) and the number of employees show similar trends, a steady decrease over the whole period (annual average growth rates of -2% for persons engaged, and -4% for employees). Moreover, self-employment in agriculture in Portugal is associated with full-time employment outside of agriculture or significant income from other economic sectors, so we believe that taking only the number of employees to measure productivity gives a more accurate picture of the broader productivity measure we are trying to capture, in the absence of TFP data, since these are the workers fully committed to the activity.

[10] If we compute labour productivity relative to the number of persons engaged (employees plus self-employed), the behaviour of the series over the period under analysis is similar, although labour productivity in agriculture becomes lower than that of industry and services in all years, a feature common to a wide range of countries as documented in Restuccia *et al.* (2008). The annual average growth rate of real value added *per* person engaged (VA_eng) was 3%, while that of real value added *per* employee (VA_emp) was 5%. An analysis for 10-year sub-periods, reveals substantial growth

Figure 1. **Sectors Gross Added Value (millions of euros, 1995 prices, in logarithm)**

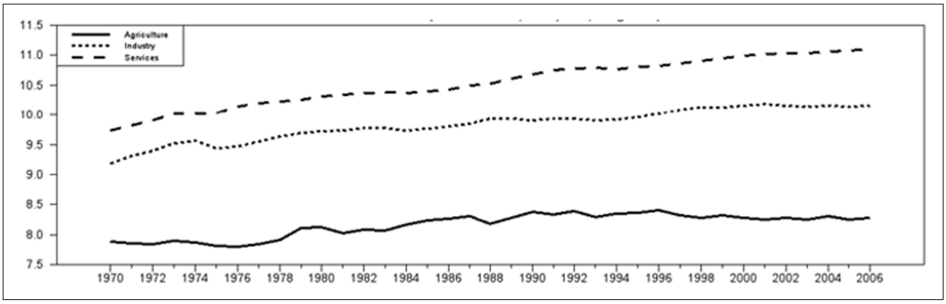


Figure 2. **Sectors Labour (in logarithm)**

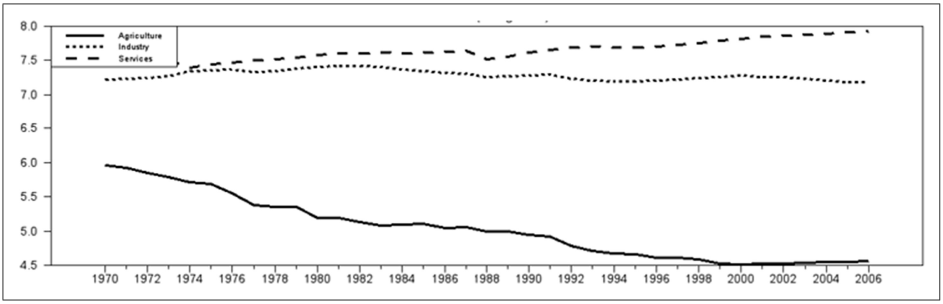
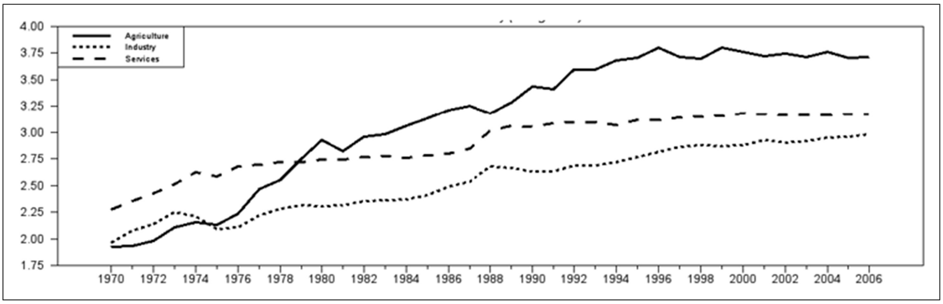


Figure 3. **Sectors Labour Productivity (in logarithm)**



(TFP) measures to truly capture the long-run productivity links predicted by the theory on inter-sectoral linkages (see section 2). However, this type of data is not available at the sectoral level for the Portuguese economy.

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

differences only for the first decade, 1970-80, when VA_eng grew 2% a year, and VA_emp 10%.

test (Dickey and Fuller, 1979), considering three lags[11], all series are integrated of order one, *I(1)*, in levels and integrated of order zero, *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 convey the true relationship between the variables, that is we might be in the presence of spurious regressions. But since non-stationary variables might be co-integrated 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 possible co-integration relationships in the data. We interpret co-integration as evidence of interdependence between the different sectors.

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

Let y_t denote the column vector that contains the three sector series (value added or labour productivity) at time t. We can specify the VAR($\wp$) model as:

$$y_t = \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \ldots + \Phi_{\wp} y_{t-\wp} + \mu + \varepsilon_t \quad (7)$$

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

The VAR($\wp$) system defined in equation (7) can be reparametrized as, following Johansen and Juselius (1992),

$$\boldsymbol{\Delta}\mathbf{y}_t = \sum_{i=1}^{\wp-1} \boldsymbol{\Gamma}_i \boldsymbol{\Delta} y_{t-i} + \boldsymbol{\Pi} y_{t-\wp} + \mu + \varepsilon_t \quad (8)$$

where $\boldsymbol{\Gamma}$i and $\boldsymbol{\Pi}$ are the parameter matrices and $\boldsymbol{\Delta}y$ is a vector of first differences of y. The first element in the right hand side of equation (8), $\sum_{i=1}^{\wp-1} \boldsymbol{\Gamma}_i \boldsymbol{\Delta} y_{t-i}$, captures the short-run relationships between sectors, while the long-run effects are captured by the second term, $\boldsymbol{\Pi}\mathbf{y}_{t-\wp}$. The matrix $\boldsymbol{\Pi}$ is a matrix of order $k \times k$, where k is the number of endogenous variables.

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

If the rank r of matrix $\mathbf{\Pi}$ is less than k ($r < k$), the vector of endogenous variables will be integrated of order 1, ***I(1)***, or higher. However, the **matrix** $\mathbf{\Pi}$ can be expressed in terms of the outer product of two matrixes of order $k \times r$, so the coefficients of $\mathbf{\Pi}$ 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 co-integrating 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 co-integrating 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 co-integrating vectors and estimate equation (8) restricting $\mathbf{\Pi}$ to the r co-integrated variables.

For testing the rank of $\mathbf{\Pi}$ 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 $q_{1\max} = -T\ln(1-\lambda_r)$, 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 optimal lag order to be considered in the estimation of the VAR model is one, so we estimate a VAR(1) model with three variables, the 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[12].

We then tested for co-integration in the VAR(1) model. The eigenvalues from the estimation of the $\mathbf{\Pi}$ matrix in equation (8) and test statistics are

[12] 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), and Johansen (1995) this is not a problem.

presented in Table 2. The findings reveal the existence of one co-integrating relationship in sectoral value added. According to Table 1, both the Johansen tests for co-integration 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 co-integrating relationship is strongly accepted at the 5% level of significance by both the trace and the maximum eigenvalue statistics.

Table 2. **Johansen tests for co-integration rank (real value added)**

		Trace Statistic		Maximum-eigenvalue Statistic	
Rank	**Eigenvalue**	**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 co-integrating vector and one lag, the co-integrating matrix and the corresponding adjustment matrix are presented in Table 3[13]. Since there is only one co-integrating vector, we will focus on the first column of matrix $\boldsymbol{\beta}$ (respectively first row of $\boldsymbol{\beta}'$). The co-integration matrix shows that in the long-run agriculture is positively related to industry and negatively related to services.

Table 3. **Co-Integrating and adjustment matrix (real value added)**

	Co-Integrating matrix			Adjustment matrix		
	$\boldsymbol{\beta}_1$	$\boldsymbol{\beta}_2$	$\boldsymbol{\beta}_3$	$\boldsymbol{\alpha}_1$	$\boldsymbol{\alpha}_2$	$\boldsymbol{\alpha}_3$
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 $\boldsymbol{\alpha}$, 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.

[13] The results of the residuals analysis for the VECM in the value added model are presented in a table A.5 in the appendix.

In fact, a close examination of the adjustment matrix α 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 χ^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 co-integrating 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 ($\alpha_{11=}$ 0), we impose the restriction that the coefficient of agriculture in the co-integrating vector is zero ($\beta_{11=}$ 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 4. 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 agriculture 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 X^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 4. **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, co-integration 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 the 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 co-integration 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 allow it to produce a major influence on the other sectors. Nevertheless, we would expect to find causality in the opposite direction. A candidate explanation for this result is the fact that the evolution of agriculture in Portugal has been mainly determined by the CAP, which leaves little room for the influence of the evolution of the rest of the economy on agriculture, showing thus a lack of interest for fostering back- and forward linkages between agricultural and non-agricultural sectors that could promote an economically viable and sustainable agriculture in Portugal. The lack of sectoral linkages found is also probably linked to the fact that agriculture in Portugal is still dominated by small-size agricultural holdings run by aged farmers with low human capital levels and full-time employment outside of agriculture or significant income from other economic sectors, structural characteristics that the CAP was not able to significantly change, providing farmers with the necessary technological and organizational capabilities, and hamper agriculture from capitalizing on the expansion of non-agricultural activities. According to Avillez (2006), in 2003 76% of agricultural holdings occupied less than 5ha, 45.6% of farmers were 65 years of age or older, and for each 100 Portuguese farmers with no schooling or that completed primary schooling, only 6 had an higher education degree.

5. Results with labour productivity

In this section, we analyse inter-sectoral linkages in terms of labour 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. However, according to Johansen and Juselius (1992) and Johansen (1995), this is not a serious problem, because even though the methods are based upon Gaussian likelihood, the asymptotic properties only depend on the i.i.d. assumption concerning the errors. Thus, the deviations from normality are mainly due to the presence of too many large residuals, that, however, are approximately symmetrically distributed around zero, which is probably less serious than a skewed distribution or the presence of an Arch process.

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 **Π** matrix in equation (8) and test statistics are presented in Table 4. At the 5% significance level both trace and eigenvalue tests lead us to accept a single co-integration vector.

Table 5. **Johansen tests for co-integration rank (labour productivity)**

		Trace Statistic		**Maximum-eigenvalue Statistic**	
Rank	**Eigenvalue**	**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 one hand, services productivity is weakly exogenous since the LM test for the services productivity statistic, $\chi^2(1) = 1.0377$ ($p - value = 0.4372$), 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. On the other hand, agriculture productivity and industry productivity have test statistics higher than the critical values (at a significance level of 5%), respectively $\chi^2(1) = 7.9378$ ($p - value = 0.0048$) and $\chi^2(1) = 7.0099$ ($p - value = 0.0081$), 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 co-integration vector, to analyse the co-integration relationship, we will focus on the first column of the co-integrating matrix (β_1) in Table 6. Since agriculture's labour productivity is endogenous and the corresponding coefficient of the adjustment matrix is higher than the ones for the other sectors, we normalize the co-integration relation to agriculture. The co-integration relation is given by the following condition[14]:

$$ap = 0.258ip + 2.573s \tag{9}$$

According to the co-integration relation estimated in equation (9), improvements in labour productivity in industry and services lead, in the long-run,

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

to higher productivity in the agricultural sector. Though non-agricultural output does not seem to influence agricultural output, according to the results from the previous section, non-agricultural sectors productivity enhance productivity in agriculture, an influence that is especially strong in the services sector case. A 1 percent increase in industry's labour productivity (ip) leads in the long-run to a 0.258 percent rise in agricultural productivity (ap), while a 1 percent increase in services' labour productivity (sp) leads in the long-run to a 2.573 percent rise in agricultural productivity. Given the behaviour of the series used to compute the labour productivity measure (see Figures 1 and 2), we believe that these links result primarily from the transfer of employees from agriculture to industry, and especially to services, and not from the technological and organizational improvement of Portuguese agriculture that should have resulted from the expansion of non-agricultural sectors predicted by the theory on sectoral linkages (and lead to a bigger expansion of agricultural value added), inducing agriculture to use, for instance, more productive equipment, seeds varieties, fertilizers and pesticides, commercialization models and management practices, among other potential productivity enhancing influences. Higher (TFP) productivity implies that farmers have the capabilities to productively use advanced technologies, but Portuguese agriculture, as we mentioned already in the previous section, is still dominated by aged farmers with low human capital levels[15], characteristics that the policies directed at the agricultural sector were not able to significantly alter. The inter-sectoral labour productivity results and interpretation are thus not incompatible with the lack of influence found in terms of value added.

Table 6. **Co-Integrating and adjustment matrix (labour productivity)**

	Co-Integrating 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 between the variables in our model, we also perform a variance decomposition and impulse response analysis, based on the previous results from the VEC model. The co-integration analysis allows us to examine the long-run dynamics and causality of sectoral developments. The variance decomposition and impulse-response analysis allows us to examine the strength of causality and the short-run inter-sectoral growth experience, taking the long-run information of the series into account by including the co-integration relation

[15] More recently, between 2009 and 2011, the number of workers with secondary and tertiary education increased slightly (see Santos and Simões, 2013), a small sign that the policies towards the sector are changing.

identified previously in the corresponding error correction model. In the short-run, a shock to one of the variables implies short-run responses from the other variables in the adjustment towards the long-run equilibrium relationship. The sign and importance of these responses might thus differ from the long-run influence.

The variance decomposition analysis 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 7, 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 25th 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.

The inter-sectoral relationships can also be quantified by means of impulse response analysis, which traces the accumulated dynamic response to a hypothetical one-unit shock to 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 the response of each variable to any of the shocks stabilizes quickly so that the series adjust rapidly to the long-run equilibrium relationship. In other words, sectoral disequilibrium does not persist for long. A unit shock to agricultural productivity generates a

Table 7. **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 productivity; *Ip* – industry productivity; *Sp* – services productivity.

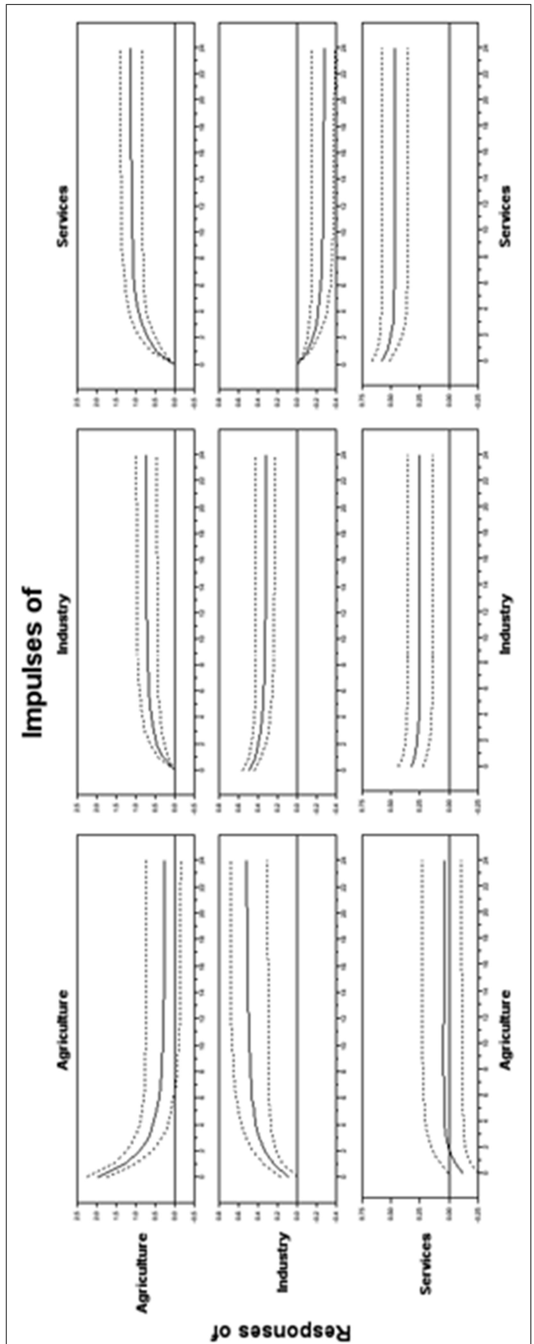
positive response from non-agricultural sectors; however, the response from services productivity is very small. Immediately after the shock, services productivity decreases but after two periods this variable increases. A unit shock to industry productivity generates also positive responses in the other two sectors. Finally, a unit shock in services productivity generates a positive response from agriculture, but the response from industry is negative.

Taken as a whole, the variance decomposition and impulse-response analysis results confirm the importance of non-agricultural sectors labour productivity to productivity in agriculture, and especially services productivity. These findings support the existence of a positive productivity link between agriculture and industry and services also in the short-run. In summary, an overall positive link from non-agricultural to agricultural productivity is established for both the short and the long run.

6. Conclusions

This paper explored the experience of Portugal since 1970 in terms of the economic size/value added and labour productivity of the three broad sectors of activity, agriculture, industry, and services to investigate the existence of sectoral interdependencies through the use of co-integration and causality data analysis techniques. By identifying sectoral patterns of behaviour over time for a recent period in the Portuguese economic history and establishing some stylised facts of structural change from the perspective of inter-sectoral relations, we tried to contribute to a better identification of the ways through which sectoral policies can more effectively help the Portuguese economy to overcome the current harsh economic and financial conditions and promote the countries' most likely to succeed economic activities, namely in what concerns agriculture that has regained a new improved status in terms of industrial policy in Portugal following the 2007-08 financial and economic crisis. It is in our opinion essential to take a step back and look at these policies within a broader perspective by providing a macro statistical description of potential inter-sectoral interdependencies that can be made effective through the adequate creation of back- and forward linkages.

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



The results from the co-integration 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. When focusing on inter-sectoral linkages in terms of labour productivity, the results point to a positive influence of both industry and services on agricultural productivity, although the latter influence is stronger. These positive impacts of industry and services productivity on agricultural productivity are not incompatible with the lack of interdependencies found for real value added, since they are most likely due to the transfer of employees from agriculture to industry and services, and not an indication of technology transfers between sectors. In fact, the rapid decrease in the number of employees in the agricultural sector was accompanied by an increase in agricultural value added at a very slow pace, with both trends resulting in a fast increase of labour productivity in agriculture. Ideally, to capture the technological and organizational transfers from non-agricultural sectors to agriculture predicted by theory, we should explore productivity linkages in terms of TFP. This was not however possible due to lack of sectoral TFP data for the Portuguese economy.

The results concerning the lack of influence of the agricultural sector on industry and services present no great surprise since the weight of agriculture in the Portuguese economy, as in other developed countries, is very low, which in turn probably does not allow it to exert a major influence on the other sectors. Additionally, the dominance of the services sector reduces the importance of sectoral linkages in the economy since this sector utilizes agricultural products to a lesser extent than industry. Moreover, industry moved from agro-based industries towards machinery, energy distribution or construction activities. However, we would expect to find causality in the opposite direction not only in terms of productivity but also in terms of sectoral economic size/value added. An additional explanation for these results, especially the latter, is the fact that the evolution of agriculture in Portugal has been mainly determined by the CAP, which probably has left little room for the influence of the evolution of the rest of the economy on this particular sector[16], and has not addressed adequately the potential back- and forward linkages between agricultural and non-agricultural sectors that could promote an economically viable and sustainable agriculture in Portugal by providing the agricultural sector with the necessary modern inputs (including services) for the expansion of agriculture, but also by constituting a market to absorb its outputs or by creating complementary activities (*e.g.* tourism). More attention should have been paid to policies to promote agriculture by having

[16] Of course the CAP did not prevent the transfer of labour from agriculture to industry and services that characterizes structural change into a modern economy, and so the results found for sectoral linkages in terms of labour productivity are not incompatible with this explanation.

industry and services directly render more support to the agricultural sector. For instance, manufacturing production in the service of agriculture such as irrigation projects[17] or biotechnology might be increased. In the current era of globalization, ICTs services must also not be forgotten as far as its importance for nontraditional agricultural activities is concerned, but it is also important to forge links with modern distribution and commercialization services, and the financial sector as well. But the possibilities for cooperation also extend to forward linkages, the most obvious of which is agro-food industry[18] that uses agricultural products that need processing to increase their value added and or/face high transportation requirements. The development of leisure activities in rural areas can also provide important complementarities with agriculture. In this last domain, successful examples can already be found in the Douro Valley region that demonstrated great vitality (higher-scale holdings and increased mechanization, for instance) in its market-orientated wine production agriculture associated with wine tourism. Other successful examples in what can be labelled as traditional products can be found in the cork, olive oil, fruits and sheep productions (see *e.g.* Mendes *et al.*, 2013a; Mendes *et al.,* 2013b). The Portuguese government must thus consider actions that promote complementary non-agricultural activities in terms of input supply and output processing to revert the past agricultural stagnation/decline.

However, the potential for agriculture to benefit from the former linkages depends on the existence of the necessary technological and organizational capabilities. According to Freire and Parkhurst (2002), p. 21: "The drastic reduction of agriculture's weight in the Portuguese economy [...] endangers the survival of vast rural areas and has spurred myriad of criticisms of European policy and the ability of the Portuguese government to negotiate solutions truly fitted to the realities and interests of the country." Agriculture in Portugal is still dominated by small-scale family holdings, run by aged farmers with low human capital levels and full-time employment outside of agriculture or significant income from other economic sectors, structural characteristics that the CAP was not able to significantly alter[19] and hamper agriculture from capitalizing on the expansion of non-agricultural activities. Policy makers should thus reconsider their role in agricultural and rural development and focus their attention on the use of mechanisms of intervention that can provide the Portuguese agriculture with those capabilities. Not enough attention seems to have

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[17] A recent successful example is that of the *Alqueva* dam in the *Alentejo* region.

[18] According to Portugalfoods (2011), in 2009 agro-food industry in Portugal represented 1.7% of GDP (processed food and beverages) and employed 109 thousand individuals. From 2005 onwards, its exports have grown at 2 digit annual rates.

[19] Even though some farmers and crops have benefitted from the CAP, especially in the *Alentejo* region that mainly produces cereals and livestock and whose competitiveness depends primarily on the supports received within the CAP and its national implementation, see Avillez (2006).

been paid to the use of CAP instruments specifically directed at addressing and incorporating the country's specificities promoting not an industrial agriculture aimed at increasing productivity and specialization, similar to that of northern European countries, but sustainable small-scale production of quality agricultural products, associated with other activities, as a viable alternative. The support to small farmers enabled by the new emphases of the CAP (since the Agenda 2000 reform) on the environment and rural development seems a step in the right direction but means in any case that if Portuguese agriculture is to benefit from the growth of the non-agricultural sectors the policies directed at the agricultural sector must address increasing investment in education, research, marketing, and extension services[20] in order to increase agriculture's absorptive capacity, *i.e.* its ability to incorporate industrial and services outputs and in turn contribute to their expansion.

For agriculture in Portugal to have a role to play in building a stronger economy, improving the current account balance, and reducing regional and economic disparities by increasing incomes and employment opportunities, while respecting the environment, more attention should be paid to the potential synergies between agriculture-industry-services. This paper was a contribution to the clarification of the existence (or lack of) such linkages. Future research should examine inter-sectoral dynamics at a lower level of disaggregation, involving for instance applying a similar methodology to the analysis of linkages between agriculture, food processing, wood, and pulp and paper manufacturing activities, as well as services such as wholesale and retail trade, hotels and restaurants, or even financial services. Other methodologies such as input-output analysis could additionally provide further insights as to the quantitative importance of the linkages. A better identification of inter-sectoral linkages could help policy makers to achieve a deeper understanding of the economic growth process in Portugal and to formulate more effective and balanced inter-sectoral growth policies.

Acknowledgments

The authors would like to thank the Portuguese Foundation for Science and Technology (FCT) for funding under the project no.1165 Bilateral Cooperation Portugal/Serbia. We are particularly grateful for a number of useful suggestions made by two anonymous referees. The usual disclaimer applies.

[20] Communication and learning activities organized for farmers that enable the application of scientific research and new knowledge to agricultural practices.

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Appendix: Additional results

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

Augmented Dickey-Fuller test for unit root					
		Interpolated Dickey-Fuller			
	Test Statistic	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					
		Interpolated Dickey-Fuller			
	Test Statistic	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					
		Interpolated Dickey-Fuller			
	Test Statistic	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					
		Interpolated Dickey-Fuller			
	Test Statistic	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**

			Normality analysis				
Equation	Mean	SD	Ex. Kurtosis	Skewness	Normality-test	ARCH	AC
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

Notes: 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**

			Normality analysis				
Equation	**Mean**	**SD**	**Ex. Kurtosis**	**Skewness**	**Normality-test**	**ARCH**	**AC**
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

Notes: 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**

			Normality analysis				
Equation	**Mean**	**SD**	**Ex. Kurtosis**	**Skewness**	**Normality**	**ARCH**	**AC**
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

Notes: 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**

			Normality analysis				
Equation	**Mean**	**SD**	**Ex. Kurtosis**	**Skewness**	**Normality**	**ARCH**	**AC**
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

Notes: 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.