Assessing an agri-food development strategy: a bi-regional input–output model with resource-constrained sectors

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Abstract

Uneven regional development is widely recognised. This paper explores the effectiveness of a regional development strategy based on the agri-food sector expansion in a laggard agriculture dependent region. We use a bi-regional rectangular Input–Output model, explicitly taking into account the methodological and policy implications of resource-constrained products. Results confirm that local transformation of agricultural products has a positive but limited effect, due to land restrictions and impact leaks to the more complex and developed region. The regional development strategy would be more effective if it focuses instead on non-tradable products or not so dependent on natural resources.

Keywords: agri-food sector, bi-regional input–output model, resource-constrained modelling

JEL classification: Q18 (Agricultural Policy | Food Policy), R11 (Regional Economic Activity: Growth, Development, Environmental Issues, and Changes), R15 (Econometric and Input–Output Models)

1. Introduction

This is a paper on an asymmetric country, where a less developed region, still relying on exports of primary products, either abroad or to the rest of the country, in particular 'Products of agriculture, animals farming, hunting and related services', coexists with a more industrialised, populated and developed region. The research explores the effectiveness of a development

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strategy for the laggard region, aiming to reduce the major regional asymmetry within the country. The focus is on a possible exogenous increase in the production of the agri-food industry products in the agriculture dependent region. By agri-food products we mean both manufactured food products and beverages. The new plants, in the laggard region, are deemed to be competitive, and a matching increase in the demand for the new products is assumed (e.g. the new products are exportable).[1] Thus, the main idea underlying this strategy is to shift the export base of the less developed region from primary products, such as the products of agriculture, to agri-food products involving a higher value added, or in other words allowing for an upgrade of the regional value chain (Marsden and Sonnino, 2008; van der Ploeg *et al.*, 2008; Irwin *et al.*, 2010; Martinho, 2015). The purpose of this paper is to make an appraisal of this policy. The methodological and empirical applications are designed to determine the overall effects of a development strategy based on the expansion of the agri-food sector in the rural region of a country, and to assess the separate effects of such a strategy in both regions (although the shock is confined only to one). Will any benefits be limited to the region where the strategy is implemented? Or will the benefits spill-over into the more economically powerful region, and if so, to what extent?

To analyse these issues a bi-regional input–output (IO) model is constructed, focusing on the interdependencies between the two regions into which the country is split: a laggard rural part and a more developed part. This model is of the 'supply and use' type, which allows for a high level of product detail: in our application 431 products (of which 63 products of agriculture, animals farming, hunting and related services) are produced by 125 industries. The first results point to a positive but relatively limited local impact of the proposed strategy, due to the high polarisation of the economic effects on the more complex and developed region. This conclusion is consistent with other literature findings (Roberts, 1998, 2000; Kilkenny and Partridge, 2009; Hyytiä, 2014), although some disagreement persists (Lindberg and Hansson, 2009).

In addition to the spill-over effects that can shift a significant part of the policy benefits to the more developed region, the research addresses a further potential limitation of the effectiveness of the policy strategy. Standard IO analysis assumes that all production activities are demand-driven, meaning that factor supplies are perfectly elastic in all sectors and that an increase in demand is sufficient to stimulate increases in output and income because excess capacity throughout the economy is presumed (Kilkenny and Partridge, 2009; Irwin *et al.*, 2010). However, the agri-food sector might be an exception because it is so heavily dependent on agricultural products and agricultural sectors cannot automatically expand or shrink the amount of land being cultivated in response to increased demand (Hubacek and Sun, 2001; Zhang, 2007). That is to say, the domestic supply of agricultural products is inherently limited by the amount of land available. A methodological contribution of this study is that it discusses

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1 The discussion on how policymakers are able to induce this new capacity is beyond the scope of this paper (although the granting of some kind of subsidy may be presumed).

an IO model of the supply and use type, where some sectors are producers of resource-constrained products.

Resource constraints have been addressed in other studies based on IO models but with different aims. Hewings, Dridi and Guilhoto (2005) analyse a constraint related to water availability, computing the reduction in agricultural output and employment that would result from an optimal allocation of water resources throughout several water-consuming sectors in the economy. But land, unlike water, is more sector-specific,[2] implying that the focus of the present paper is not on sectorial resources reallocation. de la Torre Ugarte *et al.* (2007) look at cropland as the restrained factor with the purpose of assessing the expansion of bioenergy production in the US involving a substitution between agricultural products, from their current use to energy crops. In contrast to these papers, the present study does not substitute products produced by the same industry, or industries using the same natural resource, but rather it reallocates the destination of agriculture products, from final demand to intermediate consumption of other sectors – the agri-food industry – that locally add more value to the regional final products.

The paper is organised as follows. Section 2 briefly presents the analytical framework, the methodological approach and the data sources of the proposed bi-regional IO model, which is applied to Portugal, splitting the country into the Interior part of the territory and the Coastal region. Section 3 offers a succinct picture of the regional issue in Portugal, detailing some features of the laggard rural Interior region, and gives a first assessment of the suggested agri-food sector development strategy. In Section 4, we introduce and discuss the modelling implications of the proposition that agriculture, which is a crucial supplier for the agri-food industry, may be limited in its output by the availability of resources, especially land. Section 5 examines some alternative strategies to the agri-food proposal, and Section 6 concludes.

2. Methodology and data

2.1. The analytical framework of the bi-regional IO model

This paper proposes the use of a bi-regional IO model with a laggard region, which in the case study (Section 3) is the Interior (*I*) of Portugal, and a more developed part of the country – the Coast (*C*). Bi-regional IO models allow for economic shock analysis. A shock affecting one of the regions spreads to the other, generating a feedback effect by which the second region will eventually affect the first one.

The proposed model adopts a Supply and Use (rectangular) format (Oosterhaven, 1984; Miller and Blair, 2009: Chapter 5; Sargento, Ramos and Hewings, 2011). This kind of IO model admits more products than industries producing them (in our case, below: 431 products and 125 industries). In other words, the majority of the industries are producers of several different primary

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2 Some room for reallocation exists, for example, between agriculture and forestry. However, this substitution possibility is deemed to be more limited given differences in land suitability.

products, and also, very often, of some secondary products (i.e. products that are typically produced as primary products by other industries). The main advantage of this structure is that it minimises the information loss from official statistics, as this dichotomy of products-industries is also adopted by modern National Accounts systems.[3] It is important to note that the different products have different import propensities (internationally), and our estimations of inter-regional trade also imply different balances and intensities of trade, even when the products are produced by the same industry. Thus, to keep the detail on all the products (not merging them into a reduced number, equal to the number of industries, as a classic symmetric IO model would require) is an advantage.

Besides the supply and use format, the model is also closed with respect to the consumption of (some) households. In laggard regions, but also in larger and more developed regions even if the effect looks more diffuse, a new production to a large extent impacts on households' income. This augmented income in turn implies an increase in consumption, in part directed to locally produced products. In the IO jargon, these effects are known as 'induced effects', and the closure of the model corresponds to taking them into account.[4] A relevant improvement in our model is the partition of households into two types, according to the age of the head-of-household: households in which the representative family member is less than 65 years old (hereafter <65 households) or 65 years and older (hereafter ≥65 households). The intention is to confine the induced effects of increased income that arises directly from the production process (wages and own-account work income, also called 'mixed income') to the consumption of households headed by someone younger than 65. Other household's consumption is assumed to be exogenous. Furthermore, the consumption structure of <65 households is differentiated from the typical consumption bundle of ≥65 households.

The structure of the bi-regional IO model, considering the two regions that are the focus of the empirical study is presented in Table 1.

The matrices and vectors within the bold border constitute the core of the model, that is, the basis for the Leontief Inverse computation. In the case study below, this core part of the matrix has 1,116 rows and columns. Reading the 'use matrix' (upper right-hand corner of the core part of the table) row-wise, informs us of the different uses of the 431 products, produced in region *I* and region *C*, distinguished by type and by location of use: in region *I* or *C*. The column information in the same sub-matrix concerns the industries. It depicts intermediate consumption in each industry and each region, and distinguishes the regional origin of each input (*I* or *C*). As the model is closed with respect to the <65 households, the use matrix also contains the consumption amounts and the income generated by each industry, in each region, which benefits these households. The lower left-hand side of the core table corresponds to the

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3 From the 1993 United Nations System of National Accounts (SNA1993) onwards.
4 Crossed induced effects (i.e. impacts on consumption products' demand, addressed to one region, when the households income of the other varies) also exist in multiregional IO models, as is the case in the one we are proposing.

typical 'supply table': the rows in matrices P^{II} and P^{CC} depict the product composition supply of each industry (including both primary and secondary products), in *I* and *C*, respectively. Households' incomes fill one single cell, in each region, in the diagonal of this matrix, for the sake of consistency of the row and column totals of the model.

The structure proposed in Table 1 has the advantages (e.g. the great level of detail) and limitations of this type of IO model. The main limitation is that

Table 1. The structure of the multi-sector bi-regional Interior–Coast IO model

		Products		Industries				Other Final Demand		Residues	Total
		Interior (I)	Coast (C)	Interior (I)		Coast (C)		Interior (I)	Coast (C)		
Products	Interior (I)	0		IC^{II}	HC^{II} (<65)	IC^{IC}	HC^{IC} (<65)	OFD^{II}	OFD^{IC}	R^I	TPO^I
				HI^I (<65)	0	0	0				HI^I (<65)
	Coast (C)			IC^{CI}	HC^{CI} (<65)	IC^{CC}	HC^{CC} (<65)	OFD^{CI}	OFD^{CC}	R^C	TPO^C
				0	0	HI^C (<65)	0				HI^C (<65)
Industries	Interior (I)	P^{II} 0 / 0 HI^I (<65)	0	0							TIO^I / HI^I (<65)
	Coast (C)	0	P^{CC} 0 / 0 HI^C (<65)								TIO^C / HI^C (<65)
Taxes less product subsidies levied on intermediate consumption or final demand				$T(IC)^I$	$T(HC)^I$ (<65)	$T(IC)^C$	$T(HC)^C$ (<65)	$T(OFD)^I$	$T(OFD)^C$		TT
International Imports intended for intermediate consumption or final demand				$M(IC)^I$	$M(HC)^I$ (<65)	$M(IC)^C$	$M(HC)^C$ (<65)	$M(OFD)^I$	$M(OFD)^C$		TM
Total Intermediate Consumption/ Final Demand, at purchasers' prices				TIC^I	THC^I (<65)	TIC^C	THC^C (<65)	OFD^I	OFD^C		TIC + TFD
Gross Value Added which is not distributed directly to households				$NHVA^I$	0	$NHVA^C$	0				TNHVA
<65 Households Savings and net transfers to other institutional sectors					S^I (<65)		S^C (<65)				TS
Total		TPO^I HI^I (<65)	TPO^C HI^C (<65)	TIO^I	HI^I (<65)	TIO^C	HI^C (<65)	OFD^I	OFD^C		

Note: I, Interior; C, Coast; IC^{ij} $i,j = I, C$, Intermediate consumption of i's regional products, used by j's industries; HC^{ij}(<65) $i,j = I, C$, Final consumption of i's regional products, consumed by households living in j, in which the representative family member is aged less than 65; OFD^{ij} $i,j = I, C$, Other final demand for i's regional products, used in j; R^i, $i = I, C$, Residues of the demand for products in region i; HI^i (<65) $i = I, C$, region i's <65 Households' income (compensation of employees and mixed income); TPO^i $i = I, C$, Total output of products produced in region i, at basic prices; P^{ii} $i = I, C$, i's regional products, according to the producing industry (generic element of the supply table); TIO^i $i = I, C$, region i's total industry output, at basic prices; T (g)^i $i = I, C$; $g = IC,HC,OFD$, Taxes (less subsidies) on products falling upon g, in region i; TT, Total taxes less subsidies on products; $M(g)^i$ $i = I, C$; $g = IC, HC, OFD$, International Imports destined to use g, in region i; TM, Total International Imports; TIC^i $i = I, C$, Total intermediate consumption by industries, in region i, at purchasers' prices; THC^i (<65) $i = I, C$, Total region i's <65 Household consumption, at purchasers' prices; OFD^i $i = I, C$, other final demand in region i, at purchasers' prices; TIC + TFD, Total intermediate and final demand, at purchasers' prices; $NHVA^i$ $i = I, C$, Gross Value Added which is not directly distributed to households, in region i; TNHVA, Total Gross Value Added which is not directly distributed to households; S^i (<65) $i = I, C$, <65 Household savings and net transfers to other institutional sectors in region i; TS, Total <65 Households' savings and net transfers to other institutional sectors.

price variations are not considered, and so they do not play any role in allocating the resources and balancing the markets. All of the resources are deemed to be available up to the level needed by the (regional and national) economies. Produced inputs expand their supply to meet demand. Unproduced resources (labour, capital and also land except for the case addressed in Section 4) are assumed to be underemployed or to reallocate frictionless from other regions/countries, such that there is always potential to increase their use. These assumptions make the IO (mainly) a short-term model. In the following sections, where the focus is on the Portuguese regional division case, the main effects of these assumptions are discussed.

2.2. The impacts estimation

After completion of the bi-regional table, the next purpose is to implement the bi-regional IO model, allowing for the estimation of the regional impacts of different shocks. The table described in the previous section may be written in matrix notation:

$$\begin{bmatrix} 0 & U \\ V & 0 \end{bmatrix} + \begin{bmatrix} f \\ 0 \end{bmatrix} = \begin{bmatrix} p \\ g \end{bmatrix} \tag{1}$$

where U is the 'use matrix' and V the 'supply matrix'. f is the column vector of the products' other final demands. It excludes the endogenous consumption of <65 households, which was moved into the U matrix. p and g are column vectors representing total product outputs and total industry outputs, respectively.

The first step in model construction consists then in dividing all the elements of the core part of the matrix, i.e. the sub-matrices U and V, by the corresponding column totals (given in the bottom row of Table 1), i.e. by p and g. The coefficient matrices Q and S are computed as follows:

$$Q = U\hat{g}^{-1} \qquad \text{and} \qquad S = V\hat{p}^{-1} \tag{2}$$

where the ^ identifies square diagonal matrices, with the cells in their diagonal displaying the same values as the corresponding column vectors p and g. Given that the model is a bi-regional one, Q and S split by regions, with the following structure:

$$Q = \begin{bmatrix} Q^{II} & Q^{IC} \\ Q^{CI} & Q^{CC} \end{bmatrix} \qquad \text{and} \qquad S = \begin{bmatrix} S^{I} & 0 \\ 0 & S^{C} \end{bmatrix} \tag{3}$$

where the superscripts *I* and *C* refer to the regions, the first one (in the Q case) to the region of origin of the product (or income), and the second one to the region of use.

The following methodological considerations must also be kept in mind:

– Because of the specific closure of the model, the intermediate consumption matrices (part of U and then of Q) have been extended in each

region by an additional column and an additional row. Column $m + 1$ in
Q (m being the number of industries) is composed of <65 household
consumption coefficients, computed as the division of each product's
consumption by the <65 households. Row $n + 1$ (where n is the number
of products) in each region represents the labour (and mixed income)
input coefficients of that region, derived from the quotient of employees
compensations and mixed income received by own-account workers in
each industry and the corresponding total industry output.[5] The resulting
coefficient matrix **Q** has the dimension $2 * (n + 1)$ by $2 * (m + 1)$.

 – Concerning the supply matrix, the division of each element by the col-
umn total (total product output) relies on the hypothesis that each indus-
try has its own specific mode of production, irrespective of its product
mix (corresponding to the Industry-Based Technology assumption).[6] The
dimension of **S** is $2 * (m + 1)$ by $2 * (n + 1)$.

The bi-regional IO model can thus be written as a matrix system, which
can be solved as follows:

$$\begin{bmatrix} \mathbf{0} & \mathbf{Q} \\ \mathbf{S} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{p} \\ \mathbf{g} \end{bmatrix} + \begin{bmatrix} \mathbf{f} \\ \mathbf{0} \end{bmatrix} = \begin{bmatrix} \mathbf{p} \\ \mathbf{g} \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{p} \\ \mathbf{g} \end{bmatrix} = \begin{bmatrix} \mathbf{I} & -\mathbf{Q} \\ -\mathbf{S} & \mathbf{I} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{f} \\ \mathbf{0} \end{bmatrix} \qquad (4)$$

$$\begin{bmatrix} \mathbf{p} \\ \mathbf{g} \end{bmatrix} = \begin{bmatrix} \mathbf{D_1} & \mathbf{D_2} \\ \mathbf{D_3} & \mathbf{D_4} \end{bmatrix} \begin{bmatrix} \mathbf{f} \\ \mathbf{0} \end{bmatrix}$$

The **D**-blocks of the inverse matrix have the dimensions of the sub-
matrices above: $\mathbf{D_2}$ of –**Q**, $\mathbf{D_3}$ of –**S**, and $\mathbf{D_1}$ and $\mathbf{D_4}$ of the two identity matri-
ces. **D** is the multipliers matrix representing impacts on products' or indus-
tries' outputs from demand shocks. For example, $\mathbf{D_1}$ and $\mathbf{D_3}$ give the effects,
respectively on products' outputs and industries' outputs of changes in the
final demand by products comprised in **f**. The last rows of both matrices are
equal, and provide the impacts on (endogenous) <65 households' income of
shocks to the different products in **f**. $\mathbf{D_2}$ and $\mathbf{D_4}$ depict the impacts on the
same variables of eventual shocks designed at the industries (not the pro-
ducts) level. As the objective in the majority of applications, as in this paper,
is to simulate impacts on industries' supplies (**g**), and related variables, as for
example, gross value added (GVA) and employment, caused by changes in

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5 In the application developed in this paper, the labour income generated in each region was
   deemed to be distributed only to households living in the same region. Commuting and other
   periodical or seasonal migrations between *I* and *C*, which realistically are negligible between
   these two regions, were not considered. Releasing this assumption in other bi-regional models is
   straightforward, however, provided that information on commuter workers by industry exists.
6 An alternative hypothesis, named the Commodity-Based Technology assumption, can also be
   applied to develop an IO model from the rectangular format. For a detailed discussion, see
   Miller and Blair (2009: 187–201), Pereira, Carrascal and Fernández (2011) and Sargento, Ramos
   and Hewings (2011). The adoption of the Industry-Based Technology assumption in Portugal is
   justified by the irrelevance of secondary production in the majority of the industries.

products exogenous final demand (**f**), $\mathbf{D_3}$ becomes the most important part of **D**. It should be noted that $\mathbf{D_3}$ can be calculated alone, using the partitioned matrices rules (Miller and Blair, 2009: 699–701). Applying these rules we get:

$$\mathbf{D_3} = (\mathbf{I} - \mathbf{SQ})^{-1}\,\mathbf{S} \qquad (5)$$

Furthermore, when developing the IO model with resource-constrained sectors, $\mathbf{D_1}$ is used for part of the calculations. $\mathbf{D_1}$ can be computed as:

$$\mathbf{D_1} = \mathbf{I} + \mathbf{Q}(\mathbf{I} - \mathbf{SQ})^{-1}\,\mathbf{S} \qquad (6)$$

2.3. Regionalisation methodology

The modelling approach presented in the previous sections requires the decomposition of national flows between regions *I* and *C*. This was undertaken using the MULTI2C (multi-sectoral multi-regional Coimbra model) database. MULTI2C is a general flexible approach, developed by a group of researchers mainly from the University of Coimbra (Portugal) that allows the construction of IO tables for different geographic configurations and empirical applications. Ramos *et al.* (2015) provide a more detailed description of this general methodology. Here, the 2007 version of the MULTI2C was used, which has a significant level of detail concerning both the number of products (431) and the number of industries (125). MULTI2C has a top-down basis [as in Lahr (1993), Hulu and Hewings (1993), Barata *et al.* (2011) and Ramos *et al.* (2015)]. Taking as the starting point the national supply and use table, with the maximum disaggregation provided by the Portuguese *National Accounts,* for reference year 2007 the maximum available data of the official *Regional Accounts* were employed. For Portugal, the available Regional Accounts data comprise the following variables: Total Industry Output, Total Intermediate Consumption at purchasers' prices and Gross Value Added (including separate knowledge of employees' compensations), for each of the 125 industries and by region.

In the use matrix, the national technology assumption has been adopted and applied to both regions, for each of the 125 industries. This means that the same structure (for the 431 products) of each industry's intermediate consumption is considered, since GVA by region is already known. It should also be noted that this equal technology assumption is considered from a 'total flow' perspective, that is, each input is assumed to have the same weight in total intermediate consumption, regardless of the local source of production. Furthermore, the international import propensity for each product is also assumed to be the same in both regions (and thus the same as the national one), irrespective of product use.[7]

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7 Except for international exports, for which re-exporting was excluded for the majority of products.

In addition to the National and Regional Accounts information, other regional data sources were used with specific purposes, namely:

- The estimation of household consumption is based on the *Households Expenditure Survey*, applied every 5 years by Statistics Portugal (INE). This survey, together with demographic regional data, enables the estimation of consumption patterns by region and also by the head-of-household age group (<65 or ≥65 years old).
- The generic assumption, in the supply matrix, concerning industries' secondary production (which, in most cases, was not significant) is that the weight of secondary products in each industry would be the same in each region, and the same as for the whole country (using *National Accounts* data). However, regarding primary products, wherever the same industry produces more than one primary product, regionally specific supply-side data were gathered in order to infer the dominant primary products by industry, in each region. This information usually came from employment data based on the Portuguese Ministry of Employment and Social Security database. In the case of agriculture, where one industry corresponds to 63 distinct products, direct information from the 2009 Agricultural Census was used. The National Forestry Survey was also used for the corresponding industry and products.[8]

Interregional trade estimation requires particular attention, even in this condensed methodological section, given the usual difficulties associated with this step in any multiregional IO table construction. The problem is simply that, contrary to the other aggregates, there is no national reference value in national statistics (as consolidated interregional trade is obviously zero when the whole country is taken into account). Miller and Blair (2009: 347–361) provide a survey of the ways in which the literature deals with this issue. In fact the bi-regional setting simplified this task. In any regional IO model, net interregional exports by region may be estimated through the commodity-balance method: having estimated each product's supply and use components for any given region, the difference between supply and use corresponds to net interregional trade,[9] and is positive (negative) whenever regional supply is higher (lower) than regional use. In a bi-regional model, the net export of any product by one region is necessarily symmetric to the net import of the same product by the other region, as long as the estimation methodologies are consistent for both regions. Similarly, in the

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8 The specific sources used in estimating the supply matrix provided only initial values that were then further adapted to the 2007 general model following the RAS procedure. Total production by industry and by region is known from the official Regional Accounts and total production of all products at national level is also known through the National Accounts. Actually, only the nucleus of the matrix – which region produces each product inside each industry – was missing and was estimated using the RAS algorithm. In the agricultural case information on cultivated areas by product and on livestock numbers by region from the Agricultural Census provided the initial values for the RAS procedure. A standard description of the RAS method can be found in Miller and Blair (2009: 313–332).

9 This difference also includes any estimation errors related to either the supply or demand side.

presence of only two regions that sum up the whole country, one region's in-country exports are the other region's in-country imports and vice versa. Such information about the origin and destination of interregional trade flows is very important in the context of multiregional IO models, the aim of which is the correct estimation of spill-over and feedback effects prompted by any exogenous shock in one of the regions.

Nonetheless, the gross value of interregional imports (and, as a consequence, interregional exports) cannot be estimated immediately, even in a simpler bi-regional IO model. The typical regional IO impact analysis is designed to estimate the local effect of any given final demand change. This depends on the degree of local provision in each transaction flow resulting from the exogenous shock. This means that gross imports, either international or interregional, must be known so that they can be removed from the local impact analysis. In other words, we have to solve what is usually called the cross-hauling problem (Robison and Miller, 1988; Jackson, 1998; Polenske and Hewings, 2004; Kronenberg, 2009; Llano *et al.*, 2010).

Our approach to estimating gross interregional imports involves the prior classification of all 431 products (that in some cases may not be the same in both regions), depending on an appraisal of the tradability degree of each product, and the adoption of different local source coefficients by product type.[10] Most products can be included in one of two extreme categories for which estimating interregional gross imports is straightforward:

- *Type A* products are regionally non-tradable, that is, they are products that must be produced in the region where they are consumed, and therefore are not imported from other regions (or from other countries). Examples include: building construction, retail trade (except fuel) margins, general government services, education and certain personal services. For products in this category, interregional imports were assumed to be null in both regions. Consequently, there are no interregional exports either. In other words, the regional intermediate or final-demand flow is assumed to be entirely met by regional source production.
- *Type B* products are fully tradable, internationally and interregionally, that is, they are products that move between regions at no (or non-significant) cost within a small country like Portugal. In this case, there is no valid reason for any regional preference and the following is proposed: the proportion of local supply is assumed to be the same as the regional output weight of that product in the national total. Given the relative weight of each region in the national output, in most cases C is almost self-sufficient and supplies a high percentage of I's demand. Most manufacturing products fall into this category.

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10 A similar approach was adopted in Barata *et al.* (2011) to estimate gross interregional imports in the context of single region models for small regions belonging to the Portuguese Interior, and detailed in Ramos *et al.* (2015) for a bi-regional model context.

However, there are exceptions to this binary classification. Some products (not many, but with significant transaction amounts) fall into an intermediate category:

– *Type C* products are regionally tradable under specific conditions for several reasons, one being the high shipping cost, leading to trade only between neighbouring areas. Another interesting situation leads to classifying some other products as *type C*. This results from the 'headquarters effect' (Ramos, Barata and Pimentel, 2013; Ramos *et al.*, 2015). Although the demand for some services is local, it is met by nationwide companies that, for reasons of internal organisation, have a significant part of their business located in the national or regional headquarters, which do not tend to be located in the Interior region of Portugal. Although this is essentially local demand matched by a locally provided supply, a significant part of production actually occurs in big coastal cities, which is equivalent to importing a fraction of the total product output from this region (*C*). Examples of the 'headquarters effect' include financial intermediation, and postal and telecommunications services, as well as some other services provided mainly to businesses. In these cases, a detailed analysis was carried out at the NUTS III level, leading to the conclusion that production is concentrated in a few NUTS III regions, which are deemed to be exporting these services to the other regions. Finally, the majority of agricultural products, wholesale trade, transportation services and some specific industrial products are also treated as *type C* products, with a basic assumption being a minimum local source provision of 50 per cent, plus a percentage equal to the region's weight in the national output of the same product.[11]

This methodology produced a first estimate of gross interregional imports by product for the two regions. Interregional gross exports were computed by adding up interregional gross imports and the previously known interregional net trade. Yet, even if net trade is symmetric between the two regions, this method does not imply that the estimated gross imports for one region mirror the estimated gross exports of the other. Hence, a final consistency adjustment was needed: increasing the interregional exports and imports of one region while decreasing the interregional exports and imports of the other region, until the gross exports of one matched the gross imports of the other, for each product. The adjustment in each region was distributed while taking into account its relative weight in the product's output.

3. The Interior region of Portugal and the agri-food development strategy

The regional asymmetries within the Portuguese economy are essentially between the Coast (shoreline) and the Interior (inland) regions of the country. The Interior

11 This *ad-hoc* percentage was subjected to a sensitivity analysis, reducing it to 30 per cent and 40 per cent, and increasing it to 60 percent and 70 per cent. Overall 'macro' results are relatively robust to that analysis (Ramos, Barata and Pimentel, 2013).

suffers from a recognised relative backwardness, which is at the heart of the public debate regarding Portuguese regional policy. Though occupying 57 per cent of Portuguese territory, its population is only about 15 per cent of the country's total, and its economic activity amounts to only 11 per cent of the Portuguese gross domestic product (GDP). The Interior and Coast regions (*I* and *C*, respectively) are geographically defined in this paper as in Figure 1, using an aggregation of the NUTS III regions. As these two regions do not coincide with the official NUTS II map, it is relatively uncommon to discuss regional contrasts with this configuration in Portuguese regional science. Table A1 in the Annex, in its two first columns, gives some further detail on the sectoral structure of regions *I* and *C*.

It is worth mentioning that *I* still represents 1.6 million inhabitants. This is a paper on a rural region, not on a rural community. *I* is said to be rural due to its dependence on primary products, in a country with reduced agricultural aptitude. However, *I* comprises several middle-sized urban centres (where realistically agri-food plants are supposed to be located). In spite of this focus on a region, this paper shares with rural communities IO models (Robison, 1997; Robison and Lahr, 1997) the recognition of the great openness of rural economies.

It is also notable that the population in *I* has a much higher percentage of persons over 65. According to the *2011 Census* data, 25.8 per cent of the
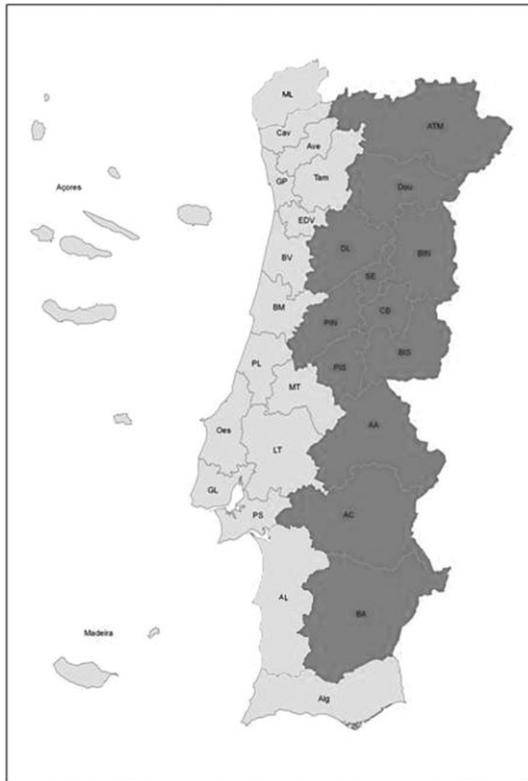

Fig. 1. Interior and Coast regions in Portugal.

interior's population is over 65, compared with 18.8 per cent in the coastal region. Furthermore, people younger than 25 represent only 22.6 per cent of the population in *I*, against 26.3 per cent in *C*. The demographic ageing of *I* is due to persistent migration to *C* or abroad, especially by younger adults. Significantly, since the 1980s the emigration of young adults from *I* has tended to be offset by the immigration of older age groups, presumably as a result of the return of migrants. However, despite the relative migratory equilibrium, the *I* population has continued to decline sharply, since being older the birth rate is lower and the mortality higher, and the natural balance is strongly negative (Ramos, Castro and Cruz, 2011; Martins, Marques and Castro, 2013).

The primary purpose of applying our bi-regional model is to analyse the impacts on regions *I* and *C* of shocks occurring in either of these territories. But it also has the virtue of allowing a highly detailed, multi-sector, characterisation of the two regional economies. In particular, the estimation of inter-regional trade undertaken in the modelling process is valuable in itself, as it allows an analysis of the (regional and international) trade balance of the regions, and their economic base. Table 2 highlights the major export products of region *I*, in terms of both gross exports and exports less imports.

Table 2 reveals the still enormous dependence of region *I* upon exports of products from agriculture and animals farming. This finding is relatively unexpected, especially because Portugal as a whole is a country with limited agricultural capacity and a huge national trade deficit in agricultural products. In Portugal, the agriculture sector, which is mainly located in *I*, is characterised by poor labour productivity, thus contributing to the weak economy of this region. Exports of products from agriculture and animals farming in *I* are delivered mainly to *C*, and only rarely exported abroad. Table 2 further shows that manufactured food products (except beverages) are also an important product in region *I*'s exports, but in this case, contrary to products of agriculture, imports exceed exports and there is a negative trade balance.

Table 2. Main international and interregional exports (in gross and net terms) from the Interior region of Portugal

Unit: 10^6 € (2007)	Gross exports		Exports less imports
Products of agriculture, animals farming, hunting and related services	1,243.8	Products of agriculture, animals farming, hunting and related services	554.1
Manufactured food products (except beverages)	1,169.3	Metal ores	471.2
Motor vehicles, trailers and semi-trailers	961.6	Land transport (including via pipelines) services	407.4
Food and beverage services (restaurants activity)	742.8	Beverages	362.4
Electricity, gas, steam, cold and hot water and cold air	640.7	Wood and cork products, except furniture	326.5

Table 3. Economic impacts from a EUR 10 million increase in exogenous final demand for agri-food products, and their production, in the Interior region of Portugal

Unit: 10^6 € and no. employees (2007)	Direct effect	%	Indirect effect	%	Induced effect	%	Total effect	%
Output	16.0378		4.9079		6.8669		27.8126	
Interior	12.9216	*80.6*	1.0378	*21.1*	2.1253	*31.0*	16.0848	*57.8*
Coast	3.1161	*19.4*	3.8701	*78.9*	4.7416	*69.0*	11.7278	*42.2*
GVA	4.6431		1.7586		3.5051		9.9069	
Interior	3.6226	*78.0*	0.4751	*27.0*	1.3386	*38.2*	5.4362	*54.9*
Coast	1.0206	*22.0*	1.2836	*73.0*	2.1665	*61.8*	4.4707	*45.1*
<65 Households Inc.	4.1817		1.3325		2.5322		8.0464	
Interior	3.1675	*75.7*	0.4234	*31.8*	1.0455	*41.3*	4.6364	*57.6*
Coast	1.0142	*24.3*	0.9091	*68.2*	1.4867	*58.7*	3.4100	*42.4*
Employment	412.4		88.4		117.0		617.9	
Interior	330.4	*80.1*	39.3	*44.4*	48.9	*41.8*	418.6	*67.8*
Coast	81.9	*19.9*	49.2	*55.6*	68.1	*58.2*	199.2	*32.2*

The values presented in bold and italic in these tables correspond to the relative/percentual distribution of the values represented at the column at its left.

Beverages, however, enjoy a positive trade balance in region *I*, as they include wine, a product with a significant relative weight for both *I* and the overall Portuguese economy. The enormous dependence of *I* on agriculture suggests an incentive strategy for local transformation such that many of the region's commodity products become manufactured food products, including beverages, a composite aggregate that in this paper we call 'agri-food products'. The idea would be to shift the exporter base of *I* from primary 'products from agriculture' to these 'agri-food products', which would involve a higher value added and encourage labour productivity growth in this region.

Table 3 portrays this scenario for development of the agri-food sector in *I*, and estimates the impact of an (hypothetical) increase in demand for/production of these products to be worth EUR 10 million directed exclusively to the *I* economy. As IO are linear model other shocks can be calculated proportionally. Any compensatory reduction of the production capacity in *C* for the same products was considered. Table 3 breaks down the total effects of this simulation: direct effects (including not only the shock impact on the production of agri-food products, but also the first wave effects on all of the other inputs used directly in their production[12]), indirect effects (the second and following waves of inputs required to produce the inputs used directly in the agri-food industry), and, finally, induced effects (products required to satisfy, in the form of final consumption, the additional income enjoyed by households where the head is younger than 65).

12 This is why the direct effects do not concentrate exclusively on *I*.

According to the results in Table 3, the multiplier effect on the national economy, from an injection of EUR 10 million into the Interior's agri-food industry, has a sound value of approximately 2.8. But what is remarkable in these calculations is that a significant part of the impact on the output (more than 42 per cent) spills over to *C*. Therefore, the ability of *I* to retain the benefits of a shock to its exogenous demand and own production is comparatively weak. Also concerning the GVA and households income (<65), *I*'s ability to capture the stimulus benefit does not reach even 60 per cent of the total effects.

The reason region *I* can only take relatively small advantage of agri-food expansion in its own territory is the high degree of overspill of the indirect and induced effects into the economy of *C*. Similarly Roberts (2000) points out the limited ability of a North East Scotland rural area for retaining the benefits of increased local activity and Hyytiä (2014) identifies two Finish regions (rural – urban) where positive effects on regional GDP and employment tend to accumulate in the urban centres. The direct effect is mostly felt in *I*, since this is where the shock takes place. But this impact is offset by the fact that the inputs needed to produce both the agri-food products and the inputs themselves, as well as the extra consumer goods needed because of increased households income, are almost without exception produced in *C*, where the majority of non-agricultural economic activities are concentrated. Table A1 in the Annex sheds some further light on the sectoral composition of the shock's effect. The dominance of agri-food products in the local effect – inside *I* – is quite evident. Beyond the initial impact, non-tradable products play a significant role.

It should be noted that the inability of region *I* to efficiently capture the indirect and induced effects prompted by an increase in agri-food production does not stem from the region's inability to supply primary agricultural products to meet local needs. The Portuguese economy under-produces some agricultural products or does not produce them at all, and therefore any agri-food expansion in *I* (as would also happen in *C*) implies a relatively significant increase in the international import of such products. But regarding national agricultural production overall, the results are quite different. Of the 60 agricultural products produced in Portugal that are considered in our model, *I* meets more than 70 per cent of its own national demand for 27 products and more than 50 per cent for 48 products.

The results in Table 3 assume fixed price of inputs, and therefore no retroaction on quantities of price variations. If we release these assumptions we may expect higher prices for agricultural products in *I*, and for other inputs used in the production of agri-food. The result should be a reinforced shift of the triggered demand to *C*, and still a higher concentration of the indirect and induced effects in this latter region.

4. Agriculture as a sector constrained by availability of resources (land)

When an agri-food development strategy in a rural region is proposed, as for region *I* of Portugal, in fact, the subsumed idea is that the available quantity of agricultural products is limited, and therefore it is preferable to transform

them locally, namely using them in the production of agri-food sector, generating more value added, instead of selling them to the rest of the country, or abroad as primary products. Indeed, the availability of agricultural products is constrained by the availability of natural resources needed to produce them, especially land. Agriculture is therefore a resource-constrained sector.

Within the framework of a supply and use model, incorporating resource-constrained industries and resource-constrained products is not straightforward. In this case, our methodological option is to consider that for the 60 nationally produced 'agriculture, animals farming, hunting and related services' products (three agricultural products are fully imported from abroad), the production in *I* will not exceed in real terms its value in the reference year of 2007. Of course, this must be seen as an extreme hypothesis. On the one hand, some productive land (and/or other specific resources) may still be available and can be used to increment agricultural production. Furthermore, if prices are allowed to vary it may be affordable to mobilise some unused less productive land, or it may be profitable to divert some land from other uses (e.g. forestry); also in the medium term new technological solutions may substitute land by other factors, for example capital. In all of these cases agriculture production can be expanded beyond the 2007 values, though on a moderate scale, compared to the results in Section 3.

Thus, when we assume that agriculture production is constrained to a fixed value (or to a small variation), the increase in intermediate demand for these products caused by the expansion of the agri-food sector in *I* must be offset by fewer uses in the region's final demand, in particular for international exports or sales to *C*. For some products this may even result in a final demand deficit. In other words, the region may be forced to import these products in order to supply the newly emerging manufacturing sector.

In formal terms, our approach follows the mixed exogenous–endogenous models (Miller and Blair, 2009: 621–633), adapted to models of the rectangular type. We assume that there is a variation in final-demand $\Delta \mathbf{f_0}$, which is confined here to an increased final-demand for agri-food products exclusively in *I*. The increase in domestic production of products in both regions can be calculated by:

$$\Delta \mathbf{p_0} = \mathbf{D_1} \cdot \Delta \mathbf{f_0} \qquad (7)$$

where $\mathbf{D_1}$ gives the impacts on the products' outputs $\mathbf{p}$ of a shock on products' final demand $\mathbf{f}$.

Let $\mathbf{p}^*$ be a subset of products contained in the vector $\mathbf{p}$, whose production is constrained by the availability of resources, that is, $\Delta \mathbf{p}^* = 0$ necessarily. Let $\mathbf{D_1^*}$ be an array composed of the rows and columns of $\mathbf{D_1}$ corresponding to the resource-constrained products contained in the subvector $\mathbf{p}^*$. The problem is that in the sequence of $\Delta \mathbf{f_0}$, there is $\Delta \mathbf{p_0^*} > 0$, which is part of the vector $\Delta \mathbf{p_0}$ calculated by (7). The $\Delta \mathbf{p_0^*}$ must be nullified through a corresponding reduction in final demand $\mathbf{f}^*$, addressed to resource-constrained products. The offsetting value of $\mathbf{f}^*$ may be compiled by:

$$\left(-\Delta \mathbf{f}_*\right) = \mathbf{D}_1^{*-1} \cdot \left(-\Delta \mathbf{p}_0^*\right) \tag{8}$$

The final step is to build a vector $\Delta\mathbf{f}$, containing the variation of final demand arising from the exogenous shock (in our case, the demand expansion for agri-food products), and also comprising the vector $(-\Delta\mathbf{f}_*)$, composed of the compensatory reduction in the resource-constrained products' (in our case agricultural products) final demand.

$$\Delta\mathbf{f} = \begin{bmatrix} (-\Delta\mathbf{f}_*) \\ \cdots \\ \mathbf{0} \\ \cdots \\ \Delta\mathbf{f}_0 \\ \cdots \\ \mathbf{0} \end{bmatrix} \tag{9}$$

In the end, the output variation in the economy, by industry, can be calculated by:

$$\Delta\mathbf{g} = \mathbf{D}_3 \cdot \Delta\mathbf{f} \tag{10}$$

where multipliers $\mathbf{D}_3$ are the impacts on industries' outputs $\mathbf{g}$ of changes in products' final demand $\mathbf{f}$.

Table 4 shows the impact of the assumed EUR 10 million capacity and demand increase in agri-food products, including beverages, on the total output in the two regions, and on their GVA, <65 households income, and employment. Now, however, this shock is restricted by the non-availability of additional resources needed to produce more agricultural products in *I*, whose output variation is therefore exactly 0.

As one might expect, this change in the use of agricultural products from exports (or other final-demand destinations) as primary products to their use for intermediate consumption in the *I* economy, in particular for agri-food industry production, has a positive effect on the economy, and increases the GVA of this region. But it is also clear that this impact is relatively small.

Table 4. Economic impact of EUR 10 million increase in exogenous final demand for agri-food products, and their production, in the Interior region of Portugal, constrained by a null variation in agricultural products in the same region

Unit: 10^6 € and no. employees (2007)	Interior	%	Coast	%	Total effect
Output	13.2523	*57.8*	9.6566	*42.2*	22.9088
GVA	4.1198	*52.5*	3.7314	*47.5*	7.8512
<65 Households Inc.	3.0502	*51.3*	2.8947	*48.7*	5.9449
Employment	232.1	*57.4*	172.4	*42.6*	404.5

The values presented in bold and italic in these tables correspond to the relative/percentual distribution of the values represented at the column at its left.

The limited availability of resources is an active constraint, which restricts the ability of the economy to expand as a whole and in *I* in particular. Table 4 shows that the impacts on the different variables are now much lower than those in the right-hand side of Table 3, when agricultural production was able to grow freely in reaction to increased production of agri-food products. Clearly, if the constraint were not so binding, recall our calculations were based on an extreme hypothesis, the ability to expand the economy of *I* might have been higher.[13]

5. Alternative strategies to the development of the agri-food industry

This analysis supports the argument that for regions like *I*, a development strategy based on developing an agri-food industry will have limited effectiveness for two main reasons:

– the indirect and induced effects arising from increased demand for these products would mainly spill-over into region *C*, the dominant region in terms of economic activity.
– the limited natural resources, especially land, would prevent (or at least mitigate) the expansion of agricultural production in *I*, and thus constrain the pulling impact on this region from the growth of production and demand for agri-food products.

According to these arguments, a region like *I* should consider alternative strategies involving different types of products, in particular regionally non-tradable products (type A, in the terminology of Section 2.3), or products that are intensive users of inputs with these characteristics. Additionally, these products should not be critically dependent on scarce resources in the *I*-economy.

An example of such a product is 'education services'. The fact that education services contribute to stimulating regional economies has been widely recognised (Pastor, Peraita and Pérez, 2016). As an illustration, Table 5 gives the results of a simulation of a EUR 10 million increase in exogenous final demand and production of 'education services' and its impact in *I*.

The results in Table 5 confirm that this strategy has a greater impact than the agri-food strategy, especially in terms of its effect on GVA and on the income of <65 households, even if, as assumed in Section 3, resource limitations to agricultural production are not taken into account. Additionally, comparing the total impact on *I* and on *C*, region *I* now enjoys a much better outcome. Consistent with these findings, Kilkenny and Partridge (2009) argue that 'service sectors would enhance rural development more successfully than traditional export-driven manufacturing' (Hyytiä and Kola, 2013: 723).

However, the main problem with this strategy lies in its policy feasibility. Indeed, how can one argue for exogenously increasing the demand for

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13 Table A1, in the Annex, gives the sectoral composition of the shock effects on both regions.

education services in *I* when this region's average age is so high and when the public sector in Portugal is faced with a severe budget constraint? This same problem arises for other non-tradable products, especially those whose main target is public consumption, such as public administration services. The relative advantage of implementing policies based on the development of natural resource intensive sectors, such as the agri-food strategy, for regions like *I*, might not lie in the strength of their hauling effects but rather in the creation of more opportunities to market new products, thereby stimulating an effective change in the level of final demand. At the end of the day, final-demand shocks have to be based on feasible policy, in the context of market conditions. Moreover, resource-intensive products specific to certain regions are potentially more marketable, in that such regional specificity can be linked to the perception that those products are of better quality and truly genuine.

Finally, an additional, pragmatic, policy approach suited to region *I* can be suggested. As explained in Section 3, this region has benefited from a significant inflow of older people, assumed to correspond mostly to the return of former migrants. For a discussion of the potential role of in-migrant households in rural areas, particularly associated with their income sources and consumption structures, see Roberts (2005). Accordingly, the impacts presented in Table 6 assume a strengthening of this trend and posit an additional EUR 10 million consumption by *I*'s >65 households, with an equivalent reduction in such consumption in region *C*.

Table 5. Economic impact from EUR 10 million increase in exogenous final demand and production of education services in the Interior region of Portugal

Unit: 10^6 € and no. employees (2007)	Interior	%	Coast	%	Total effect
Output	16.0346	*69.5*	7.0366	*30.5*	23.0712
GVA	12.7184	*81.3*	2.9318	*18.7*	15.6502
<65 Households Inc.	12.1005	*86.4*	1.9101	*13.6*	14.0106
Employment	432.4	*82.2*	93.6	*17.8*	526.0

The values presented in bold and italic in these tables correspond to the relative/percentual distribution of the values represented at the column at its left.

Table 6. Economic impact from a EUR 10 million shift in the exogenous final consumption of >65 households from the Coast to the Interior region of Portugal

Unit: 10^6 € and no. employees (2007)	Interior	Coast
Output	10.0462	−10.9385
GVA	6.6411	−6.4471
<65 Households Inc.	5.2832	−5.0411
Employment	224.4	−202.3

It is important to stress that the shock contemplated in the construction of Table 6 is different in nature from the others considered here. In fact, this is not a national shock that would result in greater demand within the Portuguese economy as a whole; it is simply a shift in demand from *C* to *I*. *I*'s economy expands, but *C*'s contracts. Still, the notably positive impacts both on the GVA and on the income of younger households headed by an under-65-year-old in region *I* exceed those derived from the development of the agri-food sector. The main reason for this is the significant consumption of personal, non-tradable services by these older families that return to region *I*.

6. Conclusions

The unequal development of regions has been a reality for many years in Portugal and elsewhere in the world, and policies not adjusted to this reality tend to increase these asymmetries. Based on a bi-regional rectangular (supply and use) IO model empirically, applied to Portugal with a significant degree of detail (431 products; 125 industries), this paper evaluates the effectiveness and the benefits and drawbacks of a development policy based on the agri-food industry (manufactured food products and beverages), implemented in the less developed part of the country.

The motivation for this research is the dependence of the rural region's economy (the interior region, *I*, in the case of Portugal) on the exports of primary products, namely 'products of agriculture, animals farming, hunting and related services'. The paper analyses an incentive policy aimed at generating more value added from primary products in the less developed region by exporting them as agri-food products. The simulation results, however, suggest a relative low effectiveness of such a development strategy, either because the more developed region will eventually attract a significant part of the benefits, or because increase in the agricultural production may be limited by land constraints.

Of course, this work admits the need to tackle the economic and social vulnerability of regions that are not positioned on the benefit side of the global logistics scale (Marsden and Sonnino, 2005). In other words, a shift from agricultural growth to rural development is required (Martinho, 2015), meaning a diversification of the economic base of those regions (Psaltopoulos *et al.*, 2004). Agri-food products may be part of this diversification, despite the arguable limitations of this strategy. As an alternative or complementary strategy, it is possible to find alternative products that are not agriculture-based and that could have a far more significant impact on the local economy of a laggard region. This might be because such products must be produced where they are consumed (or they are intensive users of these non-tradable products), or because they depend neither on limited natural resources nor on products that use scarce natural resources intensively. The major advantage of products such as agri-foods is not so much the strength of their pulling effect on the local economy, but rather their potential marketability, which

derives from the markets' tendency to regard products based on traditional regional resources as truly genuine and of higher quality.

Finally, this research suggests, albeit only in an exploratory way, that promising strategies specifically tailored to the specificity of region *I* in Portugal may exist. One interesting example of such strategies would be to attract more former migrants even if they are retired. According to the available statistics they are already returning to *I* in significant numbers. Their consumption patterns greatly favour the type of products considered as non-tradable, mainly personal services, this being the reason that these products have such an impact on *I*'s local economy.

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Appendix

Table A1. Sectoral structure of the interior and the Coast regions of Portugal, and of the shock's effects of the agri-food *I* strategy

	Structure of the economy (before shock)		Unrestricted shock		Interior's agriculture as a constrained sector	
	Interior (%)	Coast (%)	Interior (%)	Coast (%)	Interior (%)	Coast (%)
Agriculture products	6.32	1.30	11.65	12.19	0.00	13.49
Other primary products, including extractive industry	3.49	0.67	0.13	0.61	0.13	0.64
Agri-food products	6.98	3.99	65.16	17.06	78.56	16.06
Other manufacturing products	16.37	21.42	1.06	15.68	1.12	15.61
Energy, water supply and sewerage services	3.32	5.24	0.63	7.95	0.59	7.77
Construction	9.98	10.26	1.52	2.19	1.34	2.21
Trade, accommodation and food services; transportation	18.87	20.10	8.95	19.05	8.16	18.86
Other business services	11.13	17.45	7.11	16.29	6.78	16.50
Financial services	2.71	5.26	1.94	6.03	1.80	5.92
Public administration and social and personal services	20.82	14.28	1.86	2.95	1.53	2.94
Total	*100*	*100*	*100*	*100*	*100*	*100*
of which:						
• non-tradable products	38.47	31.84	9.55	11.14	8.11	11.35
• non-tradable products (excluding the 10 million initial impact)			25.26	11.14	33.04	11.35