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Article

The forestry products value chain and the costs of reshaping it: Multi-regional impacts of shrinking the pulp and paper industries in Portugal

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ABSTRACT:

Forestry industry macroeconomic assessments typically concentrate on the production, harvesting, and earliest processing of wood products, underestimating the full range of forests impacts in regional economies.

This work proposes a broader concept – *forestry products value chain* – that ponders the contribution of the downstream activities relying (directly and indirectly) on Silviculture and Forestry products.

The paper adopts a methodology based on a Multi-Regional Input-Output framework. We apply this approach to the Portuguese economy. Results clarify the role of eucalyptus in "Pulp", "Paper and Cardboard" and "Paper and Cardboard Articles". Finally, the projected wider macroeconomic consequences from a reduction of these productions is evaluated.

KEYWORDS: Forestry; multi-regional input-output analysis; Portugal; pulp and paper; value chain.
JEL CLASSIFICATION: Q23; R15; R12.

La cadena de valor de los productos forestales y los costes de su remodelación: Impacto multirregional de la reducción de las industrias de pulpa y papel en Portugal.

RESUMEN:

Las evaluaciones macroeconómicas de la industria forestal tienden a subestimar su impacto en las economías regionales.

Este trabajo propone un concepto más amplio – la *cadena de valor de los productos forestales*- que incluye la contribución de las actividades que dependen (directa e indirectamente) de la silvicultura y los productos forestales. Con una metodología basada en un modelo de input-output multirregional y centrado en la economía portuguesa. Los resultados elucidan el papel del eucalipto en las producciones de pulpa, papel y cartón y artículos de papel y cartón. Finalmente, se evalúan las consecuencias macroeconómicas proyectadas para una reducción de estas producciones.

PALABRAS CLAVE: Cadena de valor; modelo de input-output multirregional; pulpa y papel; Portugal; silvicultura y explotación forestal.
CLASIFICACIÓN JEL: Q23; R15; R12.

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1. INTRODUCTION

Forestry activity encompasses the extractive consumption of forest resources, biodiversity, and ecosystem protection, and plays a critical role in mitigating many of the consequences of global warming (FAO 2018; IUCN 2017). This multiplicity of roles makes it clear that when a human or environmental event shapes forestland, the effects felt will be beyond those of traditional economic measures (Pelli 2018; Simões et al., 2013).[1] Indeed, in OECD countries, there are only three cases (Finland, Estonia, and Latvia) where the forestry industry weights more than 1% of the Gross Domestic Product (GDP). The undervalue phenomenon of forestry is even more visible when, in 16 of the 44 countries described in the 2016 *World Input-Output Database* (WIOD) (Timmer et al, 2015), the forestry industry weights less than 0.1% of the national GDP while representing more than 20% of the land area. The forest industry's contribution to national economies and its share of the GDP usually is limited to the production, harvesting, and earliest processing of wood and non-wood forest products. However, after wood or non-wood products produced by forestry are sold, a significant part continues in the production process and is used as an input of other manufacturing products. That is, the economic value of a forest product goes beyond the value of the wood that is sold. Accordingly, the most relevant feature added with this research is that we envisage to consider and measure all the downstream activities that substantially rely on the existence of a forest as an ecosystem.

Throughout this work, forestry will be part of a broader concept designated by *forestry products value chain*, which includes an additional number of products and productions based on the economic linkages established between industries and production structures.

Therefore, and focusing on Portugal as a case study, a Multi-Regional Input-Output (MRIO) model is applied to identify the *forestry products value chain* and measure its contribution to national GDP (while including the respective indirect effects). When there is no (inter)regional information with a suitable level of sectoral disaggregation, many studies derive benchmark chains from national input-output tables (Kosfeld and Titze 2017). But, whenever possible, the MRIO tool, as an important offshoot of the original contributions of Walter Isard to Regional Science with the formulation of Interregional Input-Output Accounts, remains the preferable approach for a comprehensive analysis of the myriad links established among sectors, final demand components, and regions (Polenske and Rockler 2014).

The disaggregation level of our model includes 431 products produced by 134 industries in the Portuguese economy. This disaggregation level allows a link between tree species and their specific use to establish better forest management practices capable of ensuring forest protection and supporting rural development (Kassioumis et al., 2004). This methodology can be replicated to assess the forest value chain in other countries or regions, as data have becoming increasingly available through MRIO models and databases such as *WIOD* (Timmer et al., 2015), *IMPLAN* (2019), *EORA* (Lenzen et al., 2013) or *EXIOBASE* (Stadler et al., 2018).

Besides identifying and characterizing the *forestry products value chain* in Portugal, this research aims to explore the features of the MRIO model, with particular emphasis to detailed specification of the regional and national economic structures and linkages, to enlighten the differential macroeconomic impacts, at the national and regional levels, of alternative shocks/policy actions.

The remainder of this study is organized as follows. Section 2 presents the approach applied to establish which products integrate the *forestry products value chain* by providing a more comprehensive appraisal of the economic value of products that rely on forests for production. Section 3 presents a tri-regional IO model that comprises the Portuguese economy and details how this analytical framework allows to capture the direct and indirect effects of the complete value chain. Section 4 presents the main results. Section 5 complements the analysis by evaluating the induced economic impacts of specific shocks or policy measures – scenarios of reduction of Portuguese exports of pulp, paper and cardboard, and articles

[1] Montagné-Huck and Brunette (2018) offer an extensive list of bibliographic references in the field of economic analysis of forest natural disturbances.

of paper and cardboard. Section 6 concludes by discussing policy implications and future avenues for research.

2. THE PORTUGUESE CASE AND THE *FORESTRY PRODUCTS VALUE CHAIN*

Forests are now a permanent presence in the Portuguese landscape. This reality is derived from anthropogenic activities and is specifically the outcome of demographic and economic changes in rural areas (Cruz et al., 2017; Ribeiro and Lovett 2009) and the accelerated shift from a rural to an urbanized society. The abandonment of low productive and marginal agriculture has promoted forest expansion (either naturally or by active planting) in Portugal. According to Uva (2015), in 1900, forest represented 7% of Portuguese land, compared to 36.2% of mainland Portugal in 2015 (ICNF 2019).

During this period, pine species were used to afforest abandoned agricultural fields. At this point, cork and other Mediterranean oaks lost their predominance in the Portuguese landscape. Then, in the 1960s, eucalyptus was introduced on a commercial scale and has been consistently expanding.[2] Portuguese forests are now dominated by these three tree species as follows: cork oaks (720,000 hectares (ha)), pinasters (714,000 ha), and eucalyptus (844,000 ha) (ICNF 2019). In Portugal, these tree species are associated with four main manufacturing activities: cork products, furniture and construction, pulp and paper products, and, more recently, biomass for energy (Louro et al., 2014).

Portuguese forests are heterogeneous in terms of property (Feliciano et al., 2017). Compared with other European countries, Portugal has the highest proportion (73%) of forestry land owned by non-industrial private forest owners, with the smallest average size (Canadas et al., 2016). The Portuguese national government and other public entities own only a residual share (around 2.5%). This heterogeneity explains why 70% of properties have less than 4 ha, and only 1% have 100 ha or more (Louro 2015). Pines, eucalyptus, and cork oaks can be found on small, middle, and large properties that may belong to small landlords, companies, the state, or undetermined owners (abandoned). This relatively scattered forest expansion has brought new problems and challenges such as forest fires and tree diseases/pests. More than 2.8 million ha of forest burned between 1990 and 2015, and nearly 274.000 ha between 2016 and 2018 (Nunes et al., 2016; Viegas 2018), and a high incidence of human casualties to forest fires occurred in 2017 (Molina-Terrén 2019). Tree diseases/pests include pine wilt (De la Fuente and Beck 2018; Uva, 2015) and fungi (Branco et al., 2014).

Finally, forestry location and species diversity are also heterogeneous in regional terms and so are their impacts. Despite being a small country, the forest landscape in the south of Portugal is entirely different from the other Portuguese regions. This is the rationale for a model that specifies distinct regional structures and several forest-based activities (e.g., the pulp and paper industries).

From a macroeconomic perspective, the value added of the Portuguese Silviculture and Forestry industry in 2016 totaled 866.7 million euros, representing 0.46% of the GDP. This same industry was responsible for 13,353 jobs (at full time equivalent), i.e., 0.30% of total employment in Portugal, as well as 0.10% of the Portuguese total exports This resulted in a negative trade balance of 215 million euros for forest products (see Table 1 ahead). The national demand for forestry products has been growing even more than the (largely) increasing national supply. This inclusively affects an iconic Portuguese product, "Natural Cork", which must be imported to satisfy the demand for cork product manufacturing in Portugal.

It is the fact that forest economic contribution does not rely only on the Silviculture and Forestry industry numbers (Latta et al., 2013) that justifies the study of the *forestry products value chain* (i.e., all the main final products that are dependent of the existence of forests and its exploitation). This value chain includes products produced directly or indirectly from wood and other forest products. For example, "Paper and Cardboard Articles" do not directly require forest products. Instead, it uses "Paper and Cardboard" that depends on "Pulp" consumption, which finally demands for wood.

[2] This expansion originated an intensive debate on the (dis)advantages of this species (see, e.g., Carvalho-Santos et al. 2016).

A preliminary step consists in establishing which products integrate the *forestry products value chain*. FAO (2014: 8) acknowledge this difficulty when defining the forestry sector:

> There is no commonly agreed definition of forestry sector. (…) the sector should be defined to include all economic activities that mostly depend on the production of goods and services from forests. This would include commercial activities (…) also activities such as the commercial production and processing of non-wood forest products and the subsistence use of forest products. It could even include economic activities related to production of forest services (although it would be difficult to determine exactly which activities are really dependent on forest services).[3]

The selection of such products can also be debated in light of the literature. Beyond the main products of the Silviculture and Forestry industry, Sathre and Gustavsson (2009) analyze the production process of 14 traditional Swedish forest products (including pulp, newspapers, and furniture) to understand the technology that maximizes value-added formation. The relationship between pulp, paper, and the forestry business is also addressed in Brandeis and Guo (2016). Complementarily, von Geibler et al. (2010) show that Silviculture and Forestry is relevant to allow the production of diverse construction materials. Using a different approach, the role of "Natural Cork" and cork manufacturing (among other products) in the wine production value chain is analyzed in Ferreira et al. (2019). Further, Keča et al. (2013) and Shabani et al. (2013) establish the relationship between forestry non-timber products and the production of touristic products, bioenergy, clothing, or food. In our appraisal, however, most of the value chain literature regarding forestry-based products mainly focuses on the discussion of particular products and their specific production processes, rather than on assessing the relevance of the entire chain. As Mansourian and Vallauri (2014) and Houghton et al. (2017) note, the role of forests in the environment and how human actions impact forests is greatly undervalued by society.

Therefore, we emphasize the contribution of forests to the general economic activity beyond the traditional approach. To do this, we use an MRIO model for the Portuguese economy to describe the linkages and interdependencies established between sectors, demands, and regions and to identify a *forestry products value chain* amid the complex links of a given national economy. We start by assuming that the products belonging to this value chain must obey two criteria:

1. Products that represent, as a destination, more than a residual share of the value added of Silviculture and Forestry (signaled within box with black and white backgrounds in Figure 1).
2. Products whose final value incorporate more than a residual share of value-added proceeding from Silviculture and Forestry (identified within box with black and grey backgrounds in Figure 1).

Figure 1 summarizes the final products obtained, accordingly with these criteria, and for the threshold of 0.3%, defined for empirical purposes, in order to exclude marginal contributions.

The products identified with the black background result from the interception of the two criteria, meaning they consume and incorporate a relevant share of the Silviculture and Forestry value added in its production. These products correspond to the designated *forestry products value chain*. The products identified with the white background are relevant destinations of Silviculture and Forestry sales, but this use represents only a small residue among the global inputs consumed by such products. These productions mainly include large industries, such as Retail and Wholesale Trade, Public Administration or Health Services. Identified with the grey background are the products that rely on forestry products to be produced, but this dependence means less than a residual value to the Silviculture and Forestry industry. Finally, it is important to highlight that ultimately all the sectors in one economy incorporate some small share of the value added of silviculture and forestry (for example, paper is consumed by all of them). However, it is noticeable that the 17 products (within a universe of 431) represented in the black box

[3] According to FAO (2014), the subsectors included within the definition of forestry sector given above are ISIC Rev.4 Division 02 (forestry and logging); ISIC Rev.4 Division 16 (manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials); and ISIC Rev.4 Division 17 (manufacture of paper and paper products).

(Figure 1) are responsible for absorbing, directly and indirectly, 77.4% of the national silviculture and forestry value added. Of course, this endogenous definition of *forestry products value chain* is dependent of the products classification and of each country or region economic circumstances. Still, the products here empirically identified, through this endogenous process, have a strong correspondence with the core of the forestry products as defined by FAO (2014).

FIGURE 1.
Products belonging to the forestry products value chain

Next, Table 1 compares the macroeconomic role of strictly considering Silviculture and Forestry products, as defined in official statistics, with the figures for the set of products identified (with black background) in Figure 1.

Table 1 illustrates how this new wider concept provides a more comprehensive appraisal of the economic value of products that rely on forests for production. The main products produced within our *forestry value chain* account for more than 10% of Portuguese exports compared to products from Silviculture and Forestry at only 0.1%. Also, the trade balance of the whole forestry chain products is clearly positive (+ € 2,417 million), with the sectors that produce them as main products representing 2.4% of GDP and 2.7% of total employment in Portugal. The number of products and the jobs that rely on forestry are very relevant and policy makers should be aware of this.

TABLE 1.
Macroeconomic indicators of *Silviculture and Forestry* and of the *forestry products value chain* (Portugal, 2016)

	Of the *Silviculture and Forestry*	Of the main industries producing the products of the *forestry value chain*
Weight of the main producer sectors on GDP	0.46%	2.42%
Weight of the main producer sectors on employment (*FTE*)	0.30%	2.73%
Weight of the main products on the output of the economy (at basic prices)	0.36%	3.60%
Weight of the main products on the exports	0.10%	10.09%
Trade balance *(€ million)*	-215	2,417

Source: Portuguese National Accounts (INE, 2019).

3. VALUE CHAIN ESTIMATION AND THE COMPLEXITY OF USES OF SILVICULTURE AND FORESTRY VALUE ADDED

Forestry is an ecosystem that provides inputs through trade and linkages between industries and regions. Because exclusively looking at Silviculture value added can bias the analysis of what exactly is a *forestry products value chain*, we apply a MRIO framework using the input-output technique to capture the direct and indirect effects of the complete value chain (Miller and Blair, 2009). This approach has been widely applied in value chain studies (e.g., Los et al., 2015; Timmer et al., 2015), some of them addressing primary products (Tokgoz and Majeed 2019; Xing et al., 2017). This type of model presents an accurate picture of wood and other forestry products as inputs in manufacturing processes (e.g., pulp, paper, cork products, or furniture).

The MRIO model used in this work is based on the MULTI2C (Multi-sectoral Multi-regional Coimbra Model) framework, for 2010, disaggregated at the NUTS III level for the Portuguese territory (Ramos et al., 2015). At the national level it uses information provided by the Portuguese System of National Accounts. As for regionalization, besides Regional Accounts, several other sources are used. In the Silviculture and forestry products case, the Forest Inventory information is the main data source. All regionalized matrices comprise 431 products (of which 11 are silviculture and forestry products[4]) and 134 industries (of which one is silviculture). The matrices describe "domestic shipments", that is, the products produced within the regional and national boundaries and their uses (international imports are treated separately). Transactions are in "basic prices", which exclude Value Added taxes and other taxes, less subsidies, on products. Trade and transportation margins are treated as inputs of the retail and wholesale trade industries and the transport services, respectively.

To include regional differences while understanding the *forestry products value chain*, we divide the country into three regions. Two of these regions match the Centro region of Portugal (a NUTS II region): Coastal Centro and Interior Centro. Both regions concentrate more on forestry and forestry-based products (as pulp and paper) than the national average. The third region is the *Rest of the Country*. We employed three steps to estimate interregional trade. First, we estimated gross interregional imports using

[4] "Living forest trees; forest products seeds" (the National Accounts imputation of species growth to GDP, recorded as changes in inventories), "Products of forest nurseries", "Forest standings" (the planting, clearing and thinning of the forest, considered as investment), "Coniferous softwood", "Hardwood, except tropical wood", "Tropical wood", "Firewood", "Resins", "Natural cork or simply prepared cork", "Other forestry products" and "Services related to silviculture and forestry". Some of these products are not produced or only residually produced in Portugal (tropical wood; resins) although they are imported and used as inputs in others production processes.

a "tradability" typology by product. Second, we estimated net interregional trade using the commodity-balance technique (Miller and Blair 2009). Third, we estimated gross exports by products by added up net outflows and gross imports.

The starting point to estimate the output multipliers is the Make and Use **A** matrix, as presented in Equation (1).

$$A = \begin{bmatrix} 0 & B \\ D & 0 \end{bmatrix} \quad (1)$$

A is a square matrix (although **D** and **B** are rectangular) of dimension 1,695 [(431 products + 134 industries) x 3 regions]. The bottom left partition of matrix **A** is the Make (or supply) matrix (**D**). It shows products production both by industry and by region. The upper right partition (**B**) is the Use matrix, which displays intermediate consumption of production by industry. This matrix also provides the region of origin of each product used as an intermediate consumption in each region. The standard IO procedure for calculating the impacts of any given final demand is as follows:

$$x = (I - C)^{-1} y, \quad (2)$$

where **y** is the 1,695 x 1 vector of exogenous final demand by product and region. The 1,695 x 1,695 **C** matrix is the coefficient matrix derived from **A** (estimated by dividing each cell of matrix **D** by the total products output and each cell of the regionalized matrix **B** by the total industries output in each region), and **I** is an identity matrix of conforming size. Thus, **x** is the total outputs vector by region of dimension 1,695 x 1.

Let us more simply denote the Leontief Inverse matrix as **L** such that:

$$L = (I - C)^{-1}. \quad (3)$$

Recall that **L** necessarily has a dimension of 1,695 x 1,695. Let us now partitionate it as follows (in both rows and columns we group first products and then industries):

$$L = \begin{bmatrix} L^1 & L^2 \\ L^3 & L^4 \end{bmatrix}. \quad (4)$$

Partitions $\mathbf{L^1}$ and $\mathbf{L^3}$ deserve particular attention, as they show the effects of changes in the final demand of products, respectively, on the product and industry productions by region.

Let $\hat{\mathbf{w}}$ to be a diagonal square matrix with 402 rows and columns, with each entry in its main diagonal representing the value added coefficient of each of the 134 industries in the 3 regions (e.g., the ratios between the value added and the total regional outputs of the industries). The matricial multiplication

$$V = \hat{w} \, . \, L^3 \quad (5)$$

give us the value added generated in each industry and in each region, directly and indirectly incorporated, in one unit of each product produced in each region. The three rows referring to the Silviculture and Forestry industry (one for each region) display the forest value added contents of all 431 products produced in the three regions. In this case, considering the 17 products included in the *forestry products value chain*, we analyze the share of their final values generated by the Silviculture and Forestry industry.

4. Results and discussion

The following tables provide some insights on the structure of final uses of the value added by the Silviculture and Forestry sector, which spreads to the rest of the economy through the *forestry products value chain*. Table 2 depicts the final destination of the value added by Silviculture and Forestry industry in Portugal. These destinations are described both according to the type of final demand and region.

TABLE 2.
Final destination of the value added by *Silviculture and Forestry*, by type of demand and regions

		Coastal Centro			Interior Centro			Rest of Portugal			Portugal - Total		
		Value added (10^6€)	Weight in regional VA (%)	Weight in the country (%)	***Value added*** (10^6€)	Weight in regional VA (%)	Weight in the country (%)	***Value added*** (10^6€)	Weight in regional VA (%)	Weight in the country (%)	***Value added*** (10^6€)	Weight in regional VA (%)	Weight in the country (%)
Location of the forest activity	Private Consump.	**14,13**	*12,4*	*17,4*	**14,60**	*13,2*	*18,0*	**52,46**	*12,1*	*64,6*	**81,20**	*12,4*	*100*
	Public Consump.	**2,97**	*2,6*	*14,8*	**2,85**	*2,6*	*14,2*	**14,24**	*3,3*	*71,0*	**20,07**	*3,1*	*100*
	Investment	**43,25**	*38,0*	*20,1*	**42,01**	*38,0*	*19,5*	**130,3**	*30,1*	*60,4*	**215,56**	*32,8*	*100*
	Exports	**53,47**	*47,0*	*15,7*	**51,07**	*46,2*	*15,0*	**235,93**	*54,5*	*69,3*	**340,48**	*51,8*	*100*
	Tt. Silvic. &Forestry	***113,83***	*100*	*17,3*	***110,53***	*100*	*16,8*	***432,94***	*100*	*65,9*	***657,30***	*100*	*100*
Location of the productive processes that incorporates forest products	***Total of Silvicult. &Forestry***	127,07	100	19,3	82,98	100	12,6	447,26	100	68,0	657,30	100	100

Concerning the type of final demand, the value generated is predominantly exports (51.8%) of wood and timber not directly exported as a rule, but rather as inputs (incorporated) in other products. Around one-third (32.8%) of the value added is ultimately investment, for three main reasons: the "Forest Standings" product is investment in future plantations; the "Living Forest Trees" product is recorded mainly as changes in inventories, and there is also some value added with origin in the forestry sector that is incorporated in "Buildings and Building Construction Works" product. Finally, according to this analysis, private and public final consumption have a modest relevance.

In regional terms, the activity of the Silviculture and Forestry sector in Portugal has a relatively higher concentration in the Centro Region (34.1% of total national value added, representing 17.3% in the Coastal Centro and 16.8% in the Interior Centro). These figures illustrate the importance of the two subregions (Coastal and Interior Centro) in the Silviculture and Forestry sector in Portugal, particularly if we consider that in 2010, the Coastal Centro accounted for 13.5% and the Interior Centro for only 5.2% of Portuguese GDP. Conversely, the Rest of the Country, which generated 81% of Portuguese GDP, limited its contribution to the national value added in the forestry sector to 66%. This happens even though Natural Cork production, and its processing activity, is predominantly located outside the Centro Region.

Alternatively, the value added of Silviculture and Forestry can be divided regionally according to the place where the downstream final productive processes occur (instead of according to the forest location). Following this alternative rationale, the Interior Centro still represents 12.6% of the national value added by the Silviculture and Forestry sector. This happens because the relative ability of the Interior Centro for forestry activities has shaped its economic structure and now other forest-related industries are also relatively more concentrated in this region. The part that failed to be retained in the region spilled over mainly to the Coastal Centro, where manufacturing activities are more important. This explains why, according to this second regionalization criterion, Coastal Centro retains 19.3% of the value added of Silviculture and Forestry, being the remaining 68% captured by the Rest of the Country (though, still well below its 81% share of the GDP).

Table 3 illustrates the regional distribution of the value added absorbed by the 17 products of the forestry chain according to the place where the forest activity occurs. Table 4 illustrates the regional distribution of the same value added, but according to the region where the 17 products of the *forestry value chain* are manufactured.

TABLE 3.
Value Added by the *Silviculture and Forestry* industry incorporated into the 17 products of the *forestry products value chain*, according to the region of origin of the forest products

	Coastal Centro		Interior Centro		Rest of Portugal		Portugal - Total	
	Value added incorporated (10^6€)	%	Value added incorporated (10^6€)	%	Value added incorporated (10^6€)	%	Value added incorporated (10^6€)	%
Living forest trees; forest products seeds	23,31	*20,5*	21,25	*19,2*	68,53	*15,9*	113,10	*17,2*
Forest standings	12,67	*11,1*	12,36	*11,2*	33,55	*7,8*	58,57	*8,9*
Hardwood, except tropical wood	12,35	*10,9*	12,05	*10,9*	32,28	*7,5*	56,68	*8,6*
Firewood	4,19	*3,7*	4,09	*3,7*	11,07	*2,6*	19,36	*3,0*
Natural cork or simply prepared cork	0,55	*0,5*	0,39	*0,4*	8,31	*1,9*	9,22	*1,4*
Other forestry products	3,95	*3,5*	3,60	*3,3*	11,60	*2,7*	19,14	*2,9*
Articles of cork	6,21	*5,5*	4,60	*4,2*	93,31	*21,6*	104,21	*15,9*
Sawn and flattened wood	1,61	*1,4*	2,62	*2,4*	5,14	*1,2*	9,41	*1,4*
Veneers and other wood panels	1,50	*1,3*	4,01	*3,7*	6,91	*1,6*	12,45	*1,9*
Floors, builder's joinery and carpentry of wood	1,07	*0,9*	1,19	*1,1*	4,20	*1,0*	6,46	*1,0*
Wood packages	0,22	*0,2*	0,34	*0,3*	1,60	*0,3*	2,12	*0,3*
Other wood articles; products of straw and plaiting materials	0,45	*0,4*	0,47	*0,4*	1,37	*0,3*	2,29	*0,4*
Pulp	4,53	*4,0*	4,70	*4,3*	13,37	*3,1*	22,59	*3,4*
Paper and cardboard	14,45	*12,7*	10,04	*9,1*	28,73	*6,6*	53,22	*8,1*
Articles of paper and cardboard	0,53	*0,5*	0,39	*0,4*	1,13	*0,3*	2,05	*0,3*
Other furniture	1,62	*1,4*	2,58	*2,3*	6,27	*1,5*	10,48	*1,6*
Serv. collection, treat. and disposal of waste; materials recovery serv.	0,60	*0,5*	0,65	*0,6*	6,00	*1,4*	7,24	*1,1*
17 products of the Forest Value Chain	89,83	***78,9***	85,48	***77,3***	333,33	***77,0***	508,62	***77,4***
Total products of the economy	113,83	***100***	110,53	***100***	432,94	***100***	657,30	***100***

Tables 3 and 4 illustrate how the value added of Silviculture and Forestry is incorporated into the 17 products that belong to the *forestry products value chain*. At the country level, these 17 products incorporate in their final value 77.4% of the total final destinations of the value generated in the Silviculture and Forestry sector. In the Rest of the Country, "Articles of Cork" is the product that incorporates most of the value generated in the Silviculture and Forestry industry. This happens whether we consider the place of production of the raw material or the place of its final transformation. In the Centro Region (Coastal and Interior), "Pulp" and "Paper and Cardboard" stand out as final uses of value added by forests.

Table 5 illustrates the contribution of the different products produced by the Silviculture and Forestry industry, displaying which of the forest products are most intensively incorporated, either in the total of the 17 final products of the forestry chain or in some of the individual products that compound it.

TABLE 4.
Value Added by *Silviculture and Forestry* industry incorporated into the 17 products of the *forestry products value chain* according to region of destination where the final products are produced

	Coastal Centro		Interior Centro		Rest of Portugal		Portugal - Total	
	Value added incorporated (10^6€)	%	Value added incorporated (10^6€)	%	Value added incorporated (10^6€)	%	Value added incorporated (10^6€)	%
Living forest trees; forest products seeds	23,45	*18,5*	21,55	*26,0*	68,10	*15,2*	113,10	*17,2*
Forest standings	12,76	*10,0*	12,58	*15,2*	33,23	*7,4*	58,57	*8,9*
Hardwood, except tropical wood	12,44	*9,8*	12,27	*14,8*	31,97	*7,2*	56,68	*8,6*
Firewood	4,22	*3,3*	4,17	*5,0*	10,97	*2,5*	19,36	*3,0*
Natural cork or simply prepared cork	0,51	*0,4*	0,34	*0,4*	8,40	*1,9*	9,25	*1,4*
Other forestry products	3,97	*3,1*	3,65	*4,4*	11,52	*2,6*	19,14	*2,9*
Articles of cork	1,94	*1,5*	0,21	*0,3*	102,06	*22,8*	104,21	*15,9*
Sawn and flattened wood	2,04	*1,6*	2,95	*3,6*	4,42	*1,0*	9,41	*1,4*
Veneers and other wood panels	0,95	*0,8*	5,00	*6,0*	6,49	*1,5*	12,45	*1,9*
Floors, builder's joinery and carpentry of wood	1,37	*1,1*	0,45	*0,5*	4,65	*1,0*	6,46	*1,0*
Wood packages	0,07	*0,1*	0,04	*0,1*	2,01	*0,5*	2,12	*0,3*
Other wood articles; products of straw and plaiting materials	0,69	*0,5*	0,28	*0,3*	1,33	*0,3*	2,29	*0,4*
Pulp	8,36	*6,6*	2,45	*3,0*	11,78	*2,6*	22,59	*3,4*
Paper and cardboard	30,18	*23,8*	3,66	*4,4*	19,38	*4,3*	53,22	*8,1*
Articles of paper and cardboard	0,41	*0,3*	0,16	*0,2*	1,49	*0,3*	2,05	*0,3*
Other furniture	1,34	*1,1*	0,74	*0,9*	8,39	*1,9*	10,48	*1,6*
Serv. collection, treat. and disposal of waste; materials recovery serv.	0,48	*0,4*	0,35	*0,4*	6,41	*1,4*	7,24	*1,1*
17 products of the Forest Value Chain	105,17	***82,8***	70,84	***85,4***	332,61	***74,4***	508,62	***77,4***
Total products of the economy	127,07	***100***	82,98	***100***	447,26	***100***	657,30	***100***

Table 5 also illustrates that "Natural Cork", which is mainly produced in the Rest of the Country, is the product with greater importance, directly and indirectly, in "Articles of Cork". In "Pulp", "Paper and Cardboard", and "Paper and Cardboard Articles", the most important raw product, directly and indirectly, is "Hardwood" (essentially eucalyptus), with a prominent role to the Interior Centro (despite the relatively small size of the region). As for "Sawing Products" the raw product most used, directly and indirectly, is "Coniferous Softwood".

The results of the value chain established downstream of forest production provides a better picture of the value of forest products. Further, it allows highlighting that a considerable part of the manufacturing activity also depends on this activity and may be used to show what might occur if any disruption happens somewhere along the value chain. This is the basis for the scenarios presented in the next section. Actually, the approach applied to identify the *forestry products value chain* is simultaneously a descriptive tool and an analytical instrument.

TABLE 5.
Main products of *Silviculture and Forestry* (11 products) incorporated into the total (17 products), and in some selected products, of the *forest products value chain*

	Whole products of the *Forest Value Chain*		**Pulp**		**Paper and cardboard**		**Articles of paper and cardboard**		**Sawn and flattened wood**		**Articles of cork**	
	Output incor-porated (10^6€)	%	Output incor-porated (10^6€)	%	Output incor-porated (10^6€)	%	Output incor-porated (10^6€)	%	Output incor-porated (10^6€)	%	Output incor-porated (10^6€)	%
Living forest trees; forest products seeds	142,18	*19,4*	--	--	--	--	--	--	--	--	--	--
Products of forest nurseries	2,64	*0,4*	0,12	*0,4*	0,29	*0,4*	0,01	*0,4*	0,05	*0,4*	0,49	*0,3*
Forest standings	73,80	*10,1*	--	--	--	--	--	--	--	--	--	--
Coniferous softwood	60,09	*8,2*	5,72	*17,9*	13,53	*17,8*	0,56	*19,7*	8,22	*66,0*	1,75	*1,2*
Hardwood, except tropical wood	160,94	*22,0*	22,41	*70,0*	53,00	*69,9*	1,88	*66,7*	2,55	*20,5*	0,59	*0,4*
Tropical wood	--	--	--	--	--	--	--	--	--	--	--	--
Firewood	31,11	*4,3*	0,00	*0,0*	0,00	*0,0*	0,00	*0,0*	0,00	*0,0*	0,00	*0,0*
Resins	0,03	*0,0*	0,01	*0,0*	0,02	*0,0*	0,00	*0,1*	0,00	*0,0*	0,00	*0,0*
Natural cork or simply prepared cork	152,87	*20,9*	0,12	*0,4*	0,26	*0,3*	0,04	*1,2*	0,10	*0,8*	132,79	*88,3*
Other forestry products	27,93	*3,8*	0,00	*0,0*	0,00	*0,0*	0,00	*0,0*	0,00	*0,0*	0,00	*0,0*
Services related to silviculture and forestry	79,64	*10,9*	3,63	*11,3*	8,72	*11,5*	0,34	*11,9*	1,54	*12,3*	14,75	*9,8*
Products of Silviculture and Forestry - Total	***731,24***	*100*	***32,01***	*100*	***75,82***	*100*	***2,82***	*100*	***12,46***	*100*	***150,38***	*100*
S&F Products - Coastal Centro	136,74	*18,7*	6,800	*21,2*	21,71	*28,6*	0,78	*27,6*	2,24	*18,0*	10,20	*6,8*
S&F Products - Interior Centro	129,78	*17,7*	7,07	*22,1*	15,11	*19,9*	0,53	*19,9*	3,84	*30,8*	7,58	*5,0*
S&F Prod. - Rest of the Country	464,72	*63,6*	18,14	*56,7*	38,99	*51,4*	1,48	*52,5*	6,38	*51,2*	132,61	*88,2*

5. SCENARIOS OF REDUCTION OF PORTUGUESE EXPORTS OF PULP, PAPER AND CARDBOARD, AND ARTICLES OF PAPER AND CARDBOARD

Forest sustainability depends on human activity and, as a source of raw materials, it can be positively or negatively impacted based on market forces or distinct practices and policies. Salvo et al. (2015) showed how humans would increase or decrease land use in Amazonia according to different economic scenarios. Here, we follow a similar approach for the specific products of Pulp and Paper manufacturing. According to Berg and Lingqvist (2019), the year 2015 saw worldwide demand for some types of paper decline for the first time ever. This was a result of declining demand in North America and Europe over the past five years and is the motivation for our scenario. There is also an ongoing debate with extreme relevance in Portugal about the environmental sustainability of these productions (Pätäri et al., 2016), particularly due to the increased shortage of water resources (Lobanova et al., 2016).[5] Another critical feature is how pulp is dependent on eucalyptus. Eucalyptus has been greatly associated with the number, extension, and severity of wildfires in Portugal, which has resulted in public pressure to adopt other species, wildfire-resistant, in Portugal (Fernandes et al., 2019; Rego et al., 2013) [6].

[5] The most important pulp mill plant in the Interior Centro was shut down for several weeks in 2017, following an alleged polluting discharge, which affected the quality of the Tagus River water.
[6] The discussion is similar in Galicia, a Spanish region located on the northwest corner of the Iberian Peninsula, right at the north border of Portugal (Chas-Amil, 2007; González-Gómez et al., 2013).

In this section, we added some methodological features to provide another layer of analysis to our model. Namely, an extension was included to endogenize part of the final demand that is mostly dependent of the production process. According to the input-output literature, such models are known as "closed" and, in this case, include (or endogenize) the effect of labor income in households consumption. Therefore, this analytical tool allows evaluating not only the direct and indirect, but also the induced economic impacts of specific events or policy measures on the productive structure of the chosen geographical area(s), e.g. with respect to each sector's output, employment or Gross Value Added (Fuenmayour et al., 2019; Ramajo-Hernández et al., 2014). Mathematically, sub-matrices **B** and **D**, in (1), are extended in three rows, corresponding to the income distributed to households (employees and own account workers) in each region, and three columns describing the households consumption. Households living in each region consume products produced in all the regions, this being one of the main sources of interregional trade. This extended model was then employed to consider a potential change involving an exogenous reduction (50%) in "Pulp", "Paper and Cardboard", and "Articles of Paper and Cardboard" exports (scenario 1). Table 6 summarizes the macroeconomic impacts (at the national and regional levels) in the Portuguese economy resulting from this shock.

In direct terms, the expected impact of this shock on the Portuguese economy should be significant, as these products are relevant for total Portuguese exports. Indeed, we estimate a reduction of more than 0.5% in GDP and 0.3% in total employment. Yet, abandonment of these traditional products may favor, through a new resource allocation, an increase in other product exports. Scenario 2 extends Scenario 1 by adding a proportional increase in all other Portuguese exports. This way, while total Portuguese exports remain constant, the change of this mix may have an impact on the economy.

Finally, using Scenario 3, we admit that the abandonment of this specific production, which is an intensive hardwood consumer will, in the mid-term, contribute to reduce the area planted with eucalyptus. Hypothetically, other autochthonous species, such as oaks and chestnuts, could be added to the national forest that are better adapted to the climate, and more resistant to fire. Further, it is assumed that the contribution of this emerging forest to GDP is either by investment in "Forest Standings" or through the estimation and imputation of their annual growth to GDP, as changes in inventories, via the "Living Forest Trees" product, without examining the long-term impact. The value of the additional output attributed to those products is equal to the estimated reduction in hardwood output. As this compensation accrues to the reallocation of resources for exports in scenario 2, scenario 3 implies an increase in final demand: more investment, including changes in inventories, and stabilization of the overall value of national exports.

As illustrated in Table 6, in scenarios 2 and 3, the negative impact on the Portuguese economic activity is significantly reduced and, in some cases, non-existent. When the reallocation of resources is made only at the export level, a decline in GDP (-0.02%) is still estimated, albeit close to a neutral effect, while there is already a positive impact on employment (+ 0.20%). The reduction in GDP persists even though exports are constant due to the estimated growth in imports (+0.21%). This is because exports, largely based on endogenous resources, as the ones associated with the *forestry products value chain*, are replaced by other exported products that have higher imports content. At the regional level, however, there is a shift in economic activity from the Centro Region, especially from the Coastal Centro, where the Pulp and Paper industries are concentrated, but also from the Interior Centro (an important eucalyptus provider) to the Rest of the Country, where many of the other exports are produced. The changes in regional GDP are -0.84%, -0.31%, and +0.13%, respectively.

The mild impact of the change in Portugal's specialization profile is even more evident when investment in the planting of new species is also admitted. A positive change in GDP (3.9 million €) is now estimated, although this is due to an effect on taxes on products, less subsidies, since GVA continues to decrease (- 7 million €). The Interior Centro is the region where the planting of new forests contributes more to mitigate the GDP decline. This method allows us to estimate that a shock in traditional forest chain products may not have a severe contractionary effect on the Portuguese economy, provided there is a proper reallocation of the resources.

TABLE 6.
Macroeconomic impact of distinct scenarios by region (10^6 €)

		Coastal Centro		Interior Centro		Rest of the Country		Portugal -Total	
Scenario 1: 50% reduction in Exports, alone	GDP	-308,3	*-1,4%*	-67,9	*-0,7%*	-487,0	*-0,4%*	-863,2	*-0,5%*
	Gross Value Added	-288,6	*-1,4%*	-60,2	*-0,8%*	-449,5	*-0,4%*	-798,3	*-0,5%*
	Households' Income	-111,6	*-0,8%*	-25,7	*-0,5%*	-233,5	*-0,3%*	-370,8	*-0,4%*
	Employment (FTE)	-4,6	*-0,7%*	-1,25	*-0,4%*	-9,2	*-0,3%*	-15,05	*-0,3%*
	International Imports	-116,7	*-1,7%*	-23,6	*-1,0%*	-213,7	*-0,5%*	-354,0	*-0,7%*
Scenario 2: Resources reallocated to the production of other Exports	GDP	-187,9	*-0,8%*	-28,1	*-0,3%*	178,7	*0,1%*	-37,4	*-0,0%*
	Gross Value Added	-178,7	*-0,9%*	-26,8	*-0,4%*	159,9	*0,1%*	-45,6	*-0,0%*
	Households' Income	-41,3	*-0,3%*	-2,3	*-0,0%*	157,9	*0,2%*	114,3	*0,1%*
	Employment (FTE)	-0,5	*-0,1%*	0,4	*0,1%*	9,6	*0,3%*	9,43	*0,2%*
	International Imports	-53,2	*-0,8%*	-2,8	*-0,1%*	164,4	*0,4%*	108,4	*0,2%*
Scenario 3: Resources reallocated, including planting of other species in the forest area abandoned by eucalyptus	GDP	-178,8	*-0,8%*	-21,3	*-0,2%*	204,0	*0,2%*	3,9	*0,0%*
	Gross Value Added	-170,0	*-0,8%*	-20,3	*-0,3%*	183,4	*0,2%*	-7,0	*-0,0%*
	Households' Income	-39,4	*-0,3%*	-1,4	*-0,0%*	171,0	*0,2%*	130,2	*0,1%*
	Employment (FTE)	-0,4	*-0,1%*	0,5	*0,2%*	10,1	*0,3%*	10,15	*0,2%*
	International Imports	-52,3	*-0,8%*	-2,3	*-0,1%*	168,0	*0,4%*	113,3	*0,2%*

6. CONCLUSIONS

Conventional approaches underestimate forests economic impact in regional and national economies. In a period where society strives to understand the consequences of anthropogenic activities, it is now evident that, beyond the direct effects of our actions, there are indirect consequences that matter and shape our world. Identifying and quantifying these effects is of upmost relevance.

This paper adds an extended way to account for forest contributions that goes beyond the residual direct share of the Silviculture industry in national GDP measurements, both mapping and explaining inter- and intraregional linkages. The rationale is simple yet often forgotten. As it is impossible to produce wine without grapes or cars without metal parts, it is also impossible to produce paper, cardboard, furniture, and many other products, without forests and their derivatives. This is also a (significant) part of forest value.

In this way, our methodology enhances forest studies, both at national and regional levels, as it measures an additional hidden economic relevance of forest activity – the *forestry product value chain* – that ultimately is responsible for more than 10% of Portuguese exports. In a period where society is pushed toward changes, this method has proved to be useful in understanding how regional and national economies are affected when changes happen. Also, this kind of "simulation" is a powerful tool to evaluate other impacts of sustainability-driven policies that induce demand shocks as, for example, the recycling and reuse of wood materials or biomass energy production (not focused on this paper). These are all goals that encompass policy measures that will necessarily imply changes in the way we collectively consume and produce goods and that we are still far from understanding its fully consequences. Yet we know, they will be far more extensive than the ones the simple direct GDP structure can capture. In our case study, the focus is on the reduction of paper use (or at least of Portuguese exports) and promotion of autochthonous species. The results at the national level show that the reallocation of resources tends to cancel the restrictive impact of the decline in the pulp and paper sector. But the full sectoral and spatial range of the economic consequences is differentiated. Actually, by highlighting inter-sectoral and inter-regional interdependencies, our methodological approach allows to enlighten that the differences in

the structural composition of regional economies generate differentiated effects by region, with almost balancing changes between losers (the Costal and Interior Centro Regions) and winners (the Rest of the Country).

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