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Title: DIRECT AND INDIRECT GENERATION OF WASTE IN THE SPANISH PAPER INDUSTRY

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DIRECT AND INDIRECT GENERATION OF WASTE IN THE SPANISH PAPER INDUSTRY

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Abstract

The paper industry has a relatively high degree of reliance on suppliers when compared to other industries. Exploring the role of the paper industry in terms of consumption of intermediate inputs from other industries may help to understand how the production of paper does not only generate waste by itself but also affects the amount of waste generated by other industries. The product Life Cycle Assessment (LCA) is a useful analytical tool to examine and assess environmental impacts over the entire life cycle of a product "from cradle to grave" but it is costly and time intensive. In contrast, Economic Input Output Life Cycle Assessment Models (IO-LCA) that combine LCA with Input-Output analysis (IO) are more accurate and less expensive, as they employ publicly available data. This paper represents one of the first Spanish studies aimed at estimating the waste generated in the production of paper by applying IO-LCA. One of the major benefits is the derivation of the contribution of direct and indirect suppliers to the paper industry. The results obtained show that there was no direct relationship between the impact on output and the impact on waste generation exerted by the paper industry. The major contributors to waste generation were the mining industry and the forestry industry.

Keywords

Paper industry

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1. Introduction

Spain is the sixth leading paper producing industry in Europe. In 2010 its total output was 7.4 million tonnes, with a monetary value of 3.4 billion euro (CEPI, 2012). The output of this industry does not only satisfy the final demand from individual consumers (households, public sector, etc.) but it is also distributed among the industries of the economy (intermediate demand). From an economic perspective the final demand shows the consumption patterns of an economy (consumption, investment, government expenditures and exports) while the intermediate demand consists of the purchases from other industries. The intermediate demand reflects the fact that all industries are interdependent: each industry employs the output of other industries as inputs (or intermediate consumptions) in its production process while other industries are users of its output in their production processes.

According to the Spanish National Statistics Institute (INE, 2009a) the intermediate demand for the paper industry in Spain was superior to 11 billion euro while the final demand was less than 3 billion euro. This reveals that most of the demand for the paper industry comes from other industries that employ its products as inputs.

Table 1 shows the production structure of the Spanish paper industry and the average for the total of Spanish industries in 2005. The first three rows show the amount of total, domestic and imported intermediate consumptions, that is, the amount outputs from other industries employed as intermediate inputs by the paper industry, distinguishing between those produced domestically and those imported.

Insert Table 1 about here

The proportion of intermediate consumptions in total output considerably exceeds the national average (72% in comparison to 54%) thereby confirming that one the main characteristics of the Spanish paper industry is its high share of intermediate inputs (Del Río González, 2005). In addition, the paper industry relies more intensively of imported intermediate consumptions than the average (35% of the intermediate consumptions were imported in comparison with a national average less than 19%). The comparison of the importance of imports and exports in total supply reveals that the paper industry is more opened than the average (the shares of exports and imports in total supply more than twice exceed the national average).

As noted before, the production of paper requires intermediate inputs from a wide range of industries. Any change in the demand for the paper industry will exert an impact on other industries directly and indirectly. Thus, when the output of the paper industry increases, the use of direct inputs from other industries grows, which in turn increase their output. The increase in the output of these industries will expand their needs of inputs from other industries and so forth, resulting in a multiplier effect in the output of all industries.

But is the environmental impact associated with this multiplier desirable? It is clear that a higher use of intermediate inputs will imply increases in output to satisfy a growing intermediate demand, but the volume of waste generated throughout the production processes will grow (Berglund et al., 2002). We have to note, however, that the Spanish paper industry is the second larger paper recycling industry in Europe, second only to Germany (ASPAPEL, 2009; CEPI, 2012). Process models, such as the product Life Cycle Assessment (LCA), have been employed to analyse this issue (for a systematic review of existing LCAs on paper and cardboard waste see Villanueva and Henzel, 2007). But these models are expensive, require much time and introduce many uncertainties. An alternative are Economic Input Output Life Cycle Assessment Models (IO-LCA) that combine LCA with Input-Output analysis (IO), as they are more accurate and less expensive (Nakamura and Kondo, 2002). In this study we apply an IO-LCA model to estimate the amount of waste directly and indirectly generated by the suppliers of the Spanish paper industry in 2005.

2. Methodology

The product Life Cycle Assessment (LCA) is a useful analytical tool to examine and assess environmental impacts over the entire life cycle of a product "from cradle to grave". It involves tracing the main stages over the life cycle of a product, including raw materials extraction, manufacturing, product use, recycling and final disposal (Joshi, 2000). It requires a rigorous examination of the energy consumption and of the materials used, co-products, by-products, etc., as well as an analysis of the environmental burdens associated with each stage in the life cycle of the product. Several methodological frameworks have been introduced to implement LCA, such as those by the *Society of Environmental Toxicology and Chemistry* (SETAC), the *U.S. Environmental Protection Agency* (EPA) or the *International Organization for Standardization* (ISO).

One of the major advantages of these models is their simplicity. They consider the entire life cycle of the products, examine in detail each stage and identify weaknesses, threats, strengths and opportunities which allows for both environmental improvements and economic benefits (Huijbregts et al., 2008; Karmperis et al., 2013). But, in spite of being a powerful tool, the LCA models have some disadvantages like problems of truncation (Hawkins, 2007), problems of comparability caused by the use of different simplifying assumptions by different analysts (Karmperis et al., 2013) or the fact that "require a large investment of time and resources due to the volume of data required, as they are not readily available and might even be confidential" (De la Rúa Lope, 2009). Moreover, it can be argued that LCA has traditionally not been subjected to public involvement (Morrissey and Browne, 2004).

Based on the environmental input-output analysis (IO) developed by Leontief in the 70s (Leontief, 1970), hybrid models combining process analysis with input-output analysis have been developed. During the 1990s, the Carnegie Mellon University introduced a new methodology presented as a complementary analysis to process models (www.eiolca.net). This methodology combines the product life cycle analysis with the input-output analysis (IO-LCA) to trace the supply chain impacts of the production processes both in monetary terms and in environmental terms. Since then the IO-LCA model has been broadly used (Costello et al., 2011; Hawkins, 2007; Hawkins et al., 2007; Hendrickson et al, 1998; Hendrickson et al, 2006; Joshi, 2000; Suh, 2004; Suh et al., 2004).

Among its advantages, we have to note that this model requires less detailed data than process models, that is, it is less time intensive and costly. Additionally, the data required are published by government agencies, ensuring data transparency and reliability. This avoids problems of replication that appear when confidential data are used. Moreover, IO-LCA does not require a subjective setting of system boundaries (AENOR, 2006a and AENOR, 2006b). In addition, the IO-LCA takes into account all inter-industry relations, providing a real view of the production system of a good or service (Hendrickson, et al., 2006). However, there are also disadvantages. For instance, product assessment contains aggregate data which makes process assessment difficult and the environmental burdens associated with product use and end-of-life options are not included (Joshi, 2000). Other disadvantages are related to the hypotheses employed in IO analysis (Miller, 2009). Firstly, the technology and the economic structure used to produce imported goods and services are assumed to be the same as those to produce domestic goods and services, which are not true in open economies (Peters and Hertwich, 2006; Suh, 2004). Secondly, monetary values have to be transformed into physical units (Hendrickson et al., 2006; Hoekstra and van den Bergh, 2006; Nakamura et al., 2007).

Table 2 provides a summary of the main advantages and disadvantages of LCA and IO-LCA models.

Insert Table 2 about here

2.1. The Economic Input-Output Life Cycle Assessment Model (IO-LCA).

Input-output analysis is widely recognized in economic analysis as a useful framework where the interdependencies across different industries of the economy are represented by a set of linear equations.

Figure 1 shows the structure of an input-output table. Each element x_{ij} represents the intermediate inputs required from industry i to produce output of industry j. In the input-output table the columns sum of x_{ij} represents the total amount of intermediate inputs from other industries employed in the production process. Value added (V_j) is the difference between total output and intermediate inputs. The total output of each industry (X_i) can also be obtained as the rows sum of the intermediate inputs sold to other industries (or intermediate demand) and the final demand (y_i). The gross domestic product (GDP) is the sum of all final demands.

Insert Figure 1 about here

As can be seen, a given industry *n* requires intermediate inputs from other industries to produce. We can distinguish between those who supply directly the industry, called direct suppliers, and those that do not directly supply the industry but are suppliers to the suppliers of industry *n*, referred to as indirect suppliers of first level, second level, and so on. Thus, the group of suppliers that serve an industry creates a sequence of suppliers called *supply chain*. The production of a particular good or service will generate a multiplier effect that will not only affect that industry's direct suppliers, but also involve the indirect suppliers. Depending on the complexity of the good or service concerned, the multiplier effect will affect more or less economic industries. For example, vehicle manufacturing requires so many suppliers that directly or indirectly it may affect the entire economy (Hendrickson et al. 2006).

In an economy with *n* industries, we can define the technical coefficients matrix (*A*). *A* is a square *n x n* matrix that represents the intermediate inputs that each industry requires from the others to produce. An element a_{ij} of matrix *A* is obtained by dividing element x_{ij} of the input-output table by the total output X_j and shows the value of intermediate inputs required from industry *i* to produce one unit output of industry *j*. Above, we defined total output of industry *i* (X_i) as the sum of the intermediate demand and the final demand. Therefore, in an economy with *n* industries, the total output of industry *i* can be obtained as follows:

$$x_{i1} + x_{i2} + \ldots + x_{in} + y_i = X_i \tag{1}$$

As technical coefficients are obtained by dividing intermediate inputs by total output, equation (1) can be written as follows:

$$a_{ij} = x_{ij} / X_j \Rightarrow x_{ij} = a_{ij} X_j \qquad (2)$$

$$a_{i1} X_j + a_{i2} X_j + \ldots + a_{in} X_j + y_i = X_i \qquad (3)$$

and in matrix form:

$$AX + y = X \qquad (4)$$

where A is the technical coefficients matrix, X is an output column vector and y is the desired final demand. From equation (4) we can obtain vector X and express it as follows:

$$X = (I + A + A \cdot A + A \cdot A \cdot A + \ldots)y \qquad (5)$$

In equation (5) Iy represents the requirements associated to the desired final demand; $(I+A)y$ shows the contribution of the first-level or direct suppliers; $(I+A+A^2)y$ represents the contribution of second-level suppliers and so on. Equation (5) can be rewritten as follows:

$$X = (I - A)^{-1} y \qquad (6)$$

In equation (6), X takes into account all supplier levels, I is the $n \times n$ identity matrix, A is the technical coefficients matrix and y is the desired demand. Matrix $(I-A)^{-1}$ is a square $n \times n$ matrix called the Leontief inverse matrix. Each element of this matrix represents the direct and indirect intermediate inputs requirements per unit of final demand. Equation (6) is the base for the demand model and shows how requirements of intermediate inputs change to satisfy a given final demand. In other words, equation (6) represents the multiplier effect that the production of a good or a service has on the total economy as it takes into account all the elements of the supply chain.

Using these equivalences the output required from the direct suppliers to produce a given good or service can be obtained as follows:

$$X = (I + A)y \qquad (7)$$

and the output from the indirect suppliers can be obtained as:

$$X = \left\lfloor \left\lceil (I - A)^{-1} - (I + A) \right\rceil \right\rfloor y \qquad (8)$$

Once the demand model has been developed and the equations for obtaining the multiplier effect has been specified, it is necessary to modify the model to estimate the waste generation. The original extended model (Hendrickson et al. 1998; Hendrickson et al. 2006) defines a vector of environmental output. In our study *b* will be waste generation vectors that capture how the multiplier effect of the paper industry affects the generation of waste its total suppliers (9), direct suppliers (equation 10) and indirect suppliers (equation 11):

$$b = RX = R(I - A)^{-1} y \qquad (9)$$

$$b = R(I + A)y \qquad (10)$$

$$b = R\left\lfloor \left\lceil (I - A)^{-1} - (I + A) \right\rceil \right\rfloor y \qquad (11)$$

where R is a square n x n matrix with diagonal elements that represents the waste generation at each stage per euro of output.

Figure 2 summarizes the relationships between the paper industry, its direct and indirect suppliers, and the generation of waste in our model.

Insert Figure 2 about here

3. Results and discussion.

In order to carry out our analysis, we only need data from public sources which guarantees transparency and allows verification of the results. In particular, we employ the Spanish symmetric input output table for 2005 published by the INE (INE, 2009a) and data on waste from the *Survey on Waste Generation in the Industrial Sector 2005* (INE, 2010), the *Survey on Waste Generation in the Service Sector 2005* (INE, 2009b), the *Survey on Waste Generation in the Agriculture 2003-2006* (INE, 2009c) and the *Survey on Waste Generation in Fisheries 2004-2006* (INE, 2009d).

The symmetric input-output table published by the INE covers 73 products that we aggregate into 30 industries, as it is not possible to establish a one-to-one correspondence between products and activities. The symmetric input-output table employs the National Product Classification 2002 (CNP-2002). Each type of good or service distinguished by the CPN-2002 is defined so that it is normally produced by only one industry as defined in the National Classification of Economic Activities 1993 (CNAE-93) which is based on the

General Industrial Classification of Economic Activities within the European Communities (NACE rev. 2). The final group of industries analysed is reported in Table 3.

Insert Table 3 about here

In our analysis we employ the domestic technical coefficients matrix that shows intermediate inputs to domestic output. As was mentioned before, input-output models hypothesize that the technology and the economic structure used to produce imported goods and services are the same as those to produce domestic goods and services, which is not true in open economies. By using the domestic matrix we try to avoid potential biases in the results.

In the Appendix, Table A1 reports the Spanish domestic technical coefficients in 2005. Each element represents the value in euro of inputs produced in the domestic economy required from industry i to produce one unit output of industry j.

We also define the column vector y that represents the goods and services employed by the Spanish paper industry in 2005 to produce 11 billion euro.

Firstly, to apply our model, we need to compute the Leontief inverse matrix, reported in Table A2 of the Appendix. As can be noticed, the number of elements different from zero is very high in comparison with the technical coefficients matrix. This indicates that there are a high number of industries with a direct or indirect participation in the supply chain of the paper industry.

Secondly, equations 6, 7 and 8 are employed to compute the multiplier effect on the output of total (direct and indirect) suppliers. Table 4 reports the results.

Insert Table 4 about here

The output of the Spanish paper industry in 2005 was 11,188.3 million euro and had an impact on the total output of the economy of 8,681.6 million euro. From this total, 7,165.2 million euro corresponded to direct suppliers and 1,516.4 to indirect ones. As can be noticed, the interactions between suppliers give place to a multiplier effect, stronger for the direct suppliers and weaker for the indirect suppliers. Although the impact that the paper industry has on each indirect supplier may be small individually, taken as a whole they can be significant, because the number of industries implied is likely to be high. For example, the impact on other business activities (industry 25) was 965.8 million euro. Of this impact, 828 million euro corresponded to direct suppliers and 137.8 to indirect suppliers. A similar impact was shown by manufactures (industry 5): 964.1 million euro.

Once the multiplier effect on the suppliers of the paper industry is calculated, we estimate the amount of waste generated in 2005. We compute matrix R that represents the waste generated at each stage per euro of output.

The four surveys on waste generation employed covered more than 30 different types of waste. For a more comprehensive view of the waste generated, vectors b were computed for each type of waste by applying equations 9, 10 and 11, and the results obtained were aggregated to obtain the total amount of waste generated by each industry.

Figure 3 shows a first overview of the waste generated broken down by industries.

Insert Figure 3 about here

As can be noticed there is a high a concentration in waste generation. Two industries were the major generators of waste: mining of coal, lignite; extraction of pet (industry 4) and forestry logging and related services activities (industry 2). Together, they accounted for more than 50% of the total waste generated. The contribution of the industry of production and distribution of electricity (industry 13) also deserves attention.

More detailed data on waste generated by direct and indirect suppliers are provided in Table 5.

Insert Table 5 about here

The waste generated by the suppliers of the paper industry in 2005 amounted to 885 million tonnes. As was expected, most of waste was generated by direct suppliers (753 million tonnes, that is, 85%).

Broadly speaking, the economic sector that mainly contributed to waste generation was the primary sector (494 thousand tonnes, of which 407 were generated by direct suppliers), followed by the manufacturing sector (582 thousand tonnes). In contrast, the service sector generated 45 thousand tonnes, of which 44 arose from direct suppliers and only 8 from indirect suppliers.

It can be highlighted that the main contribution to waste generation from direct suppliers came from forestry, logging and related services activities (industry 2), with 219 thousand tonnes, followed by mining (industry 4), with 175.86 thousand tonnes. The industry of production and distribution of electricity (industry 13) ranked third.

Regarding the waste generated by indirect suppliers, we have to note, in addition to the contribution of the mining industry (industry 2), the waste generated by agriculture, livestock and hunting (industry 1) which ranked second.

4. Conclusions

This paper proposed a model that combined the LCA methodology with IO analysis to assess the waste generated by the direct and indirect suppliers of the Spanish paper industry in 2005.

It showed that the multiplier effect exerted by the paper industry does not only affect its direct suppliers but almost all domestic industries. As can be seen in the Leontief inverse matrix, almost all industries showed values different from zero, thereby confirming that the supply chain was fairly extensive. Given this extensive network of inter-industry linkages, it is interesting to examine not only the direct and indirect impact on production but also environmental impacts like waste generation.

Results show that the primary and manufacturing sectors were the major contributors to waste generation while, in comparison with these two sectors, the contribution of the service sector was fairly low.

A great degree of concentration was observed: only two industries: mining of coal, lignite; extraction of pet and forestry, logging and related services activities accounted for more than 50% of the total waste generated by the suppliers of the paper industry.

Moreover, there was no direct relationship between the impact on output and the impact on waste generation. Thus, two out of the three suppliers industries with a highest impact on output were service industries (other business activities and wholesale and commission trade).

This study presents some limitations like the assumptions on linearity of the production function or the existence of constant technical coefficients imposed in IO analysis. Moreover, it focuses on the amount of waste generated but it does not distinguish among waste types. It would be necessary to analyse, not only which industries generate more waste, but also which industries generate more hazardous waste, in order to more accurately assess the environmental impact associated with the multiplier effect exerted by the paper industry (Liang et al., 2011). In this vein, it would be interesting to widen the analysis and studying waste types containing paper (Villanueva and Eder, 2011). Thus, the main advantages of the model: it is easy to apply and based on data regularly published by public sources make it suitable for further analyses of the environmental impacts of the paper industry.

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Insert Table 1 about here

Comment [B1]: The terms "intermediate" and "final" were defined

Comment [B2]: The reference for the data was introduced

Comment [B3]: The sentence "increased demands come from other sectors" was rephrased

Comment [B4]: The sentence was rephrased to specify that the average refers to the total of the Spanish industries

The proportion of intermediate consumptions in total output considerably exceeds the national average (72% in comparison to 54%) thereby confirming that one the main characteristics of the Spanish paper industry is its high share of intermediate inputs (Del Río González, 2005). In addition, the paper industry relies more intensively of imported intermediate consumptions than the average (35% of the intermediate consumptions were imported in comparison with a national average less than 19%). The comparison of the importance of imports and exports in total supply reveals that the paper industry is more opened than the average (the shares of exports and imports in total supply more than twice exceed the national average).

As noted before, the production of paper requires intermediate inputs from a wide range of industries. Any change in the demand for the paper industry will exert an impact on other industries directly and indirectly. Thus, when the output of the paper industry increases, the use of direct inputs from other industries grows, which in turn increase their output. The increase in the output of these industries will expand their needs of inputs from other industries and so forth, resulting in a multiplier effect in the output of all industries.

Comment [B5]: The sentence refers to the output of other industries used as intermediate inputs

But is the environmental impact associated with this multiplier desirable? It is clear that a higher use of intermediate inputs will imply increases in output to satisfy a growing intermediate demand, but the volume of waste generated throughout the production processes will grow (Berglund et al., 2002). We have to note, however, that the Spanish paper industry is the second larger paper recycling industry in Europe, second only to Germany (ASPAPEL, 2009; CEPI, 2012). Process models, such as the product Life Cycle Assessment (LCA), have been employed to analyse this issue (for a systematic review of existing LCAs on paper and cardboard waste see Villanueva and Henzel, 2007). But these models are expensive, require much time and introduce many uncertainties. An alternative are Economic Input Output Life Cycle Assessment Models (IO-LCA) that combine LCA with Input-Output analysis (IO), as they are more accurate and less expensive (Nakamura and Kondo, 2002). In this study we apply an IO-LCA model to estimate the amount of waste directly and indirectly generated by the suppliers of the Spanish paper industry in 2005.

2. Methodology

The product Life Cycle Assessment (LCA) is a useful analytical tool to examine and assess environmental impacts over the entire life cycle of a product "from cradle to grave". It involves tracing the main stages over the life cycle of a product, including raw materials extraction, manufacturing, product use, recycling and final disposal (Joshi, 2000). It requires a rigorous examination of the energy consumption and of the materials used, co-products, by-products, etc., as well as an analysis of the environmental burdens associated with each stage in the life cycle of the product. Several methodological frameworks have been introduced to implement LCA, such as those by the *Society of Environmental Toxicology and Chemistry* (SETAC), the *U.S. Environmental Protection Agency* (EPA) or the *International Organization for Standardization* (ISO).

One of the major advantages of these models is their simplicity. They consider the entire life cycle of the products, examine in detail each stage and identify weaknesses, threats, strengths and opportunities which allows for both environmental improvements and economic benefits (Huijbregts et al., 2008; Karmperis et al., 2013). But, in spite of being a powerful tool, the LCA models have some disadvantages like problems of truncation (Hawkins, 2007), problems of comparability caused by the use of different simplifying assumptions by different analysts (Karmperis et al., 2013) or the fact that "require a large investment of time and resources due to the volume of data required, as they are not readily available and might even be confidential" (De la Rúa Lope, 2009). Moreover, it can be argued that LCA has traditionally not been subjected to public involvement (Morrissey and Browne, 2004).

Comment [B6]: Table 2 has been modified and the contributions from Karmperis et al. (2013) and Morrissey and Browne (2004) are included in the table and cited in the main text.

Based on the environmental input-output analysis (IO) developed by Leontief in the 70s (Leontief, 1970), hybrid models combining process analysis with input-output analysis have been developed. During the 1990s, the Carnegie Mellon University introduced a new methodology presented as a complementary analysis to process models (www.eiolca.net). This methodology combines the product life cycle analysis with the input-output analysis (IO-LCA) to trace the supply chain impacts of the production processes both in monetary terms and in environmental terms. Since then the IO-LCA model has been broadly used (Costello et al., 2011; Hawkins, 2007; Hawkins et al., 2007; Hendrickson et al, 1998; Hendrickson et al, 2006; Joshi, 2000; Suh, 2004; Suh et al., 2004).

Among its advantages, we have to note that this model requires less detailed data than process models, that is, it is less time intensive and costly. Additionally, the data required are published by government agencies, ensuring data transparency and reliability. This avoids problems of replication that appear when confidential data are used. Moreover, IO-LCA does not require a subjective setting of system boundaries (AENOR, 2006a and AENOR, 2006b). In addition, the IO-LCA takes into account all inter-industry relations, providing a real view of the production system of a good or service (Hendrickson, et al., 2006). However, there are also disadvantages. For instance, product assessment contains aggregate data which makes process assessment difficult and the environmental burdens associated with product use and end-of-life options are not included (Joshi, 2000). Other disadvantages are related to the hypotheses employed in IO analysis (Miller, 2009). Firstly, the technology and the economic structure used to produce imported goods and services are assumed to be the same as those to produce domestic goods and services, which are not true in open economies (Peters and Hertwich, 2006; Suh, 2004). Secondly, monetary values have to be transformed into physical units (Hendrickson et al., 2006; Hoekstra and van den Bergh, 2006; Nakamura et al., 2007).

Table 2 provides a summary of the main advantages and disadvantages of LCA and IO-LCA models.

Insert Table 2 about here

2.1. The Economic Input-Output Life Cycle Assessment Model (IO-LCA).

Input-output analysis is widely recognized in economic analysis as a useful framework where the interdependencies across different industries of the economy are represented by a set of linear equations.

Figure 1 shows the structure of an input-output table. Each element x_{ij} represents the intermediate inputs required from industry i to produce output of industry j. In the input-output table the columns sum of x_{ij} represents the total amount of intermediate inputs from other industries employed in the production process. Value added (V_j) is the difference between total output and intermediate inputs. The total output of each industry (X_i) can also be obtained as the rows sum of the intermediate inputs sold to other industries (or intermediate demand) and the final demand (y_i). The gross domestic product (GDP) is the sum of all final demands.

Insert Figure 1 about here

Comment [B7]: Table 3 was replaced by Figure 1 and the explanation of the structure of an input-output table was based on it.

Comment [B8]: A diagram summarizing the basic structure of an input-output table replaced “old” Table 3, more difficult to understand.

As can be seen, a given industry *n* requires intermediate inputs from other industries to produce. We can distinguish between those who supply directly the industry, called direct suppliers, and those that do not directly supply the industry but are suppliers to the suppliers of industry *n*, referred to as indirect suppliers of first level, second level, and so on. Thus, the group of suppliers that serve an industry creates a sequence of suppliers called *supply chain*. The production of a particular good or service will generate a multiplier effect that will not only affect that industry's direct suppliers, but also involve the indirect suppliers. Depending on the complexity of the good or service concerned, the multiplier effect will affect more or less economic industries. For example, vehicle manufacturing requires so many suppliers that directly or indirectly it may affect the entire economy (Hendrickson et al. 2006).

In an economy with *n* industries, we can define the technical coefficients matrix (*A*). *A* is a square *n x n* matrix that represents the intermediate inputs that each industry requires from the others to produce. An element a_{ij} of matrix *A* is obtained by dividing element x_{ij} of the input-output table by the total output X_j and shows the value of intermediate inputs required from industry *i* to produce one unit output of industry *j*. Above, we defined total output of industry *i* (X_i) as the sum of the intermediate demand and the final demand. Therefore, in an economy with *n* industries, the total output of industry *i* can be obtained as follows:

$$x_{i1} + x_{i2} + \ldots + x_{in} + y_i = X_i \qquad (1)$$

As technical coefficients are obtained by dividing intermediate inputs by total output, equation (1) can be written as follows:

$$a_{ij} = x_{ij} / X_j \Rightarrow x_{ij} = a_{ij} X_j \quad (2)$$

$$a_{i1} X_j + a_{i2} X_j + \ldots + a_{in} X_j + y_i = X_i \quad (3)$$

and in matrix form:

$$AX + y = X \quad (4)$$

where A is the technical coefficients matrix, X is an output column vector and y is the desired final demand. From equation (4) we can obtain vector X and express it as follows:

$$X = (I + A + A \cdot A + A \cdot A \cdot A + \ldots) y \quad (5)$$

In equation (5) Iy represents the requirements associated to the desired final demand; $(I+A)y$ shows the contribution of the first-level or direct suppliers; $(I+A+A^2)y$ represents the contribution of second-level suppliers and so on. Equation (5) can be rewritten as follows:

$$X = (I - A)^{-1} y \quad (6)$$

In equation (6), X takes into account all supplier levels, I is the $n \times n$ identity matrix, A is the technical coefficients matrix and y is the desired demand. Matrix $(I-A)^{-1}$ is a square $n \times n$ matrix called the Leontief inverse matrix. Each element of this matrix represents the direct and indirect intermediate inputs requirements per unit of final demand. Equation (6) is the base for the demand model and shows how requirements of intermediate inputs change to satisfy a given final demand. In other words, equation (6) represents the multiplier effect that the production of a good or a service has on the total economy as it takes into account all the elements of the supply chain.

Using these equivalences the output required from the direct suppliers to produce a given good or service can be obtained as follows:

$$X = (I + A)y \tag{7}$$

and the output from the indirect suppliers can be obtained as:

$$X = \left[(I - A)^{-1} - (I + A)\right]y \tag{8}$$

Once the demand model has been developed and the equations for obtaining the multiplier effect has been specified, it is necessary to modify the model to estimate the waste generation. The original extended model (Hendrickson et al. 1998; Hendrickson et al. 2006) defines a vector of environmental output. In our study *b* will be waste generation vectors that capture how the multiplier effect of the paper industry affects the generation of waste its total suppliers (9), direct suppliers (equation 10) and indirect suppliers (equation 11):

$$b = RX = R(I - A)^{-1}y \tag{9}$$

$$b = R(I + A)y \tag{10}$$

$$b = R\left[(I - A)^{-1} - (I + A)\right]y \tag{11}$$

where *R* is a square *n x n* matrix with diagonal elements that represents the waste generation at each stage per euro of output.

Figure 2 summarizes the relationships between the paper industry, its direct and indirect suppliers, and the generation of waste in our model.

Insert Figure 2 about here

Comment [B9]: A diagram showing the relationships between direct suppliers, indirect suppliers and waste generation was incorporated.

3. Results and discussion.

In order to carry out our analysis, we only need data from public sources which guarantees transparency and allows verification of the results. In particular, we employ the Spanish symmetric input output table for 2005 published by the INE (INE, 2009a) and data on waste from the *Survey on Waste Generation in the Industrial Sector 2005* (INE, 2010), the *Survey on Waste Generation in the Service Sector 2005* (INE, 2009b), the *Survey on Waste Generation in the Agriculture 2003-2006* (INE, 2009c) and the *Survey on Waste Generation in Fisheries 2004-2006* (INE, 2009d).

The symmetric input-output table published by the INE covers 73 products that we aggregate into 30 industries, as it is not possible to establish a one-to-one correspondence between products and activities. The symmetric input-output table employs the National Product Classification 2002 (CNP-2002). Each type of good or service distinguished by the CPN-2002 is defined so that it is normally produced by only one industry as defined in the National Classification of Economic Activities 1993 (CNAE-93) which is based on the

General Industrial Classification of Economic Activities within the European Communities (NACE rev. 2). The final group of industries analysed is reported in Table 3.

Comment [B10]: Abbrevation "A" was removed

Comment [B11]: Tables A1 and A2 were merged in one sole table (Table 3) easier to interpret.

Insert Table 3 about here

In our analysis we employ the domestic technical coefficients matrix that shows intermediate inputs to domestic output. As was mentioned before, input-output models hypothesize that the technology and the economic structure used to produce imported goods and services are the same as those to produce domestic goods and services, which is not true in open economies. By using the domestic matrix we try to avoid potential biases in the results.

Comment [B12]: The domestic need refers to the demand from the national economy.

In the Appendix, Table A1 reports the Spanish domestic technical coefficients in 2005.

Each element represents the value in euro of inputs produced in the domestic economy required from industry *i* to produce one unit output of industry *j*.

We also define the column vector *y* that represents the goods and services employed by the Spanish paper industry in 2005 to produce 11 billion euro.

Firstly, to apply our model, we need to compute the Leontief inverse matrix, reported in Table A2 of the Appendix. As can be noticed, the number of elements different from zero is very high in comparison with the technical coefficients matrix. This indicates that there are a high number of industries with a direct or indirect participation in the supply chain of the paper industry.

Secondly, equations 6, 7 and 8 are employed to compute the multiplier effect on the output of total (direct and indirect) suppliers. Table 4 reports the results.

Comment [B13]: Abbreviation "A" was removed

Insert Table 4 about here

The output of the Spanish paper industry in 2005 was 11,188.3 million euro and had an impact on the total output of the economy of 8,681.6 million euro. From this total, 7,165.2 million euro corresponded to direct suppliers and 1,516.4 to indirect ones. As can be noticed, the interactions between suppliers give place to a multiplier effect, stronger for the direct suppliers and weaker for the indirect suppliers. Although the impact that the paper industry has on each indirect supplier may be small individually, taken as a whole they can be significant, because the number of industries implied is likely to be high. For example, the impact on other business activities (industry 25) was 965.8 million euro. Of this impact, 828 million euro corresponded to direct suppliers and 137.8 to indirect suppliers. A similar impact was shown by manufactures (industry 5): 964.1 million euro.

Comment [B14]: Comments on this table have been introduced.

Once the multiplier effect on the suppliers of the paper industry is calculated, we estimate the amount of waste generated in 2005. We compute matrix R that represents the waste generated at each stage per euro of output.

The four surveys on waste generation employed covered more than 30 different types of waste. For a more comprehensive view of the waste generated, vectors b were computed for each type of waste by applying equations 9, 10 and 11, and the results obtained were aggregated to obtain the total amount of waste generated by each industry.

Figure 3 shows a first overview of the waste generated broken down by industries.

Insert Figure 3 about here

As can be noticed there is a high a concentration in waste generation. Two industries were the major generators of waste: mining of coal, lignite; extraction of pet (industry 4) and forestry logging and related services activities (industry 2). Together, they accounted for more than 50% of the total waste generated. The contribution of the industry of production and distribution of electricity (industry 13) also deserves attention.

More detailed data on waste generated by direct and indirect suppliers are provided in Table 5.

Comment [B15]: Abbrevation "A" was removed

Insert Table 5 about here

The waste generated by the suppliers of the paper industry in 2005 amounted to 885 million tonnes. As was expected, most of waste was generated by direct suppliers (753 million tonnes, that is, 85%).

Broadly speaking, the economic sector that mainly contributed to waste generation was the primary sector (494 thousand tonnes, of which 407 were generated by direct suppliers), followed by the manufacturing sector (582 thousand tonnes). In contrast, the service sector generated 45 thousand tonnes, of which 44 arose from direct suppliers and only 8 from indirect suppliers.

It can be highlighted that the main contribution to waste generation from direct suppliers came from forestry, logging and related services activities (industry 2), with 219 thousand tonnes, followed by mining (industry 4), with 175.86 thousand tonnes. The industry of production and distribution of electricity (industry 13) ranked third.

Regarding the waste generated by indirect suppliers, we have to note, in addition to the contribution of the mining industry (industry 2), the waste generated by agriculture, livestock and hunting (industry 1) which ranked second.

4. Conclusions

This paper proposed a model that combined the LCA methodology with IO analysis to assess the waste generated by the direct and indirect suppliers of the Spanish paper industry in 2005.

It showed that the multiplier effect exerted by the paper industry does not only affect its direct suppliers but almost all domestic industries. As can be seen in the Leontief inverse matrix, almost all industries showed values different from zero, thereby confirming that the supply chain was fairly extensive. Given this extensive network of inter-industry linkages, it is interesting to examine not only the direct and indirect impact on production but also environmental impacts like waste generation.

Results show that the primary and manufacturing sectors were the major contributors to waste generation while, in comparison with these two sectors, the contribution of the service sector was fairly low.

A great degree of concentration was observed: only two industries: mining of coal, lignite; extraction of pet and forestry, logging and related services activities accounted for more than 50% of the total waste generated by the suppliers of the paper industry.

Moreover, there was no direct relationship between the impact on output and the impact on waste generation. Thus, two out of the three suppliers industries with a highest impact on output were service industries (other business activities and wholesale and commission trade).

This study presents some limitations like the assumptions on linearity of the production function or the existence of constant technical coefficients imposed in IO analysis. Moreover, it focuses on the amount of waste generated but it does not distinguish among waste types. It would be necessary to analyse, not only which industries generate more waste, but also which industries generate more hazardous waste, in order to more accurately assess the environmental impact associated with the multiplier effect exerted by the paper industry (Liang et al., 2011). In this vein, it would be interesting to widen the analysis and studying waste types containing paper (Villanueva and Eder, 2011). Thus, the main advantages of the model: it is easy to apply and based on data regularly published by public sources make it suitable for further analyses of the environmental impacts of the paper industry.

Comment [B16]: The sentence was rephrased to highlight that the methodology applied in the paper can be improved and used for further analyses.

Acknowledgments

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Highlights

- The waste generated by the suppliers of the Spanish paper industry is estimated.
- An Economic Input Output Life Cycle Assessment Models (IO-LCA) is employed.
- No direct relationship between impact on output and on waste generation was found.
- The major contributors to waste generation were mining and forestry.

Figure

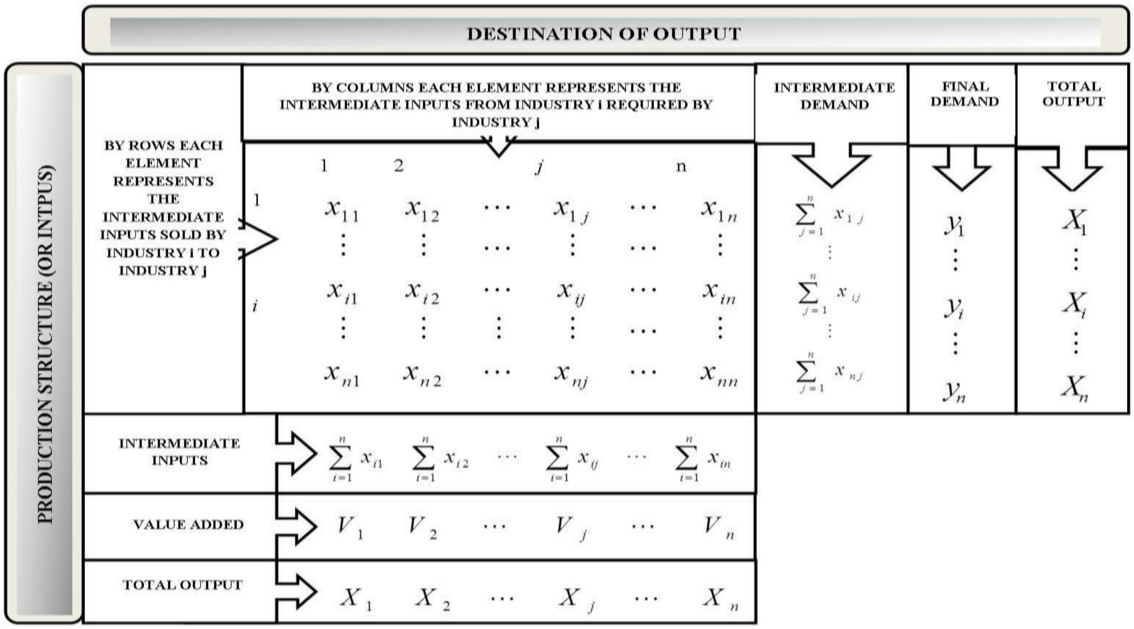

Fig 1. Basic structure of an economic input-output table

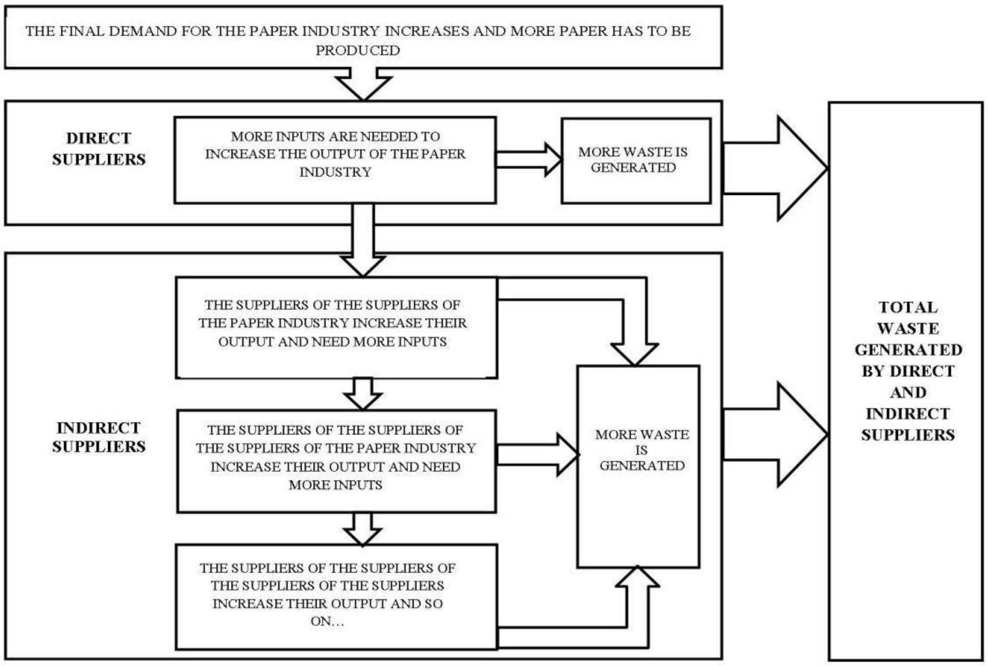

Fig 2. Direct and indirect suppliers and total waste generation

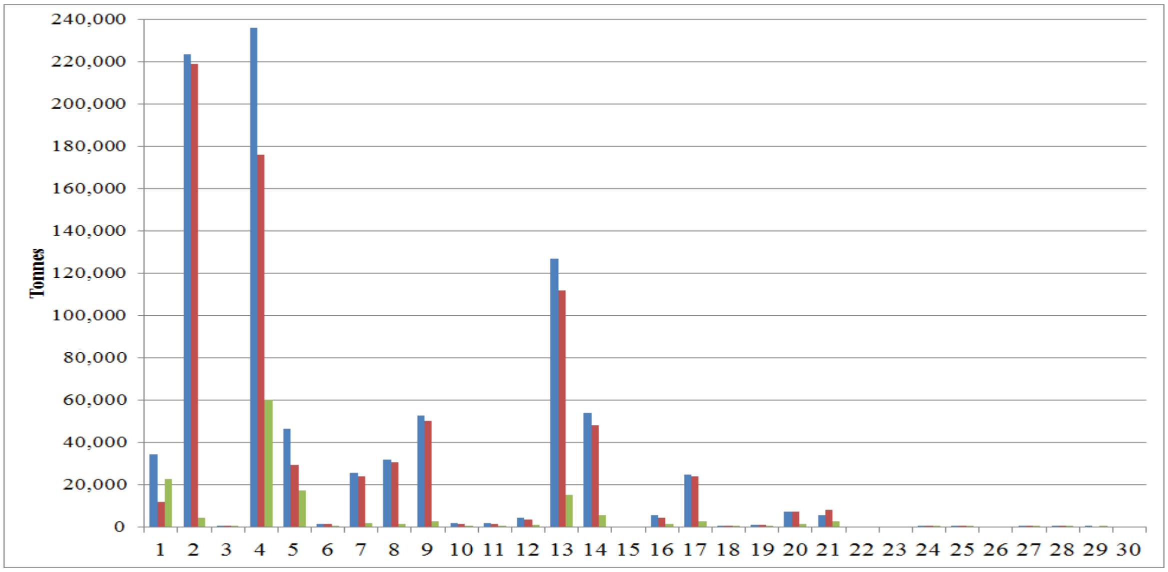

Fig 3. Waste generated, directly and indirectly, by the suppliers of the Spanish paper industry in 2005.

(1) The numbers 1, 2, 3, etc., represent each industry as detailed in Table 2. (2) Blue bars represent the waste generated by total suppliers, red bars waste generated by the direct suppliers and green bars the waste generated by indirect suppliers.

Table 1
Production structure of the Spanish paper industry, 2005 (millions of euro).

	Paper industry	National average
Intermediate consumption at purchaser's prices	8,081.3	955,261
Intermediate consumption from domestic production (basic prices)	5,177.1	760,404
Intermediate consumption from imports (basic prices)	2,855.1	177,313
Compensation of employees	1,850.5	430,832
Wages and salaries	1,427.0	334,418
Social contributions	423.5	96,414
Other net taxes on production	5.7	3,961
Operating surplus/mixed income, gross	1,250.8	378,983
Gross Value Added at basic prices	3,107.0	813,776
Output at basic prices	11,188.3	1,769,037
Imports (cif)	4,084.1	274,404
Imports intra European Union	3,577.2	172,347
Imports extra European Union	506.9	102,057
Exports (fob)	2,798.7	197,811
Exports intra European Union	2,181.9	140,890
Exports extra European Union	616.8	56,921
Total supply at basic prices	15,272.4	2,043,441

The basic price is the amount receivable by the producer from the purchaser for a unit of a good or service produced as output minus any tax payable, and plus any subsidy receivable, by the producer as a consequence of its production or sale. It excludes any transport charges invoiced separately by the producer. The purchaser's price is the amount paid by the purchaser, excluding any VAT or similar tax deductible by the purchaser, in order to take delivery of a unit of a good or service at the time and place required by the purchaser. The purchaser's price of goods includes any transport charges paid separately by the purchaser to take delivery at the required time and place.

Table 2

Advantages and disadvantages of LCA models and IO-LCA models.

	LCA	IO-LCA
Advantages	Results are detailed, process specific	Results are economy-wide
	Allows for specific product comparisons	Allows for system-level comparisons
	Identifies weaknesses, threats, strengths and opportunities	Uses publicly available data and results are reproducible
		Provides information on every industry in the economy
Disadvantages	Setting system boundaries is subjective	Product assessments contain aggregate data
	It tends to be time intensive and costly	Process assessments are difficult
	It is difficult to apply to new process design	Monetary values have to be transformed into physical units
	There are truncation problems	Imports are treated as products created within economic boundaries
	It cannot be replicated when confidential data are used	Environmental burdens associated with product use and end-of-life options are not included
	There are comparability problems	It is difficult to apply to an open economy (with substantial non-comparable imports)
	It has traditionally not been subjected to public involvement	

Modified from Hendrickson et al. (2006, p. 25).

Table 3
Classification of industries.

CNP-2002	CNAE-93	Number	Industry
1	A	1	Agriculture, livestock and hunting (except forestry, logging and related service activities)
2	A	2	Forestry, logging and related service activities
3	B	3	Fishing
4,5,6 y 7	C	4	Mining of coal and lignite; extraction of peat
8,12,13,14,15,16,18, 19,22,24,25,26,27, 28,29,30,32,33,34,35, 36, 37 y 38	D	5	Manufactures (except manufacture of textile, manufacture of wood and wood products, manufacture of pulp, paper and paper products, manufacture of chemicals and chemical products, manufacture of machinery and equipment n.e.c. and recycling)
17	D	6	Manufacture of textile
20	D	7	Manufacture of Wood and wood products
21	D	8	Manufacture of pulp, paper and paper products
23	D	9	Manufacture of chemicals and chemical products
31	D	10	Manufacture of machinery and equipment n.e.c.
39	D	11	Recycling
11	E	12	Collection, purification and distribution of water
9	E	13	Production and distribution of electricity
10	E	14	Manufacture of gas; distribution of gaseous fuels through mains; steam and hot water supply
40	F	15	Construction
41 y 43	G	16	Retail trade; repair of personal and household goods and Sale and retail of motor vehicles; retail sale of automotive fuel
42	G	17	Wholesale trade and commission trade
44 y 45	H	18	Hotel industry
46,48,49,50, 51 y 52	I	19	Transports except other land transport; transport via pipelines; and Support and auxiliary transport activities
47	I	20	Other land transport; transport via pipelines
50	I	21	Support and auxiliary transport activities
54 y 55	J	22	Insurance and pension funding, except compulsory social security and Auxiliary activities to financial intermediation
53	J	23	Financial intermediation
56, 57, 58 y 59	K	24	Real estate activities; Renting of machinery, personal and household goods; Computer and related activities; Research and development, except Other business activities
60	K	25	Other business activities
67	L	26	Public Administration
61 y 68	M	27	Education
62 y 69	N	28	Health and social work
63,64,65,66, 70,71 y 72	O	29	Other social work and services to the community
73	P	30	Private households with employed person

Table 4

Multiplier effect on the output of total, direct and indirect suppliers of the Spanish paper industry, 2005 (millions of euro).

Industry	Total suppliers	Direct suppliers	Indirect suppliers	Industry	Total suppliers	Direct suppliers	Indirect suppliers
1	69.7	24.0	45.8	16	165.9	126.3	39.6
2	455.2	446.5	8.6	17	669.5	599.7	69.8
3	1.1	0.3	0.9	18	43.7	30.0	13.8
4	45.9	34.2	11.7	19	281.2	202.6	78.7
5	964.1	606.4	357.7	20	641.5	548.3	93.1
6	139.1	124.8	14.4	21	434.1	326.2	107.9
7	458.6	424.5	34.1	22	75.5	50.3	25.1
8	529.0	508.6	20.4	23	187.7	143.7	44.0
9	642.4	613.2	29.2	24	334.1	237.1	97.1
10	124.6	101.4	23.2	25	965.8	828.0	137.8
11	149.5	139.4	10.2	26	0.0	0.0	0.0
12	23.0	17.7	5.3	27	26.5	21.5	5.1
13	660.5	582.4	78.1	28	16.9	10.2	6.7
14	279.6	250.3	29.3	29	0.1	0.0	0.1
15	296.9	168.0	129.0	30	0.0	0.0	0.0
				Total	8,681.6	7,165.2	1,516.4

Table 5.
Waste generated by total, direct and indirect suppliers of the Spanish paper industry, 2005 (thousands of tonnes).

Industry	Total suppliers	Direct suppliers	Indirect suppliers	Industry	Total suppliers	Direct suppliers	Indirect suppliers
1	34,210.0	11,754.4	22,455.6	16	5,507.2	4,368.2	1,369.9
2	223,341.9	219,099.0	4,243.0	17	24,792.7	23,896.4	2,780.8
3	14.2	3.3	10.9	18	324.9	319.2	146.6
4	236,165.9	175,861.5	60,304.3	19	1,047.3	1,104.8	429.0
5	46,494.8	29,244.3	17,250.5	20	7,235.6	6,963.1	1,182.7
6	1,393.3	1,249.2	144.1	21	5,660.9	7,871.9	2,603.2
7	25,701.0	23,791.4	1,909.7	22	-	-	-
8	31,911.8	30,681.5	1,230.3	23	-	-	-
9	52,462.7	50,077.9	2,384.8	24	107.9	82.0	33.6
10	1,659.8	1,350.4	309.3	25	312.0	286.5	47.7
11	1,654.9	1,542.5	112.4	26	-	-	-
12	4,418.6	3,392.1	1,026.5	27	50.4	44.0	10.4
13	126,796.1	111,797.6	14,998.5	28	93.3	61.3	40.3
14	53,665.1	48,038.9	5,626.2	29	0.1	0.0	0.1
15	-	-	-	30	-	-	-
				Total	885,022.5	752,881.7	140,650.3

Appendix

Table A1

Domestic requirements matrix (euros)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.054	0.000	0.001	0.000	0.052	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.049	0.037	0.001	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.003	0.006	0.006	0.000	0.000	0.001	0.009	0.000	0.000	0.000	0.020	0.009	0.005
5	0.191	0.011	0.112	0.097	0.206	0.012	0.028	0.020	0.067	0.246	0.557	0.084	0.083	0.003	0.155
6	0.000	0.000	0.022	0.000	0.008	0.166	0.001	0.009	0.001	0.000	0.001	0.000	0.000	0.000	0.000
7	0.002	0.000	0.007	0.013	0.007	0.001	0.181	0.031	0.001	0.001	0.006	0.000	0.000	0.000	0.010
8	0.001	0.000	0.000	0.001	0.010	0.006	0.010	0.040	0.008	0.002	0.170	0.000	0.000	0.000	0.000
9	0.022	0.001	0.004	0.045	0.014	0.022	0.019	0.050	0.021	0.005	0.006	0.083	0.000	0.000	0.003
10	0.008	0.003	0.000	0.030	0.009	0.011	0.011	0.006	0.015	0.042	0.011	0.101	0.005	0.000	0.009
11	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.012	0.000	0.000	0.014	0.000	0.000	0.000	0.000
12	0.008	0.000	0.003	0.004	0.001	0.002	0.001	0.001	0.002	0.000	0.001	0.001	0.002	0.000	0.000
13	0.012	0.000	0.002	0.062	0.016	0.016	0.021	0.040	0.018	0.013	0.007	0.020	0.155	0.004	0.002
14	0.000	0.000	0.004	0.008	0.004	0.007	0.001	0.017	0.009	0.001	0.000	0.001	0.099	0.000	0.000
15	0.005	0.002	0.000	0.013	0.004	0.005	0.002	0.008	0.004	0.003	0.016	0.021	0.014	0.002	0.358
16	0.013	0.013	0.006	0.012	0.010	0.008	0.006	0.006	0.009	0.004	0.023	0.047	0.004	0.001	0.012
17	0.046	0.006	0.030	0.026	0.027	0.042	0.070	0.043	0.016	0.032	0.025	0.005	0.019	0.000	0.022
18	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.006	0.001	0.002	0.000	0.002	0.000	0.001
19	0.002	0.001	0.013	0.017	0.008	0.022	0.009	0.009	0.022	0.008	0.002	0.027	0.029	0.003	0.006
20	0.003	0.002	0.002	0.028	0.030	0.036	0.036	0.038	0.026	0.015	0.001	0.000	0.005	0.001	0.006
21	0.004	0.000	0.073	0.047	0.013	0.012	0.005	0.016	0.015	0.007	0.011	0.000	0.001	0.000	0.001
22	0.003	0.008	0.020	0.003	0.001	0.003	0.002	0.002	0.002	0.002	0.000	0.003	0.002	0.001	0.002
23	0.008	0.008	0.007	0.007	0.008	0.012	0.006	0.008	0.007	0.009	0.005	0.007	0.013	0.007	0.006
24	0.000	0.003	0.007	0.028	0.015	0.018	0.010	0.010	0.022	0.020	0.013	0.012	0.024	0.006	0.019
25	0.001	0.008	0.003	0.050	0.043	0.038	0.026	0.056	0.055	0.041	0.008	0.104	0.045	0.012	0.014
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.001	0.001	0.002	0.001	0.002	0.003	0.002	0.001	0.004	0.001	0.001	0.003	0.002	0.001	0.000
28	0.007	0.003	0.003	0.001	0.001	0.003	0.002	0.000	0.002	0.000	0.000	0.001	0.001	0.000	0.000
29	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.002	0.005	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.007	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
5	0.066	0.014	0.189	0.061	0.100	0.047	0.014	0.008	0.012	0.104	0.030	0.023	0.036	0.074	0.000
6	0.000	0.002	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.002	0.001	0.000
7	0.000	0.001	0.003	0.000	0.000	0.007	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.003	0.000
8	0.000	0.001	0.001	0.003	0.000	0.001	0.004	0.003	0.001	0.007	0.005	0.003	0.001	0.002	0.000
9	0.003	0.001	0.008	0.002	0.000	0.005	0.000	0.000	0.001	0.006	0.002	0.000	0.024	0.008	0.000
10	0.003	0.002	0.004	0.008	0.002	0.005	0.000	0.000	0.001	0.001	0.008	0.001	0.001	0.005	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.003	0.002	0.002	0.001	0.007	0.001	0.000	0.000	0.000	0.001	0.002	0.002	0.001	0.005	0.000
13	0.030	0.021	0.005	0.020	0.002	0.013	0.006	0.005	0.005	0.011	0.020	0.009	0.006	0.010	0.000
14	0.003	0.003	0.001	0.001	0.003	0.000	0.000	0.000	0.000	0.001	0.003	0.002	0.001	0.001	0.000

15	0.012	0.012	0.012	0.016	0.003	0.038	0.010	0.011	0.087	0.014	0.009	0.013	0.008	0.020	0.000
16	0.032	0.007	0.011	0.004	0.059	0.006	0.004	0.000	0.006	0.005	0.006	0.003	0.015	0.011	0.000
17	0.007	0.030	0.034	0.008	0.020	0.006	0.002	0.000	0.002	0.013	0.018	0.006	0.020	0.016	0.000
18	0.002	0.003	0.001	0.029	0.001	0.002	0.009	0.005	0.001	0.010	0.006	0.005	0.007	0.009	0.000
19	0.015	0.018	0.013	0.132	0.007	0.017	0.026	0.018	0.015	0.050	0.032	0.009	0.010	0.019	0.000
20	0.012	0.053	0.001	0.004	0.011	0.154	0.002	0.000	0.002	0.003	0.007	0.001	0.002	0.004	0.000
21	0.009	0.040	0.000	0.013	0.170	0.165	0.001	0.000	0.002	0.005	0.001	0.000	0.000	0.001	0.000
22	0.005	0.007	0.003	0.001	0.010	0.002	0.242	0.000	0.013	0.005	0.000	0.001	0.001	0.001	0.000
23	0.015	0.012	0.010	0.009	0.009	0.005	0.047	0.058	0.041	0.008	0.010	0.003	0.005	0.009	0.000
24	0.096	0.061	0.044	0.051	0.036	0.028	0.029	0.030	0.035	0.028	0.018	0.017	0.025	0.034	0.000
25	0.079	0.047	0.017	0.065	0.026	0.027	0.060	0.045	0.030	0.047	0.060	0.015	0.040	0.048	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.002	0.002	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.000
28	0.003	0.005	0.002	0.003	0.001	0.000	0.001	0.001	0.001	0.004	0.002	0.001	0.046	0.002	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Each column represents the domestic intermediate inputs required from other industries to produce one euro of output. For example, to produce 100 euro the paper industry requires 5 euro of intermediate inputs from the chemical industry (industry 9).

Table A2 Total requirements matrix (euros)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.074	0.001	0.012	0.011	0.074	0.048	0.005	0.006	0.008	0.021	0.044	0.012	0.010	0.001	0.020
2	0.001	1.000	0.001	0.001	0.001	0.001	0.061	0.041	0.002	0.001	0.008	0.000	0.000	0.000	0.001
3	0.000	0.000	1.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
4	0.003	0.000	0.005	1.010	0.009	0.002	0.002	0.004	0.011	0.003	0.006	0.003	0.026	0.009	0.010
5	0.289	0.022	0.172	0.192	1.332	0.074	0.085	0.087	0.130	0.363	0.790	0.199	0.165	0.011	0.345
6	0.003	0.000	0.028	0.002	0.013	1.200	0.003	0.013	0.003	0.004	0.011	0.002	0.002	0.000	0.004
7	0.006	0.000	0.011	0.019	0.013	0.003	1.223	0.042	0.004	0.005	0.023	0.003	0.003	0.000	0.023
8	0.006	0.001	0.003	0.005	0.018	0.010	0.015	1.047	0.011	0.008	0.192	0.005	0.003	0.000	0.005
9	0.030	0.002	0.009	0.052	0.024	0.031	0.027	0.058	1.026	0.013	0.031	0.091	0.005	0.001	0.012
10	0.014	0.004	0.004	0.037	0.016	0.017	0.017	0.011	0.019	1.049	0.024	0.111	0.010	0.001	0.020
11	0.004	0.000	0.002	0.002	0.016	0.001	0.001	0.014	0.002	0.005	1.026	0.002	0.002	0.000	0.004
12	0.009	0.000	0.004	0.005	0.003	0.004	0.002	0.002	0.003	0.001	0.003	1.002	0.003	0.000	0.001
13	0.026	0.002	0.012	0.086	0.034	0.032	0.039	0.059	0.031	0.029	0.042	0.038	1.194	0.006	0.017
14	0.005	0.000	0.007	0.019	0.010	0.013	0.007	0.025	0.013	0.006	0.012	0.007	0.120	1.001	0.004
15	0.018	0.006	0.014	0.041	0.023	0.024	0.017	0.027	0.020	0.019	0.049	0.049	0.040	0.006	1.573
16	0.021	0.014	0.012	0.022	0.021	0.018	0.016	0.015	0.016	0.013	0.041	0.056	0.010	0.002	0.027
17	0.063	0.008	0.042	0.043	0.049	0.062	0.097	0.060	0.027	0.050	0.068	0.022	0.033	0.001	0.052
18	0.002	0.001	0.002	0.004	0.004	0.003	0.004	0.004	0.009	0.003	0.006	0.004	0.005	0.000	0.004
19	0.012	0.004	0.025	0.037	0.024	0.042	0.024	0.025	0.037	0.023	0.025	0.050	0.050	0.005	0.023
20	0.021	0.004	0.028	0.053	0.053	0.058	0.059	0.057	0.040	0.036	0.047	0.016	0.017	0.002	0.029
21	0.019	0.002	0.100	0.076	0.037	0.036	0.027	0.039	0.032	0.026	0.046	0.013	0.012	0.001	0.018
22	0.007	0.011	0.029	0.008	0.005	0.008	0.007	0.007	0.005	0.006	0.005	0.008	0.006	0.002	0.007
23	0.016	0.010	0.014	0.017	0.018	0.023	0.015	0.017	0.014	0.018	0.022	0.017	0.024	0.008	0.019
24	0.017	0.007	0.023	0.052	0.037	0.041	0.031	0.030	0.039	0.040	0.048	0.038	0.045	0.008	0.050
25	0.029	0.013	0.027	0.086	0.078	0.070	0.056	0.086	0.079	0.075	0.077	0.144	0.079	0.016	0.054
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.002	0.001	0.003	0.002	0.003	0.005	0.003	0.002	0.005	0.002	0.004	0.005	0.003	0.001	0.001
28	0.009	0.003	0.004	0.003	0.003	0.005	0.004	0.002	0.003	0.001	0.002	0.003	0.002	0.000	0.001
29	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.010	0.009	0.027	0.008	0.011	0.008	0.004	0.002	0.004	0.012	0.006	0.004	0.006	0.015	0.000
2	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.003	0.000
5	0.131	0.064	0.276	0.138	0.181	0.143	0.058	0.031	0.061	0.171	0.072	0.045	0.075	0.133	0.000
6	0.002	0.003	0.010	0.002	0.002	0.002	0.001	0.000	0.001	0.003	0.002	0.001	0.004	0.003	0.000
7	0.002	0.003	0.007	0.003	0.004	0.013	0.001	0.001	0.003	0.004	0.001	0.001	0.001	0.006	0.000
8	0.003	0.003	0.005	0.006	0.003	0.004	0.007	0.004	0.003	0.011	0.007	0.004	0.003	0.005	0.000
9	0.007	0.004	0.015	0.007	0.006	0.010	0.003	0.001	0.003	0.011	0.005	0.002	0.028	0.012	0.000
10	0.007	0.005	0.009	0.013	0.007	0.011	0.002	0.001	0.004	0.005	0.011	0.002	0.003	0.009	0.000
11	0.002	0.001	0.003	0.002	0.002	0.002	0.001	0.000	0.001	0.002	0.001	0.001	0.001	0.002	0.000
12	0.004	0.003	0.003	0.002	0.008	0.003	0.000	0.000	0.000	0.002	0.003	0.002	0.002	0.006	0.000
13	0.044	0.032	0.017	0.035	0.016	0.027	0.015	0.009	0.011	0.022	0.030	0.013	0.013	0.019	0.000
14	0.008	0.007	0.004	0.006	0.006	0.004	0.002	0.001	0.002	0.004	0.007	0.004	0.003	0.004	0.000
15	0.043	0.039	0.034	0.047	0.033	0.088	0.034	0.026	0.146	0.036	0.024	0.026	0.023	0.044	0.000
16	1.039	0.015	0.018	0.010	0.070	0.024	0.009	0.002	0.010	0.010	0.010	0.005	0.019	0.016	0.000

17	0.017	1.039	0.049	0.020	0.033	0.022	0.009	0.004	0.009	0.024	0.025	0.010	0.027	0.026	0.000
18	0.005	0.006	1.003	0.036	0.004	0.005	0.015	0.007	0.003	0.013	0.009	0.006	0.009	0.011	0.000
19	0.032	0.032	0.025	1.165	0.023	0.036	0.050	0.027	0.025	0.068	0.046	0.014	0.020	0.031	0.000
20	0.023	0.070	0.016	0.016	1.055	0.202	0.007	0.002	0.007	0.014	0.014	0.004	0.009	0.013	0.000
21	0.021	0.067	0.012	0.026	0.221	1.244	0.006	0.002	0.007	0.015	0.008	0.003	0.006	0.009	0.000
22	0.011	0.013	0.007	0.005	0.017	0.008	1.321	0.001	0.019	0.009	0.002	0.002	0.003	0.004	0.000
23	0.026	0.021	0.019	0.019	0.020	0.016	0.071	1.065	0.049	0.015	0.015	0.006	0.010	0.016	0.000
24	0.117	0.080	0.062	0.075	0.064	0.058	0.052	0.039	1.048	0.044	0.031	0.023	0.038	0.048	0.000
25	0.107	0.070	0.044	0.097	0.060	0.061	0.098	0.057	0.046	1.071	0.078	0.023	0.058	0.069	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
27	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.003	0.002	1.002	0.002	0.002	0.000
28	0.004	0.006	0.003	0.005	0.002	0.001	0.002	0.002	0.002	0.005	0.003	0.001	1.049	0.003	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Each element represents the direct and indirect intermediate inputs from industry *i* required to satisfy one euro of final demand for industry j.