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ABSTRACT

The aim of this paper is to study wood consumption during the industrial expansion that took place in the western world in the second half of the nineteenth and the first decades of the twentieth century, by means of the analysis of the case of Spain. For this purpose, we present the series of Spanish consumption of wood both as a raw material (WRM) and as firewood (FW) between 1860 and 1935 and we carry out two exercises with these series. The first calculates the Intensity Of Use -IOU-, which relates wood consumption in physical terms with the evolution of the GDP. The second, more complex, exercise estimates a standard consumption function that allows us to know the elasticity of WRM with respect to the GDP, the Spanish price of wood and the Spanish price of a substitute material like iron. Based on our results, we discuss the lower dependence of the Spanish industrial economy on wood, the "liberation" of forest areas that may have occurred in Spain as a result of industrialization, and to what extent the trends observed for the Spanish case can be extrapolated internationally. The main conclusion is that industrialization transformed the uses of wood and, though the importance of this resource per unit of GDP decreased, its overall consumption increased, generating greater pressure on forests at an international level.

Key Words: wood, forest, industrialization, comsumption function

JEL: C-22, N-53/54, O-13, Q-21

1. Introduction

The economic uses of wood have always been closely linked with the extension, composition and quality of the world´s forests. So, to know how these uses were affected by the industrial expansion that took place in the western world during the second half of the nineteenth and the first decades of the twentieth century, can help us to understand some important environmental issues. As far as industrialization caused

deep changes in the social metabolism of the economy (Krausmann and Haberl, 2002) it must also have altered the importance of a renewable resource like wood. However, the results of this alteration remain, mostly, unstudied.

Before industrialization, wood played a central economic role as an energy source. This was inherent to organic-based energy economies, that obtained energy from the solar flow, transformed it with traditional converters and, consequently, depended directly on the quantity of land available (Wrigley, 1988). In this context, wood (and its derivative, charcoal) offered a higher calorific power than any other vegetable fuel, was relatively evenly distributed and offered greater security and storage capacity than the energies coming from water or wind (Smil, 1983). Thus, it was essential not only for cooking and heating, but also for the development of many industrial processes. At the same time, the properties of wood and the scarcity of alternative materials, meant that it was also fundamental as a raw material in the construction of buildings and infrastructures, means of transport and tools. Obviously, the dependence on wood could vary considerably from region to region, but, generally speaking, no society could exist without it. Therefore, the growth of organic-based economies was restricted by the difficulties involved in extending the area dedicated to wood production, in increasing its yields and in importing it from distant places at viable prices (Sieferle, 2001a).

The industrial revolution was accompanied by an energetic transition that profoundly altered the situation described above. The growing use of coal (and, later, of oil) through new converters, meant that obtaining energy no longer depended directly on the solar flow, but made use of the reserves stored in the earth's crust for millions of years. The result was an exponential growth of the energy available, which, added to new technical and organizational changes, allowed generation of manufactures and new materials on a much greater scale (Debeir, Deléage and Hémery, 1991). In this new economic system, it seems obvious that the role of wood had to change. But, what happened to its consumption from then on? Perhaps because of being a traditional raw material, wood has aroused little interest among students of industrialization. Even those historians concerned with the changes in the use of resources are ambiguous about what happened with wood. For example, Wrigley (1988:32) points out that the new system greatly reduced dependence on organic raw materials, and Sieferle (2001b:48-49) affirms that forested areas could be "*liberated*" and dedicated to other uses thanks to the use of fossil fuels. But, does this mean that the consumption of wood fell as industrialization expanded? Would it be possible to speak, thus, of a kind of wood "*decoupling*", of the type that some authors (Malembaun, 1978) have suggested in the cases of certain minerals, in recent times?

In contrast to this possibility, some elements allow us to think that the use of wood continued to grow with industrialization. On one hand, if we take into account some of the papers that have analyzed long-run energy consumption, including traditional energies (Kander, 2002; Rubio, 2006), it can be argued that, at least until the Second World War, fossil energies did not necessarily substitute traditional energy from wood but were, rather, superimposed on the latter, even though the use of coal and, later, of oil reached much higher levels[1]. On the other hand, although the use of

[1] In some countries of late industrialization, Wood may have continued playing an important role as a source of energy even much later. See, for example, Dean (1995) for the case of Brasil. A discussion of

materials like iron, steel and concrete grew considerable with industrialization, this does not necessarily mean that wood ceased to have an important function as a raw material. Indeed, we know that some paradigmatic elements of industrialization, like mining or railroad building, consumed huge quantities of wood. Furthermore, the improvements in the transport systems allowed wood to be transported further and more cheaply and fomented the trade of many other products that required wood in their crating and packaging. Finally, from the end of the nineteenth century, technological change permitted the use of wood as the raw material for the manufacture of woodpulp, textile fibers and chemical products.

As far as we know, no paper has investigated this question systematically by studing the uses that wood gradually lost and those that were maintained or increased. For this reason, in this paper we present a case study based on the Spanish economy that offers some interesting clues. We argue that industrialization transformed the uses of wood and though its importance per unit of GDP decreased, its overall consumption increased, generating greater pressure on forests at an international level. To test this hypothesis, in Section 2 we describe how we have constructed the series of wood consumption in Spain and the exercises we have carried out with them; in Section 3 we present the main results; in Section 4 we discuss the lower dependence of the Spanish economy on wood, we pose some questions about the "liberation" of forest areas that may have occurred in Spain as a result of industrialization and we also discuss the extent to whitch the results observed in the Spanish case can be extended to the international level; Section 5 presents the main conclusions.

2. Measuring wood consumption in Spain

From the nineteenth century the Spanish economy started a "modern economic growth" in the way described by Kuznets (1973). Both the population and the GDP per habitant grew, and this growth was accompanied by a structural change in which the industrial sector increased its importance. Spanish industry occupied a modest position in the world ranking, but the growth rates of the Spanish industrial production index were similar to those registered by other European countries. Indeed, for the period after the First World War, they were even higher than those obtained by the most industrialized countries of Europe (Carreras and Tafunell, 2005; Prados, 2004, Nadal, 2003). The Spanish economy also started its energetic transition. Between 1830 and 1910 the consumption of coal increased fourfold. From the end of the nineteenth century, hydro-electric power became more and more important and it represented more than one fifth of the gross energy consumption in 1933. Taken as a whole, the total quantity of modern energies used by the Spanish economy was far from that achieved by the most industrialized countries, but it was in tune with that of other Mediterranean "late comers", like Italy (Sudría, 1997).

It should be pointed out that just as Spain was not a big consumer of fossil energy, neither was it a great consumer of wood. In fact, data available for the first third of the twentieth century place the consumption of wood per inhabitant in Spain among the lowest in the Western world (Lleó, 1929). This situation, shared with other Mediterranean countries, can be explained by two complementary factors. On the one hand, pressure on resources since ancient times had reduced the forested areas in many

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the thesis of Dean which, in spite of its critical approach, recognizes the important role of wood in the industrialization of Brasil can be found in Brannstrom (2005).

Mediterranean regions (McNeill, 1992) in a process which could have greater incidence in some regions of Spain due the agrarian changes of the nineteenth century (Cusso *et al.*, 2006). On the other, the characteristics of the Mediterranean climate give rise to a particular type of forest in which wood does not have the same abundance, quality or growth rate as the Atlantic and Boreal forest (Arbós, 1935; Najera, 1948, M´Hirit, 1999). Thus, the Spanish economy had had to adapt itself to the relative scarcity of wood by using alternative organic energies and by trying to minimize its use as a raw material.

Our estimation of wood consumption between 1860 and 1935 distinguishes between wood as a raw material (WRM) and firewood (FW). Spanish forestry statistics do not offer data on the production of both types of wood until the 1940s. Nevertheless, the progress made during recent decades by Spanish economic historians in the reconstruction of historical series allows an indirect but reliable approximation to wood consumption. The consumption of WRM has been estimated on the basis of the final demand of those sectors of the Spanish economy that continued using this product in their activities in the mid-1950s (Robert, 1957). The quantity of wood used annually by each of them has been calculated by applying different coefficients that have already been used by other Spanish researchers (Lleó, 1929; Arbos, 1935; Robert, 1957; and Zapata, 1998 and 2001). They are, thus, adjusted to the particular characteristics of the Spanish economy and have been sufficiently tested in a previous work (Iriarte and Ayuda, 2006). The figures are given in cubic meters with bark. With respect to the consumption of FW, we use the series provided by Rubio (2006), which estimates the annual consumption of firewood between 1850 and 2000 based on the method followed by Malanima (2006) and combining it with the information available on the production of firewood from Spanish public forests. The data of this series has been homogenized with the former and is also expressed in cubic meters with bark. Both series should be considered conservative, because of the way they are elaborated and, thus, represent a minimum estimation of the wood and firewood consumption of the Spanish economy during the period considered[2].

We carried out two exercises with thoese series. The first was to calculate the Intensity Of Use -IOU- (Labys, 2004), which relates wood consumption in physical terms with the evolution of the GDP[3]. This exercise allows us to disaggregate the different uses of wood and provides interesting data about the evolution of each of them with respect to GDP. The second, more complex, exercise was to carry out a standard consumption function that allows us to know the elasticity of WRM with respect to the GDP, with respect to the Spanish price of wood and with respect to the price of a substitute material like iron[4].

3. Results

Table 1 summarizes the evolution of the consumption of WRM and FW in Spain between 1860 and 1935 and allows us to draw the following initial conclusions. Firstly,

[2] In the elaboration of the WRM series, we have avoided using the coefficients that gave the highest levels of consumption. Neither have we taken into account the wood used in shipbuilding, considering that it was of little importance from the last decades of the 19th century (Valdaliso, 1991). On the conservative character of the FW series, see Rubio, 2006: 59.

[3] IOU= cubic meters/ GDP.

[4] This exercise has not been carried out for the FW series because of the lack of reliable data on its prices.

while the FW consumption remained almost static throughout the whole period; the WRM consumption grew both at the turn of the century (peak of the "first" industrial revolution in Spain) and after the First World War (peak of the "second" industrial revolution in Spain). As a result, the overall consumption of wood tended to grow.

During the whole period, FW represents most of the consumption, but its percentage decreased, due to the much more intensive growth of WRM consumption. Table 2 shows the variations of the WRM consumption by uses. As can be seen, all the items register an overall growth, but in percentage terms wood for construction lost weight in favor of the other products.

Figures 1 and 2 show the evolution of the IOU of the different uses of wood. If we consider wood as a whole, it is clear that the total IOU of this product descends as the IOU of FW does. However, the IOU of WRM stayed at a fairly similar level throughout the period (Figure 1). If we focus on the IOU of the disaggregated WRM, we can also observe different behavior according to the item: while the IOU of wood for construction went down, the other items (pitprops and sleepers, packaging and furniture, and woodpulp) grew (Figure 2).

With respect to the consumption function for the WRM series, the consumption of this type of wood in volume has been used as the dependent variable (WC) [5]; the GDP (GDP), the price of rough wood (WP) and the price of iron (IP) are the independent variables[6]. The model is limited to the period after 1880 because data on the evolution of the rough wood domestic price are not available for previous years. The variables of the model are in logarithms, so the estimations of the parameters of position are interpreted as elasticities. To avoid the problem of spurious regressions, we have first analyzed the order of integration of the data series. Based on the graphics of the series, on their correlograms, as well as on the augmented Dickey-Fuller test, Dickey-Fuller (1981) and that of Elliot, Rothenberg and Stock (1996), we can conclude that the four series are integrated of order 1, I(1)[7].

After that, given that the variables are non- stationary and are integrated of the same order, we have analyzed whether or not they are cointegrated with the aim of studying if there is a long-run relation between them. To do so, we have used the test of Engle and Granger (1987) and have been able to conclude that the four variables are cointegrated at the 5% of significance level[8]. But, a subgroup of them are also

[5] The series of wood consumption in cubic meters has been converted into a series of volume (in monetary units) in 1910 prices.

[6] The GDP at factor costs has been obtained from Prados (2004); the wood price series have been obtained from the data of Zapata (1998) and Sala (1997). For the prices of iron, we have taken the price of the pig iron as the indicator according to the series provided by Houpt (1998). All the series are presented in 1910 pesetas. A more thorough explanation of these operations can be seen in Iriarte and Ayuda (2006).

[7] Graphs, correlograms and the tests of Dickey-Fuller and of Elliot, Rothenberg and Stock are not shown here for reasons of space but can be requested from the authors.

[8] The Engle-Granger tests to test cointegration between the four variables are:
E-G (WC, GDP, WP and IP) = -10.31 (-4.74).
E-G (WC, GDP and WP) = - 4.22 (-4.49).
E-G (WC, GDP and IP) = -10.24 (-4.49).
E-G (WC and GDP) = -4.39 (-4.16).

cointegrated, so we have proposed a set of error correction models (ECM). These models are made up of two parts: one measures the short-run relations between the variables, with the variables expresed in differences; the other includes the long-run equilibrium relationship. Using the method of non-lineal ordinary least squares we have estimated these models taking into account a dummy (F1, that takes value 1 in the years 1917-1920 and 0 in the rest with the aim of measuring the effects of the First World War), to test whether there is some structural change. The most adequate model according to Akaike's information criterion (AIC) and the Schwarz's Bayesian information criterion (SBIC), as well as the adjusted coefficient of determination, is the following[9] where T is the trend variable and has been introduced into the model because, in the individual analysis of the variables, all of them had a deterministic trend:

Using the Breusch-Godfrey LM autocorrelation tests, LM(i), the White heteroskedasticity test, LM(Het.), and the Jarque-Bera test of normality, J-B, it can be seen that the model has no problems of either autocorrelation or of heteroskedasticity, nor does it fail to reject the null hypothesis of normality at a 5% significance level.

Table 4 presents the results obtained. Wood consumption as a raw material was expected to show a positive sign with respect to the evolution of the GDP (economic growth would require more wood and vice versa). The price of iron was also expected to show a positive sign (an increase in the price of iron should result in an increase in the use of wood and vice versa). On the other hand, a negative sign with respect to the prices of rough wood itself was expected (an increase would lead to a decrease in the consumption of the product and vice versa). Both the long-run and short-run elasticities have the expected sign, although the variables price of iron and of rough wood are not significant in the long run. It can be concluded, therefore: 1) the growth of the GDP stimulates the consumption of WRM, although the elasticity was clearly lower than one; 2) the increase in WRM consumption occurred almost independently of the evolution of the price of iron and quite autonomously from the evolution of price of rough wood itself. The price of wood presents an elasticity of approximately –0.11% in the short term that only grew during the First World War, when prices rose sharply because of the conflict (with a coefficient of –0.58 for the period 1917-1920).

4. Discussion.

The results from the previous section allow us to propose three subjects of discussion. a) How should the lower dependence of the Spanish industrial economy on wood be evaluated? b) What happened to the surface area dedicated to obtaining wood in Spain in the new economic system? c) To what extent can the results observed for the Spanish case be extrapolated internationally?

In brackets, we indicate the critical point for a level of significance of 5% and for a model with a trend (all the series have a trend). The null hypothesis of no-cointegration for this level of significance is rejected in all cases, except for the model with the variables WC, GDP and WP, which would be rejected at 10% (critical point – 4.20).

[9] Due to possible doubts about the non-exogeneity of the variable price of wood, WP, and the price of iron, IP, we have used the Granger causality test and have concluded that both variables are exogenous in the explanation of consumption, in the Granger sense, for a level of significance of 5%. H_0:WP does not cause WC, F = 4.07 [0.02] H_0:WC does not cause WP F = 0.63 [0.54] . H_0:IP does not cause WC, F = 5.88 [0.005] H_0:WC does not cause IP, F = 2.57 [0.08] .

a) The results presented can be interpreted in various ways. If we focus on the decrease in the IOU of FW or in the lower than 1 GDP elasticity of WRM, it is clear that wood lost importance for economic growth. So, Wrigley's claim that mineral-based energy economies were less dependent on wood is confirmed, as long as we view the problem in relative terms. But, if our interest lies in analyzing the changes caused in the use of wood and the effects that these changes had on forests, the idea of the lower dependence is misleading. It might, for instance, lead us to think that the pressure exerted by the industrialized economies on wood resources tended to diminish when, in fact, the increase in the overall consumption figures and the positive sign of the elasticity of the WRM with respect to the GDP show the opposite.

From this perspective, we believe that the idea of a wood decoupling in industrialized societies should be rejected. Bearing in mind that wood had many varied uses, we think it is more adequate to use the concept of *transmaterialization* proposed for other materials by Labys (2004). This concept allows us to observe the stage of the life cycle of products at which each use of wood was situated during the industrialization process.

In the case of FW and of wood for construction, the drop in the IOU together with the moderate growth of the overall consumption indicate that we are dealing with uses that entered into their "saturation stage" with industrialization. Indeed, the most dynamic sectors of the economy began to employ fossil energies and new industrial materials that displaced wood. But, this displacement was accompanied by an increase in the overall consumption that could have been due to a number of reasons. The first is related to the difficulties that existed of accessing the new energies and materials in a large part of the territory. The spatial concentration of the coal deposits and of the main industrial focal points, the difficulties of transportation derived from the rugged terrain and the limited railway network and the concentration of the electricity networks in only the largets urban areas meant that a considerable part of the population, especially the rural population, still depended on wood. In the case of construction, it should also be remembered that some non-structural elements of buildings like doors, door and window frames, and wall and floor panelling, continued (and continue) to be made, mostly, from wood. In the 20s, the appearance of plywood could have a double effect on consumption. On one hand it reduced the solid wood used in product (and influenced the reduction of IOU) but, on the other hand, it made wood more available and increased the overall consumption especially for panelling (Zapata, 2001). As for firewood, in the period after the First World War, it began to be used to obtain chemical products, which could have also caused an increase in its consumption.

The wood used for pitprops, sleepers, packaging/crating and furniture was maintained throughout the period in at *"youthful stage"* that implied a growth both in absolute terms and in IOU and which can be explained in various ways. The pitprops and sleepers were connected with modern economic uses like coal (and other minerals) mining and the building of networks (railway, telegraph and electricity) and, furthermore, need regular replacement because of the deterioration that they suffer due to environmental conditions. Thus, the appearance, at the end of the 19th century, of methods to preserve wood (Elorrieta, 1913) must have been fundamental for the continued use of this raw material. With respect to packaging/crating, the growth of wood consumption is linked to the increase in the domestic trading of agrarian products and, especially, to Spanish exports, first of wine and, later, of fruits and vegetables

(Pinilla, 1995 and 2006). Wood was important to the conservation of some products like wine and, in any case, was a light, resistant material that was adequate for transportation and difficult to substitute before the appearance of industrial materials with these characteristics. As for furniture, the situation could be even more complex because the use of the material is also linked to questions of design and comfort, which might make wood preferable to other more modern products. The appearance of plywood must also have influenced the increase in the consumption of this material for furniture.

Finally, woodpulp is a peculiar case because, during this period, it was at an "initial introduction stage", with an already considerable growth in its overall consumption and in its IOU and, furthermore, augured great expectations for the future. It was, indeed, a new product in which, from the end of the 19th century, wood substituted other materials traditionally used for the elaboration of paper. From then on, its use was bound to the intense growth in the consumption of this product, which has continued beyond the limits of the period considered here.

To sum up, industrial expansion did not imply that wood was rejected for being an archaic material. Its substitution depended on the appearance of alternative products that offered relevant advantages and on whether these products could regularly reach the majority of the territory and the population. Moreover, technological change, itself, could renovate the usefulness of wood for some uses and perpetuate or increase its use. In this context, the average prices of wood and of iron could have had an influence on the extent of the substitution but, as the consumption function suggests, it does not seem that this was the determinant variable to explain changes.

b) The second subject of discussion has to do with the use of forest areas and can be summarized as follows: How does the growth of consumption observed fit in with Sieferle´s claim about the "liberation" of forested areas of the mineral-based energy economies?

The growth of the Spanish economy during the period considered had some evident effects on the use of the territory, seen principally in the expansion of the area under cultivation (Gallego, 2001, González de Molina, 2006). This expansion carried out at the expense of areas of forest and pasture that, taken as a whole, by 1930 had been reduced by 18% with respect to their area in 1860 (GEHR, 1994). At first glance, it seems logical to think that this reduction in the area dedicated completely or in part to obtaining wood would have been impossible without the growing use of fossil energies or of modern materials (Sieferle, 2001, Krausmann and Haberl, 2002). Nevertheless, from the point of view of forest use, this situation only reveals part of the problem.

The rest of the problem becomes clear if we calculate how the domestic production of fire wood and wood evolved. This can be done, starting with the known consumption and subtracting the net imports (imports minus exports) from it[10]. The data from this operation show a clear growth in production between 1860 and 1935, modest in the case of FW (it increased by a factor of 1.1) but much more important in the case of WRM (it increased by a factor of 3.4). This situation suggests that the increase in consumption put considerably more pressure on Spanish forests. But, how was this increase in production possible? We really know very little about what happened in the

[10] Imports and exports of wood and firewood have been obtained from the Estadísticas del comercio exterior de España (Spnish statistics of foreing trade) 1860- 1935.

private forests, but we can say something about the State-run forests which, from the end of the 19th century until 1935, increased their wood production by 2.9 (GEHR, 2002). This was achieved by the gradual introduction of new forms of management that imitated those existing in other countries with a stronger forestry tradition and which, basically, tried to obtain the "*maximum sustainable yield*" from the forests and to make this production available to the arising industrial needs[11]. To do so, a series of laws were enacted restricting traditional forest uses, establishing concessions to private firms to develop an exploitation to cover the industrial demand, and favoring some public investments aimed at improving both the access to the forests and the transport of the products to the markets (Jiménez Blanco, 2002). But, it is important to point out that this system had a clearly extensive component, because it was achieved, to a great extent, on the basis of establishing a systematic exploitation of wood in areas of forest that, until then, had been outside of the market system or had been only partially integrated into it (Iriarte, 2005). In other words, the reduction of the total forest area was compensated, in part, by an extension of the comercial exploitation of many forestry areas.

Finally, an aspect that points in a similar direction is that of the net wood imports carried out by Spain, which, increased by a factor of 1.9 during the period and especially at times when economic growth accelerated. So, this suggests that the process of industrialization of the Spanish economy not only increased the pressure on the country's forests but also meant that it had to look more and more to the production of forest areas outside its frontiers. A rough measurement, trying to approximate the ecological footprint that these imports could have had at their peak (1925-1929), reveals that, to cover its demand for wood and firewood, the Spanish economy might have been using about a million hectares of foreign forest[12].

To sum up, although the new economic system, to a great extent, broke the link between the production of energy and of materials and the available area, it also produced what can be called a growing 'colonization of terrestrial ecosystems' (Fischer-Kowalski and Haberl, 1993), which also affected the forests and was caused by the increase in the consumption of wood generated by industrialization. The fact that even a modest consumer like Spain should have growing recourse to wood imports, indicates that this colonization could have been on a global scale.

c) It is worth considering the hypothesis that some of the trends detected for Spain could be extended to the set of other industrialized countries. Although there are no papers that measure the elasticity of wood consumption respect to the GDP, the available data for the period considered show a clear growth in the overall consumption for the set of Western European economies and for the United States (Hiley, 1930; Mitchel, 1985; FAO/CEE, 1963). In some cases, a wood consumption growth lower than the GDP growth has even been suggested for some countries (Myllyntaus and Mattila, 2002). Bearing in mind that in most of these countries the stock of modern

[11] The expression "maximum sustainable yield" describes a management whose aim was to extract the most wood possible without reducing the initial stock of standing timber. On the general problems of this management method, see Ludwig, Hilborn and Walters (1993).

[12] The calculation has been carried out considering the conversion of sawn timber to standing wood proposed by Hiley (1930) and considering an average yield of 2 m^3 per hectare (Lleó 1929). A calculation of the ecological footprint for Spanish forestry for the period after 1955 can be found in Carpintero (2005).

energies, the weight of the industrial sector and the technological innovation were above those of Spain, it is very possible that the IOU of some particular uses of wood (especially firewood) would fall more rapidly than in Spain. But, even in the most technically advanced countries, the real possibilities of substituting wood with other materials were limited (Koehler, 1924), and wood continued to be preferred for certain uses (Dreicer, 2000). Moreover, precisely because they were more advanced economies, the technological change applied to wood could renovate the uses of this material to a greater extent than it did in Spain (e.g. Brown, 1937 for the United States).

With respect to how to cover this growing consumption of wood, the outlines are also similar to those detected for Spain. On the one hand, from the 19th century onwards, many countries put forestry policies into practice that, though varying in their chronology and particularities, basically sought the maximum sustainable yield from their forests to cover the new industrial needs (Fernow, 1907; Smith, 1930; Agnoletti and Anderson, 2000; Bonhomme, 2002). On the other hand, there is clear evidence that the international wood and woodpulp trade grew because of the impulse of the growing demand from the industrialized countries (Institut International D'Agriculture, 1924; Hiley, 1926; Lamartine, 1959). It can be said that, as a consequence of this, the area of forest exploited for commercial ends increased in many countries (Koehler, 1924; Gaunitz, 1979; McNeill, 1988; Weill, 2006; Zarrilli, 2006) and reached, during this period, practically all the temperate forests of the planet (Latham, 1957).

5. Conclusions

In the middle of the 1920's, C. L. Pack (1926), president of the American Tree Association at the time, wrote: "We need a timber crop every year, just as we need a wheat or corn crop". What we have seen in this paper suggests that this was not mere rhetoric. Although the industrial revolution was based on the use of new energies and new materials, wood was still a necessity in many activities. As we have seen in the case of Spain, the overall consumption of wood grew as industrialization expanded and the WRM consumption presented a positive elasticity with respect to the GDP. This was not incompatible with the fact that this elasticity was less than one and that the IOU of wood fell in some of the more traditional uses of this resource. However, in other uses, linked mainly to modern activities, the possibilities of substituting wood with other materials were fewer or not very attractive and, furthermore, technological change itself revitalized the demand for wood for new activities. The concept of transmaterialization seems to us, in this sense, to be useful for explaining why and how the overall consumption of wood tended to grow.

This invites us to take another look at some of the rather ambiguous claims that have been made about the relationship between the modern economic growth and the use of wood. Firstly, Wrigley's idea that mineral-based energy economies were less dependent on organic raw materials is true, but only in relative terms. Secondly, Sieferle's claim about the "liberation" of the areas dedicated to obtaining wood as the use of fossil energies grew must also be taken with care. Although, in the new economic system, the obtaining of energy and of materials was liberated from the quantity of land available, this was not incompatible, in Spain, with a growth in the pressure on forest areas and the fact that some of this consumption had to be satisfied with wood from foreign forests. From this point of view, our line of thinking fits in with the idea of Hornborg (2005) that industrial growth could have produced a saving in space (and also

in time) to be dedicated to other uses, but that this occurred on the basis of displacing the obtaining of raw materials towards the economic periphery (domestic or foreign, we could add), with the consequent displacement of the environmental load involved. In this sense, the hypothesis sustained with some fragmentary data that results observed for Spain can be extended, generally speaking, to the set of countries that were being industrialized, lends a global dimension to this problem.

The effects of the greater pressure that the economy exerted on the forests with the industrialization process should be viewed as something complex and, in any case, not identified necessarily with deforestation processes. When all is said and done, we are dealing with a renewable resource whose stocks depend on the ratio between the rhythms of extraction and of regeneration. From this perspective, the final result depended on the particular methods of management that were implanted in each case. These involve a varied range of technical and economic, as well as social and institutional, factors that could affect the forms of exploitation of each country and each region. Nevertheless, even in the cases in which we know that, in the long term, the forested area did not decrease, it has been shown that the use of the forests to cover industrial demand led to a loss in their value in ecological terms (Ericsson, Östlund and Axelsson, 2000; Myllyntaus and Mattila, 2002).

To sum up, re-examining the role of wood in the process of industrial expansion allows us to remember a fact that is often overlooked: changes in the social metabolism of the economy linked to the process of industrialization are not only related to the predominant use of finite resources and the varied consequences that arise from this but, furthermore, have important effects on the use of a renewable resource like wood and the ecosystems from which it comes.

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TABLES

TABLE 1
WF AND WRM COMSUMPTION IN SPAIN (1860-1935) ANNUAL AVERAGES

	FW (m3)	% (1)	G	WRM (m3)	% (1)	G
1860-1879	8.720.562	86,3	91	1.381.523	13,7	72
1880-1899	9.538.494	83,2	100	1.925.604	16,8	100
1900-1913	8.985.129	77,1	94	2.665.616	22,9	138
1914-1919	8.818.595	75,4	92	2.872.952	24,6	149
1920-1929	9.514.357	72,4	100	3.617.957	27,6	188
1930-1935	9.801.559	71,5	103	3.909.899	28,5	203

(1): percentage of FW and WRM over total wood consumption (WRM+FW); G: Growth rate. 100= 1880-1899. Source: Iriarte and Ayuda, 2006.

TABLE 2
COMPOSITION AND GROWTH OF THE WRM CONSUMPTION IN SPAIN
(1860-1935)

	Construction		Pitprops/sleepers		Packaging		Woodpulp	
	%(1)	G	%(1)	G	%(1)	G	%(1)	G
1860-1879	74,53	93	14,82	54	10,65	34		
1880-1899	57,71	100	19,59	100	22,26	100	0,44	100
1900-1913	44,15	106	21,27	150	33,13	206	1,45	451
1914-1919	44,18	114	24,46	186	29,43	197	1,92	645
1920-1929	36,92	120	21,92	210	38,36	329	2,80	1.185
1930-1935	36,83	130	22,67	235	35,80	327	4,70	2.146

(1): percentage of every use over total WRM consumption; G: Growth rate. 100= 1890-1899.
Source: Iriarte and Ayuda, 2006.

TABLE 3
NON-LINEAL ORDINARY LEAST SQUARE ESTIMATION OF THE CONSUMPTION FUNCTION WRM[13]

$$\Delta WC_t = \underset{(3.68)}{0.74}\,\Delta GDP_t - \underset{(-1.71)}{0.11}\,\Delta WP_t - \underset{(-2.91)}{0.47}\,\Delta WP_t F1_t$$
$$- \underset{(-5.36)}{0.62}\left[WC_{t-1} - \underset{(-2.81)}{1.99} - \underset{(-2.55)}{0.47}\, GDP_{t-1} - \underset{(-2.77)}{0.009} T \right]$$

$R^2 = 0.60$

$LM(1) = 0.06[0.79]$
$LM(2) = 0.81[0.66]$
$LM(3) = 3.63[0.30]$
$LM(4) = 4.49[0.34]$
} *Autocorrelation tests*

$LM(Het.) = 9.08[0.76]$

$J - B = 3.35[0.19]$

* t-ratios are in brackets and p-values in square brackets.

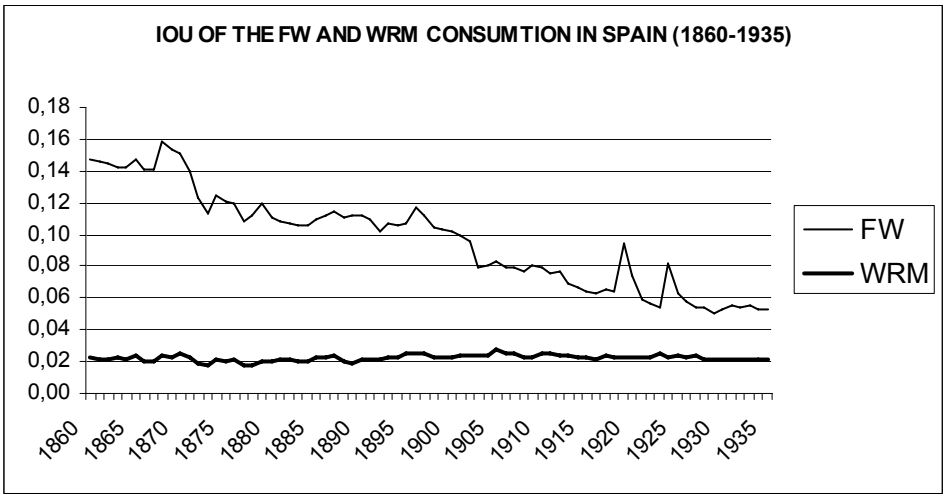
[13] The significance and negative sign of the error correction term (-0.62) indicates, according to Kremers, Ericsson and Dolado (1992), that there is a long-run equilibrium relationship between the variables WC and GDP as we had already determined with the cointegration tests previously used.

TABLE 4
ESTIMATED ELASTICITIES OF THE WOOD CONSUMPTION (WRM)

Estimated elasticities	Short Run	Long Run
GDP	0,74	0,47
WP	-0,11**	--
WP	-0,58 (1917-1920)	--

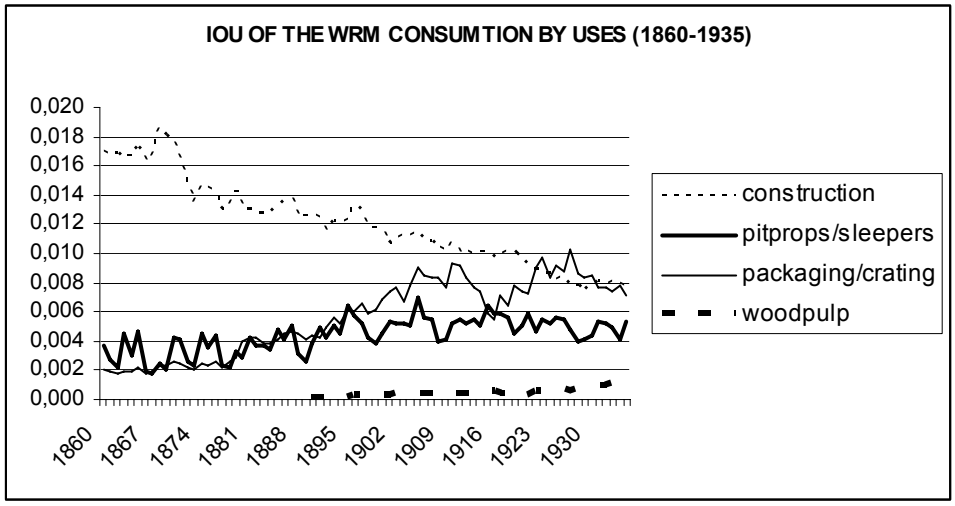
** Significant at the 10% level. -- Not in the model because they were not significant.

FIGURE 1



IOU= M3/GDP. Source: Iriarte and ayuda (2006); Prados (2004).

FIGURE 2



IOU= M3/GDP. Source: Iriarte and ayuda (2006); Prados (2004).

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