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The EU Bioeconomy: Supporting an Employment Shift Downstream in the Wood-Based Value Chains?

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Abstract: Monitoring employment in the European wood-based bioeconomy requires reliable, consistent, and comparable statistics across subsectors and over time. Statistics concerning employment in wood-based industries—the main component of the forest-based bioeconomy—must be processed carefully to cope with differences in definitions and estimation methods. In addition, specific methods must be applied to estimate wood-based employment in sectors including also non-wood activities. In this study, we first delineate the boundaries of the wood-based bioeconomy, and then create a harmonised time series on employment for the identified sectors. Finally, we estimate the share of wood-based employment along the value chain in all sectors using wood. According to the results, forestry and extended wood-based value chains employed 4.5 million people in the EU-28 in 2018. Employment in wood-based value chains decreased between 2008 and 2013 in the aftermaths of the financial crisis. Continuously decreasing employment—most apparent in the manufacture of solid wood products and pulp and paper—results from increasing productivity and a decreasing demand for graphic paper. Further, most of the wood-based employment in the EU takes place in downstream parts of value chains, although the weight of the primary sector is still high in some Eastern European countries.

Keywords: bioeconomy; forest sector; employment; labour force; European Union

1. Introduction

The updated bioeconomy strategy of the European Union (EU) aims at a cleaner and sustainable economic growth. Its deployment is awaited to boost employment [1]. In addition, a realized sustainable bioeconomy is likely to require a broader variety of professional profiles. To anticipate these needs, it is important to get a clear picture of the current employment structure in all the related sectors and activities, as well as of the way this structure has been changing in recent years. Forest-based employment—often a major, sometimes the only, source of employment in rural areas—is of crucial benefit to society, and is recognized as an integral part of sustainable development [2,3]. In 2018, forestry, the manufacture of wood, wood products, and cork, and the manufacture of paper and paper products accounted for 2.22 million employed people, i.e., about 1% of the total EU employment in manufacturing [4]. This number has been decreasing by 8.6% over the last decade, principally in the manufacturing sectors. The development of the bioeconomy might be a chance to offset this trend. In fact, forest is one of the main sources of biomass for material and energy uses in the EU bioeconomy [5], and about two third of the net annual increment in EU forests are harvested according to official statistics [6]. Although fellings, as well as increment assessments, are prone to large uncertainties, there seems to be a potential to increase wood supply and the activity in wood-based

transformation sectors [7]. However, the increase in activity will not necessarily take place in the forest-based sectors, but it might concern the manufacture of final and innovative products [8], as well as the provision of services towards more efficient value chains [9]. Therefore, knowledge on employment along the entire wood value chains—that is, beyond the traditional wood-based sector—is needed to support and evaluate policy decisions [10].

Reliable information, comparable across economic sectors and across member states of the European Union, is needed to detect trends in employment in different sub-sectors, to establish patterns of specialisation of countries, and to evaluate if the EU bioeconomy strategy [1] is meeting its targets on employment. In the forest-based sector, employment statistics cover only forestry, wood manufacturing, and pulp and paper industries, ignoring further processing as well as work undertaken to supply services [11,12] and downstream wood-based industries (furniture, energy, chemicals, etc.) [13]. To further the knowledge of employment in the forest-based bioeconomy—while dealing with numerous definitions of employment, fuzzy limits of the wood-related value-chains, and data gaps—we propose and implement a methodology covering all sectors of the value chains, from wood supply to the manufacture of the final products. Although employment is a common variable reported in socio-economic studies on the forest-based sector [14], no study has—to the best of our knowledge—attempted such an inclusive approach in constructing a dataset for the comprehensive monitoring of employment in the EU forest and wood-related value chains.

The article is organized as follows: First, definitions of the wood-based sectors and employment are reviewed and reference definitions proposed, then datasets are identified and processed to create a database on wood-based employment in the EU according to the reference definitions, and finally—using this database—trends in employment by sectors are analysed, and job opportunities in the framework of the bioeconomy are highlighted.

2. Employment in the Wood-Based Value Chains: Definitions

2.1. Identification of the Wood-Based Value Chains from the Forest to the Final Products

This analysis aims to assess employment in the wood-based value chains in the framework of the forest-based bioeconomy. According to the EU bioeconomy strategy [1] "The bioeconomy covers all sectors and systems that rely on biological resources [...], their functions and principles. It includes and interlinks [...] all primary production sectors that use and produce biological resources and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services". To apply this rather all-encompassing definition to the forest-based bioeconomy requires considering all wood-based value chains both up- and downstream. Accordingly, we understand wood-based value chains to include all steps from the primary production of wood—mainly resulting from forestry—to the manufacture of final products, taking into account the use of transformation residues (e.g., sawdust), the reuse and recycling of wood-based products (e.g., recycled paper). This definition goes beyond the delineations of most studies, which concentrate on the forest or the forest-based sector. For example, the definition used in the European Forest Sector Outlook Study [14] considers value chains from primary products to intermediate products, excluding final products: "Forest products include all of the primary wood products manufactured in the wood processing sector (sawnwood, wood-based panels, paper, and paperboard) and the main inputs of partly processed products used in the sector (roundwood, wood pulp, wood residues and recovered paper) as well as non-wood forest products. Secondary or value-added forest products (such as wooden doors, window frames and furniture) are not covered." Similarly, for Forest Europe [6], the forest sector is composed of three activities (see *forestry and primary processing* on Figure 1): *Forestry and logging* (A02 in the European Classification of Economic Activities, NACE rev. 2, [15], used here to ensure comparability with other studies and statistics), *Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials* (NACE C16), and *Manufacture of paper and paper products* (NACE C17). In economic studies, this is the most common definition of

the forest sector—often referred to as the forest-based sector [16–19]. Only rarely is the forest sector intended as including the printing industry [17]. Some recent studies of the forest sector connected to the bioeconomy consider an even wider set of activities, including second transformation and recycling [20–22]. On the other hand, studies aiming to estimate the global socio-economic impact of the wood harvest and the manufacture of wood products see, e.g., [23] tend to adopt a broader perspective, but the elements of the value chains are not explicit in those studies.

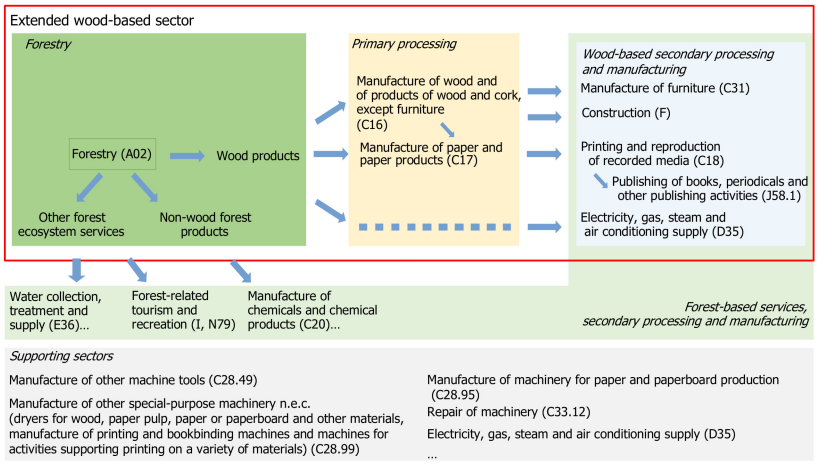

Figure 1. Connections between forestry and other economic activities (NACE rev. 2 codes are indicated in brackets).

Considering the value chains, the manufacture of wood and paper products mainly produces intermediate goods, which require further processing to become final commodities. These commodities, such as pieces of furniture, constructions (carpentry, doors, window frames), books, and newspapers, are often composed of wood combined with other materials. Moreover, these manufacturing activities as described in the NACE nomenclature [15] also produce goods that do not contain any wood-based materials. Therefore, only certain shares of the economic and social contribution of these activities can be considered as depending on forest products.

In this study, we attempt a more comprehensive analysis of the employment in the wood-based value chains, ranging from activities in the forest-based sector (*forestry* and the *primary processing* activities) to *Wood-based secondary processing and manufacturing* activities, which are defined as the collection of industries—outside the forest-based sector—that use wood-based products and services in their production activity. This includes the production of pieces of furniture mainly made of wood, wooden or cork flooring and insulation, wooden carpentry, wooden houses, hard copies of books, newspapers, brochures, fliers, bioenergy, as well as bio-chemicals from the forest. It includes both product manufacturing and intellectual activities such as conception and design, e.g., in construction and publishing (see Figure 1). Together, the wood-based primary and secondary processing are designated as the *extended wood-based sector*.

Growing activities that make use of forest ecosystem services, such as water depuration, land restoration, soil stabilisation and recreation would be part of the *forest-based services*. They are beyond the scope of this study, as data are still too scarce for a more comprehensive assessment covering all EU member states. Further, to account for the overall impact of the extended wood-based sector on the economy, supporting sectors should also be considered. Supporting sectors are all of the sectors providing services or material that allow for the functioning of the forest-based and forest-related sectors, e.g., the supply of machinery, energy, transport, and sale. Some activities in these sectors depend on the demand for services and machinery in the extended wood-based sector. However, data describing the links are scarce. The use of multipliers or macroeconomic modelling would be more appropriate to estimate these interlinks [23]. In this study, we focus on the wood-based value

chains, which include forestry (A02), primary processing (C16 and C17), and wood-based secondary processing and manufacturing sectors (C18, C31, D35, F, and J58).

2.2. Employment Definitions

Statistics about employment in Europe use different definitions and measurement units depending on their objectives. The main statistic on the topic, which covers all of the economic activities, is the Labour Force Survey (LFS). It relies on a definition that is in accordance with the guidelines of the International Labour Organisation and is in use for most employment reporting. In the LFS "a person is considered as having an employment if he or she did any work for pay or profit during the reference week. 'Work' means any work for pay or profit during the reference week, even for as little as one hour. Pay includes cash payments or 'payment in kind' (payment in goods or services rather than money), whether payment was received in the week the work was done or not. Also counted as working is anyone who receives wages for on-the-job training, which involves the production of goods or services. Self-employed persons with a business, farm or professional practice are also considered to be working in some conditions."

The Structural Business Survey (SBS) and the national accounts also include information on employment. The SBS uses a definition, which is rather suitable to analyse the activity of enterprises, since employment is identified at the firm level and possible double-counting can take place for people working in several enterprises. Statistics on labour quantities (usually in full-time equivalent) reported in the National Accounts are usually derived from the LFS and SBS. They are suitable to estimate the contribution of labour to the economy, but not to report the number of persons employed by activity. Therefore, for the purpose of this study, the LFS definition appears to be the most adequate.

3. Materials and Methods

3.1. Labour Force Surveys as the Main Data Source

Our aim is to look at all of the wood-related activities in the EU member states since 2008. In order to build a consistent employment dataset we need comparable input data across sectors and countries. Eurostat publishes the results of the LFS conducted by member states [24]. This statistic gives detailed information on employment by economic activities following the NACE Rev. 2 classification at the two digits level from 2008 onwards (table lfsa_egan22d). The LFS, relying on a survey of a household sample, classifies the population of working age (15 years and above) in economic activities in a consistent way across all EU-28 countries [25]. In the employment statistics derived from the LFS, each person is considered only once in the sector of activity of his/her main job (job with the greatest number of hours usually worked or generating the higher share of the income). This method averts double counting. Given the design of the survey, additional information is available on the social characteristics of the workers, such as gender, age class, and education.

3.2. Filling the Data Gaps

The LFS dataset released by Eurostat is detailed but incomplete. For some countries, years and sectors information is missing, often due to confidentiality issues. We filled the gap using The State of Europe's Forests 2015 report [2] for forestry (A02) in Malta and Luxembourg, as well as LFS results released by national statistic institutes ([26], for the C16, C17, and C18 sectors in Luxembourg).

In order to reconstruct a time series that follows the annual changes of the member states' economies, we relied on two additional datasets containing information on employment: The Structural Business Survey (SBS) and the National Accounts Input Output tables (NAIO). These datasets sometimes contain estimates for years for which the LFS dataset is empty. Having different purposes, these statistics use different definitions and methodologies compared to the LFS.

The first of the two datasets, the SBS, describes the economy by observing units engaged in an economic activity and includes information on employment in the EU. It covers the 'business

economy', which includes industries, construction, and services. Therefore, this dataset can be used to fill in the time gaps in all our sectors of interest except forestry. The LFS and the SBS concern different survey units (private household and business units) and rely on slightly different definitions of employment [27]. On the one hand, the LFS data relate to the number of residents in employment in the country concerned, irrespective of whether they work in the country or abroad. It also excludes people living in collective households. On the other hand, the SBS records the number of people employed in various enterprises, some of whom might be counted twice. Moreover, enterprises active in more than one economic area are classified according to their principal activity, normally the one that generates the largest amount of value added. It the second of the datasets, the NAIO, the employment reported results from the processing of the LFS and SBS statistics, combined with expert knowledge to cope with differences as to methodologies and definitions [28]. Therefore, results are not directly comparable to the two previous datasets.

However, all of the three datasets provide a description of changes in employment related to the dynamics of the economy. This should entail that, despite differences in definitions, changes in employment in a specific country and a sector are reflected similarly in all datasets. If the changes concern the core of the data, i.e., employment of residents in domestic units, then the correlation is likely to be linear. Accordingly, we tested this hypothesis using linear models between the changes in LFS estimates and changes in the NAIO or SBS estimates by sector and by country (removing the years with a break in the time series). The correlation is significant but limited. It is slightly higher between LFS and NAIO, which partially derives from LFS, than between LFS and SBS (see Equations (1) and (2)).

$$\frac{e_{LFS,\ y+1,\ s}}{e_{LFS,\ y,s}} = \alpha_s \frac{e_{NAIO,\ y+1,s}}{e_{NAIO,y,s}} \quad (1)$$

Adjusted R-squared: 0.2352, p-value: $< 2.2 \times 10^{-16}$.

$$\frac{e_{LFS,\ y+1,\ s}}{e_{LFS,\ y,s}} = \alpha_s \frac{e_{SBS,\ y+1,s}}{e_{SBS,y,s}} \quad (2)$$

Adjusted R-squared: 0.05761, p-value: $< 2.2 \times 10^{-16}$, with:

- e_{LFS}: Employment reported in the LFS database
- e_{NAIO}: Employment reported in the NAIO database
- e_{SBS}: Employment reported in the SBS database
- y: Year
- s: Sector

To estimate the employment for the years for which information is missing in the LFS, we selected the dataset presenting the highest correlation with the LFS (for the year for which both datasets contain estimates) and containing information for years for which LFS data are missing. Therefore, we used the value estimated using the NAIO data when available, since these data show a higher correlation with the LFS.

In case information is missing for a specific year/country/sector in all the databases, we estimated the value using a linear interpolation between the previous year and the following year, when employment figures are available for the same sector and country. If no data is available for any previous (respectively later) year, we repeated the value for the earliest (respectively latest) year available. This provides a complete dataset of employment in the sectors of interest.

3.3. Employment Estimates in Mixed Sectors

Further processing is needed for the mixed sectors, i.e., sectors in which only some activities use wood or wood-based products, in our case, most secondary transformation (C18, C31, D35, F, and J58). For these sectors, a limited share of the employment should be considered: The share corresponding to

activities that would cease to exist (or would be deeply transformed) if wood or wood-based products were not available. As presented hereafter, the method to calculate the shares differs depending on the nature of the sector.

The three main components of the forest-based sector, namely Forestry (A02 in the NACE rev. 2), manufacture of wood products and products of wood and cork (C16), manufacture of paper and paper products (C17), are almost exclusively related to forest and wood production. Therefore, we considered all employment in these sectors (see Figure 2) to be part of the extended wood-based sector.

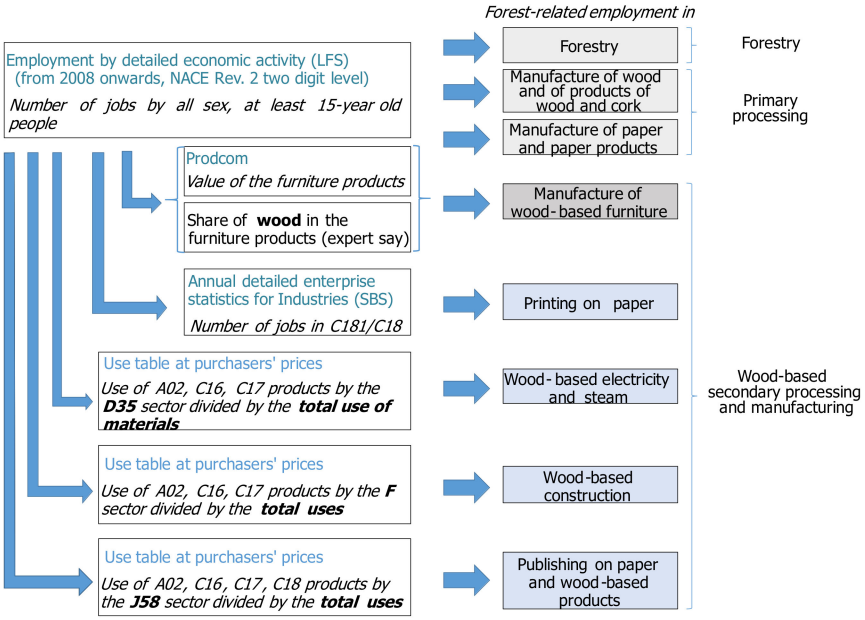

Figure 2. Summary of the data processing.

The sector *Printing and reproduction of recorded media* (C18) contains two subcategories: C18.1 *Printing and service activities related to printing* and C18.2 *Reproduction of recorded media*. Only the first part, which usually dominates the sector, can be considered as requiring wood-based products (mainly paper). In the LFS tables disseminated by Eurostat, the maximum level of details on industries is the two-level digit of the NACE rev. 2 classification. To keep only the employment of the C18 related to printing, we use the share of the C18.1 subsector in the C18 sector estimated from SBS employment data for each member state (MS) and each year (y).

$$e_{C18.1,MS,y} = \frac{e_{SBS,\ C18.1,MS,\ y}}{e_{SBS,\ C18,MS,\ y}} \cdot e_{LFS,C18,MS,y} \quad (3)$$

with:

- $e_{C18.1,MS,y}$: Employment estimated in the C18.1 subsector for the member state *MS* and the year *y*.
- $e_{SBS,\ C18.1,MS,\ y}$: Employment in the C18.1 subsector reported in the SBS database.
- $e_{SBS,\ C18,MS,\ y}$: Employment in the C18 sector reported in the SBS database.
- $e_{LFS,\ C18,MS,y}$: Employment in the C18 sector reported in the LFS database.

For mixed sectors in which wood could be substituted by other materials, we assume that the use of wood is a choice based on economic reasoning: Wood is the most suitable material for the production, entailing lower costs and/or higher product value because of the wood properties as a material, resulting in higher profitability. Thus, depending on the data available, we look at two different perspectives: (i) Product value or (ii) Input value.

To estimate the wood-related employment in the manufacture of furniture, similarly to Ronzon et al. [29], we consider the value of the wood-based furniture products compared to the total value

of furniture produced in the EU member states every year. The value of a large number of furniture products is available from the Prodcom database [30]. The separation between wood-based products and non-wood-based products is straightforward for the majority of the products registered in Prodcom. Products such as *Wooden furniture for shops* or *Wooden bedroom furniture* are clearly made of wood. Other products such as *Metal furniture for offices* and *Mattresses with spring interiors (excluding of cellular rubber or plastics)* do not contain wood. For other products, the share of wood-based products in each category was estimated based on the description of the products and expert knowledge. Shares are presented in Table A1 (Appendix A). These wood shares were crosschecked with bio-based shares defined by Ronzon and M'Barek [13], taking into account that, in that article, all of the bio-based materials used in furniture (mainly wood, but also wool, straw, cotton, etc.) are considered. The wood-based employment in the furniture sector was calculated as follows:

$$e_{C31\ wood,MS,y} = \frac{\sum_p \gamma_p v_{p,ms,\ y}}{\sum_p v_{p,ms,\ y}} \times e_{LFS,C31,MS,y} \quad (4)$$

with:

- $e_{C31\ wood,MS,y}$: Employment estimated in the wood-based manufacture of furniture for the member state *MS* and the year *y*.
- γ_p: Share of wood in the product group *p*.
- $v_{p,ms,\ y}$: Total value of the product group *p* produced by the member state *MS* during the year *y*.
- $e_{LFS,\ C31,MS,y}$: Employment in the C31 sector reported in the LFS database.

For wood-based electricity and steam (energy) production, wood-based construction, as well as publishing on paper and other wood-based products, we relied on a method based on the use values reported in the input–output tables of the national accounts. This method was inspired by Efken et al. [31], as well as the German and the Finnish examples reported in M'Barek et al. [32]. The assumption is that the value of the wood-based material used in the electricity, gas, steam, and air conditioning supply (D35), the construction (F), and the publishing (J58) sectors reveals the importance of the wood-based products in the production and employment of these sectors. Information on the value of the inputs is available from the use tables at purchasers' prices (naio_10_cp16) [33] of the national accounts published by Eurostat. The method to estimate the share of employment related to wood differs slightly across sectors to account for the variety of cases.

In the electricity, gas, steam, and air conditioning supply sector (D35), the activity still depends massively on material inputs. Oil, gas, solid fossil fuels, and primary solid biofuels represent more than 90% of the energy inputs to the energy transformation in 2017 [34], despite the increase in solar, wind, and geothermal sources of energy, as well as significant hydropower production. Therefore, we assumed that the share of wood and wood-products in total material uses (in value) of the sector D35 reflects the share of wood-related activity in this sector.

$$e_{D35,MS,y} = \frac{\sum_{i\ in\ A02,\ C16,\ C17} v_{use,\ i,D35,MS,\ y}}{v_{total\ material\ uses,\ D35,MS,\ y}} \cdot e_{LFS,D35,MS,y} \quad (5)$$

with:

- $e_{D35,MS,y}$: Employment estimated in the D35 subsector for the member state *MS* and the year *y*.
- $v_{use,\ i,D35,MS,\ y}$: Value of the uses from the sector D35 coming from the sectors *i*, for the member state *MS* and the year *y*.
- $v_{total\ material\ uses,\ D35,MS,\ y}$: Total value of the material uses from the sector D35 for the member state *MS* and the year *y*.
- $e_{LFS,\ D35,MS,y}$: Employment in the D35 sector reported in the LFS database.

In the construction (F) and publication sectors (J58), a share of the economic activity is dedicated to the supply of services such as activities related to the design or architecture. Therefore, we suggested that the share of wood products in the total uses is a better representation of the contribution of wood to these sectors. Most construction material used in construction comes from the manufacture of wood and of products of wood and cork (C16), including prefabricated pieces for construction. Some inputs come directly from forestry (A02) or come from the pulp and paper industries. Inputs from these three sectors are considered in the calculation. For publishing, the main uses are paper (C17) and printing on paper (C18.1). Some material can be sourced from forestry and the manufacture of wood products. Equation (6) shows the calculation for the construction sector and Equation (7) for the publication sector.

$$e_{F,MS,y} = \frac{\sum_{i\ in\ A02,\ C16,\ C17} v_{use,\ i,F,MS,\ y}}{v_{total\ uses,\ F,MS,\ y}} \cdot e_{LFS,F,MS,y} \quad (6)$$

with:

- $e_{F,MS,y}$: Employment estimated in the F subsector for the member state *MS* and the year *y*.
- $v_{use,\ i,F,MS,\ y}$: Value of the uses from the sector F coming from the sectors *i*, for the member state *MS* and the year *y*.
- $v_{total\ uses,\ F,MS,\ y}$: Total value of the material uses from the sector F for the member state *MS* and the year *y*.
- $e_{LFS,\ \ F,MS,y}$: Employment in the F sector reported in the LFS database.

$$e_{J58,MS,y} = \frac{\sum_{i\ in\ A02,\ C16,\ C17,\ C18} v_{use,\ i,J58,MS,\ y}}{v_{total\ uses,J58F,MS,\ y}} \cdot e_{LFS,J58,MS,y} \quad (7)$$

with:

- $e_{J58,MS,y}$: Employment estimated in the J58 subsector for the member state *MS* and the year *y*.
- $v_{use,\ i,J58,MS,\ y}$: Value of the uses from the sector J58 coming from the sectors *i*, for the member state *MS* and the year *y*.
- $v_{total\ uses,J58F,MS,\ y}$: Total value of the material uses from the sector J58 for the member state *MS* and the year *y*.
- $e_{LFS,\ \ J58,MS,y}$: Employment in the J58 sector reported in the LFS database.

In the complementary datasets that were used to calculate the contribution of wood to the different sectors, information is missing for some countries, sectors, and years. To fill the gaps, we used a linear interpolation between two known years for the same country and sector. If data is missing, we replicated the value of the latest (respectively the earliest) year for which information is available. After this calculation, programmed in an R-script [35], we obtained a dataset covering all EU-28 between 2008 and 2018. The method can be replicated when new data become available.

In this study, we conducted a first analysis of the full dataset to evaluate the employment specialisation in the EU countries. Therefore, the value chains were split into three main parts: *Forestry*, *Primary processing*, and *Wood-based secondary processing and manufacturing* (Figure 2). This emphasises the role of a country as a supplier of raw material, as a transformer into an intermediate product or as a producer of final products, which usually is the most profitable activity. The shares of wood-based employment in each category were estimated for each country. A k-means algorithm was then applied to the shares in each part of the value chains to group countries according to their wood-based employment profiles.

4. Results

According to our estimates, in 2018 the extended wood-based sector employed 4.5 million people in the EU-28. From 2008 to 2013, in the aftermath of the financial crisis, employment decreased by

20%. It has been quite stable ever since (Figure 3). The decrease was apparent in all sub-sectors except the energy and forestry sub-sectors. The most notable decrease took place in wood manufacturing (C16) and printing (C18.1). After 2013, most sectors have recovered, at least partly—including the paper industry—except for the printing industry, which continued to decrease. The replacement of newsprints and books by electronic media has played an important role in the decline of graphic papers and printing, while the development of E-commerce has favoured the expansion of packaging production (see e.g., [18,36]).

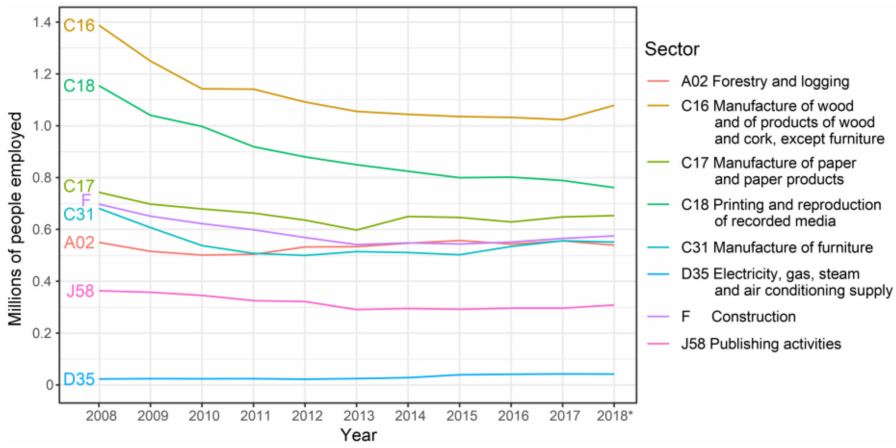

Figure 3. Change in employment in forestry, the primary, and secondary processing of wood in the EU-28 (For mixed sectors, 2018* preliminary estimates).

The total number of persons employed in wood-based energy rose from 23,000 to 42,000 from 2008 to 2018. The share of wood-related employment in the energy sector has been on the increase, responding to the political will to develop renewable energies. Wood-related employment in the construction sector stayed at the same level during the entire period (3.7% of the sector) despite policies promoting the use of wood in construction in many EU countries.

The dataset highlights the specialisation of wood-based employment in the EU member states. Figure 4 shows the distribution of countries by their share of wood-based employment in forestry, primary processing, and secondary processing. It depicts results of a k-means classification in four categories or specialisation patterns:

- Countries with an emphasis on forestry and primary processing (Croatia, Czechia, and Latvia);
- Countries with the entire value chain, from primary production to the final goods and services (Bulgaria, Estonia, Finland, Hungary, Lithuania, Romania, Slovakia, and Sweden);
- Countries with the entire value chain, but dominated by the primary processing and secondary processing and manufacturing (Austria, Cyprus, France, Greece, Italy, Luxemburg, Poland, Portugal, Slovenia, and Spain);
- Countries with an emphasis on secondary processing and manufacturing (Belgium, Denmark, Germany, Ireland, Malta, the Netherlands, and the United Kingdom). These countries are concentrated on the part of the value chains with the highest value added.

Figure 5 highlights the geographical pattern. All of the countries of the first group are located in the eastern part of the EU, the countries of the third group are in central-southern EU, while those of the fourth group are in north-western Europe. With the exception of Germany, the countries of the latter group are characterized by low endowment of forest resources. Most of the wood-related employment is located in Germany, Poland, Italy, the UK, France, and Spain. Nordic countries, where forestry and the wood-based industries play an important role in the national economy, contribute modestly to the EU-28 wood-based employment. This is hardly surprising, given their small populations and high productivity compared to central European countries.

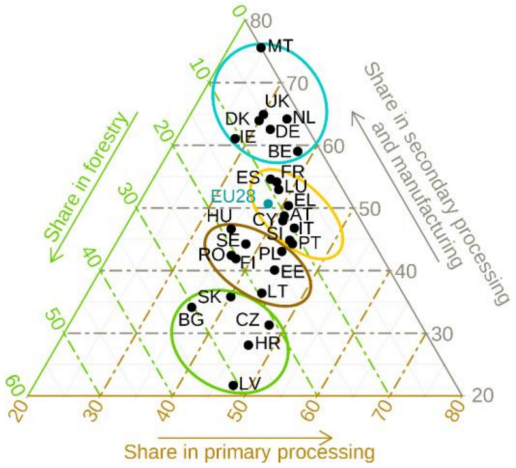

Figure 4. Distribution of wood-based employment in EU countries (average 2008–2018). Countries are indicated with their EU two-letter codes. EU28: European Union's composition in 2017. Circles highlight the grouping according to a k-means with 4 categories.

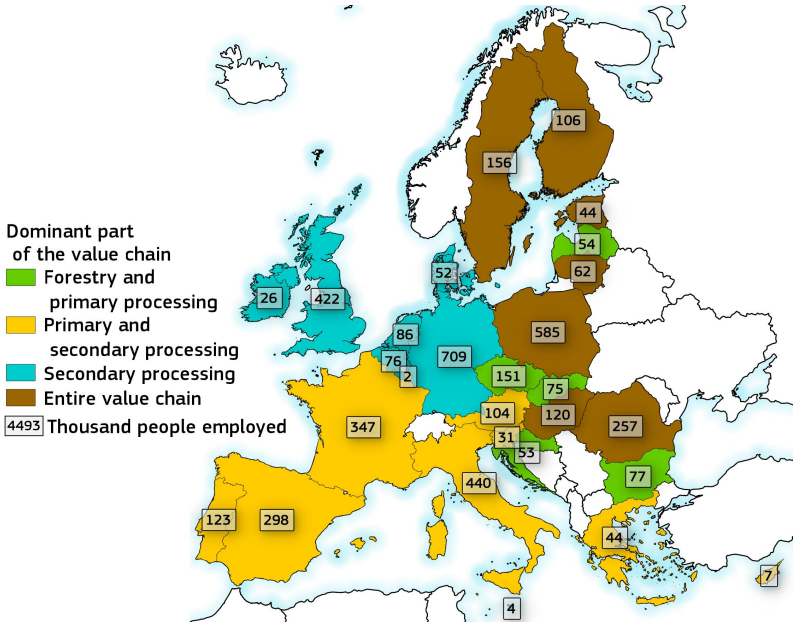

Figure 5. Number of persons employed in the extended wood-based sector in 2017 (figures) and most important parts of the wood-based value chains employing people in the EU countries (colours, average 2008–2018).

5. Discussion and Conclusions

This study has built a unique dataset for the comprehensive monitoring of forest and wood-based employment in the European Union. Earlier studies have provided only limited insight into the wood-based employment. They either restricted the analysis to the primary transformation level—generally considered as constituting the forest-based sector [6,37] or considered a smaller number of secondary processing sectors. The extension we have offered gives a better insight into the employment directly related to the manufacture of wood-based products. In addition, it allows for a more complete assessment of the latest employment trends, such as the expansion of the industries operating in the wood-based sector beyond the traditional products and their move downstream in the value chain [38,39].

Results indicate that employment in the wood-based value chains in Europe has been decreasing, albeit at a different pace depending on activities and countries. The printing sector was the most

affected, while employment in forestry, wood-based construction, and energy has remained quite stable since 2013. Upturns such as the development of the forest-based bioeconomy could be an opportunity to strengthen the vitality of the wood market players and their workforce [40]. Our results also revealed that most of the wood-based employment in the EU takes place in more downstream parts of the value chains.

We have used one single definition of employment, in line with the labour force survey used as a reference statistic. Because of the differences in definitions and sampling designs between LFS and SBS, we obtained values for the processing sectors usually 5% to 10% higher than alternative studies relying on SBS data (see e.g., estimates of primary processing in [13]).

Our methodology, which is based on the value of wood-based materials used by industries, provides a first evaluation of the share of wood-based employment. It assumes a linear correlation between work intensity and the value of inputs at the sector level. However, the processing of wood-based products may require different working intensity and skills than the processing of other materials. For example, the production of energy from biomass usually requires more people employed than the production of energy from non-renewables [41]. Moreover, higher-value products can be used as inputs in order to reduce manufacturing costs. For example, the building with wood-based prefabricated construction elements increases the value of wood product used but reduces the work required on-site, reported under the construction sector [42]. Hence, there is still room for improvement. For instance, specific data collection from industries could help improve the quality of the results and allow for prospective analyses.

We consider that the results presented in this paper reflect quite accurately actual employment patterns and trends. Nonetheless, caution is called for in interpreting the results. On the one hand, the data underlying this analysis are sometimes incomplete and/or inaccurate in spite of considerable efforts invested in the collection of information. On the other hand, comparisons between indicators for countries are often not possible because data sets, though coherent for one country over time, may not be comparable with other data series.

This study constitutes a step forward as regards the assessment of trends and patterns in forest-based employment throughout the EU economy. It is currently limited to forestry and wood-based activities. However, the methodology could be tailored to account for the differences between the manufacture of items based on wood or on other materials. Further, future effort could be expended in considering employment related to non-wood ecosystem services. Finally, to enrich the analysis, the database should be expanded to encompass other aspects of the employment dynamics, such as gender balance, age structure, and education level. On a more general note, this study has demonstrated the need to strengthen the cooperation between providers and users of the official statistics concerned, to reduce data inconsistencies and increase comparability across countries and sectors.

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Appendix A

Table A1. Shares of wood products in the furniture products registered in Prodcom.

Prodcom Code	Product Definition	Wood Share γ_p
31001150	Swivel seats with variable height adjustments (excluding medical, surgical, dental or veterinary, and barbers' chairs)	0%
31001170	Upholstered seats with metal frames (excluding swivel seats, medical, surgical, dental or veterinary seats, barbers' or similar chairs, for motor, vehicles, for aircraft)	0%
31001190	Non-upholstered seats with metal frames (excluding medical, surgical, dental or veterinary seats, barbers' or similar chairs, swivel seats)	0%
31001210	Seats convertible into beds (excluding garden seats or camping equipment)	0%
31001230	Seats of cane, osier, bamboo or similar materials	0%
31001250	Upholstered seats with wooden frames (including three piece suites) (excluding swivel seats)	20%
31001290	Non-upholstered seats with wooden frames (excluding swivel seats)	20%
31001300	Other seats, of HS 9401, n.e.c.	0%
31001400	Parts of seats	0%
31002030	Parts of furniture, of metal, n.e.s. (excl. of seats and medical, surgical, dental or veterinary furniture)	0%
31002050	Parts of furniture, of wood, n.e.s. (excl. seats)	100%
31002090	Parts of furniture, n.e.s. (excl. of metal or wood, and of seats and medical, surgical, dental or veterinary furniture)	0%
31011100	Metal furniture for offices	0%
31011200	Wooden furniture of a kind used in offices	80%
31011300	Wooden furniture for shops	80%
31021000	Kitchen furniture	50%
31031100	Mattress supports (including wooden or metal frames fitted with springs or steel wire mesh, upholstered mattress bases, with wooden slats, divans)	30%
31031230	Mattresses of cellular rubber (including with a metal frame) (excluding water-mattresses, pneumatic mattresses)	0%
31031250	Mattresses of cellular plastics (including with a metal frame) (excluding water-mattresses, pneumatic mattresses)	0%
31031270	Mattresses with spring interiors (excluding of cellular rubber or plastics)	0%
31031290	Mattresses (excluding with spring interiors, of cellular rubber or plastics)	0%
31091100	Metal furniture (excluding office, medical, surgical, dental or veterinary furniture; barbers' chairs—cases and cabinets specially designed for hi-fi systems, videos or televisions)	0%
31091230	Wooden bedroom furniture (excluding builders' fittings for cupboards to be built into walls, mattress supports, lamps and lighting fittings, floor standing mirrors, seats)	80%
31091250	Wooden furniture for the dining-room and living-room (excluding floor standing mirrors, seats)	80%
31091300	Other wooden furniture (excluding bedroom, dining-, living-room, kitchen, office, shop, medical, surgical, dental/veterinary furniture, cases and cabinets designed for hi-fi, videos and televisions)	80%
31091430	Furniture of plastics (excluding medical, surgical, dental or veterinary furniture—cases and cabinets specially designed for hi-fi systems, videos and televisions)	0%
31091450	Furniture of materials other than metal, wood or plastic (excluding seats, cases and cabinets specially designed for hi-fi systems, videos and televisions)	0%

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