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The Agency aims to support and enhance forestry and its role in sustainable development by providing innovative, high-quality scientific research, technical support and consultancy services.

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Executive summary

This report reviews existing studies estimating future timber prices and price elasticities of demand for emerging species and different product categories, focusing on studies most relevant to UK timber markets. The emerging species considered are those tree species predicted to have a more prominent role in UK forestry in the future. Undertaken as part of Forest Research's Research Programme on Markets for forest products and services, the review aims to provide information to support the transition to a low carbon economy in the context of a changing climate and to help inform decisions on planting alternative emerging species.

The core part of this review was based on a search through the academic literature, capturing publications released since 2010 that referenced relevant forestry economics terms and covered timber markets in the UK, Europe, North America, Chile and New Zealand. This search was supplemented by publications suggested by steering group members, with a total of 103 publications reviewed in full. Additionally, publicly available data and reports from relevant UK and international forestry organisations for the same period were evaluated.

The review found research estimating future timber prices and analysing historic prices for a small number of UK emerging species (red oak, aspen, silver maple, black walnut and Weymouth pine), with these studies confined to the North American market. In the USA, from 2000 to 2020:

- Black walnut has been consistently the highest priced wood, although prices have been volatile.
- Aspen has consistently been one of the lowest value woods.
- Red oak prices appear to have decreased during the period covered, with its value shifting from above that of white oak and soft maple to below.
- Maple (silver maple) has been fairly stable and has largely followed the price of white oak for both high- and mid-quality sawnwood.

No estimates of elasticities for individual emerging species were found in the literature, probably because of a lack of available data, with the general focus on wood products rather than on species when estimating elasticities. For elasticities of different product categories more estimates were found, with a small number of studies for the UK (or small groups of countries that included the UK), as well as countries similar to the UK, based on key timber market characteristics. According to UK industry reports, the most frequently reported factors influencing demand for wood products were the private housing market and the repairs, maintenance and improvement market. The review found that:

- Sawnwood demand is generally price inelastic over the short term, with prices having little effect on demand.
- Small roundwood is also price inelastic, although this is based on a single study as part of a larger product grouping (other industrial roundwood).
- Demand for wood-based panels is price inelastic, albeit slightly more responsive to prices than sawnwood and small roundwood.
- Woodfuel demand is highly inelastic according to estimates from global studies, although this result may not hold in the UK as there is more choice regarding the type of energy to use than in many lower income countries.
- For paper-based products, demand for printing and writing paper is generally found to be less inelastic (more responsive to prices) than other paper and paperboard, and also less inelastic over the long term than newsprint.

The following recommendations are made:

- Gather more data on timber sales of individual species in the UK for emerging species. Findings from ongoing and future research into key characteristics of emerging species could help complement price data and allow greater focus on those species with the highest potential timber and non-timber values.
- Gather data on a wider selection of non-emerging species that could be used to benchmark prices for emerging species with similar characteristics.
- Consider analysing data for emerging species in other countries to estimate relative prices in their markets as a way to help benchmark and estimate the level of prices for emerging species that might be expected in the UK.
- There are often comparatively small gains in the accuracy of short-run (i.e. less than one year) timber forecasts when using more complex models compared with a simple average of previous prices. Relatively simple models such as the SARIMAX model (using historical price data, time of year and construction activity) could be useful for short-run timber price forecasting.
- For forecasting long-term demand and prices, the Global Forest Products Model appears to be the best starting point and is the most frequently used model of this type.

Introduction

This Research Report reviews studies that estimate future timber prices and price elasticities of demand for emerging species and different product categories, especially those that are most relevant to UK timber markets. The emerging species considered in this study are those tree species that are predicted to have a more prominent role in UK forestry in the future because of the increased risks associated with continuing reliance on the narrow range of species currently in widespread use. These risks include threats such as pests and diseases, wind, and fire, each of which is expected to increase with climate change.

There has been research on the biological suitability and physical characteristics of emerging species in a UK context, but there is a significant gap in knowledge regarding economic aspects and how increased use of these species will fit with the UK timber market. This is of critical importance for productive forestry, as decisions are made with economic returns in mind. The review of existing studies aims to provide a clearer picture of prices that may be expected for these species and the economic factors likely to affect them. This knowledge is expected to be useful for decision-makers considering planting emerging species in the future, helping to ensure more efficient use of resources.

Emerging species

In this review, emerging species are defined as those listed in Table 1 and identified in Forest Research's Priorities for research on Emerging Species. Emerging species are split into two categories based upon the scale at which planting trials have been undertaken to date, thus reflecting the extent of existing knowledge about the performance of each species in the UK. Secondary species are those that have been planted on a small but significant scale, providing a solid knowledge base and therefore greater confidence in their suitability for use (Forest Research, 2022c). Plot-stage species are species that have not been planted on any significant scale but have shown promise in their suitability for wider use (Forest Research, 2022c). Because of the more limited experimental data for the latter, until further trials have been carried out on them, there is less confidence in their suitability compared with secondary tree species. It should be noted that emerging species are not necessarily non-native species.

Table 1 Emerging species.

Emerging species according to Forest Research classification
Secondary species
• Black and balsam poplar species and hybrids *(Populus nigra spp. Betulifolia)*
• Black walnut *(Juglans nigra)*
• Cider gum *(Eucalyptus gunnii)*
• Common walnut *(Juglans regia)*
• Grand fir *(Abies grandis)*
• Grey alder *(Alnus incana)*
• Lawson cypress *(Chamaecyparis lawsoniana)*
• Leyland cypress *(Cuprocyparis leylandii)*
• Noble fir *(Abies procera)*
• Norway maple *(Acer platanoides)*
• Radiata/Monterey pine *(Pinus radiata)*
• Rauli *(Nothofagus alpina)*
• Red oak *(Quercus rubra)*
• Roble *(Nothofagus obliqua)*
• Serbian spruce *(Picea omorika)*
• True service-tree *(Sorbus domestica)*
• Western hemlock *(Tsuga heterophylla)*
• Western red-cedar *(Thuja plicata)*
• Wild cherry/gean *(Prunus avium)*
• Wych elm *(Ulmus glabra)*
Plot-stage species
• Aspen *(Populus tremula)*
• Atlas cedar *(Cedrus atlantica)*
• Big-leaf maple *(Acer macrophyllum)*
• Caucasian silver fir *(Abies nordmanniana)*
• Cedar of Lebanon *(Cedrus libani)*
• Coast redwood *(Sequoia sempervirens)*
• European silver fir *(Abies alba)*
• Giant sequoia *(Sequoiadendron giganteum)*
• Italian alder *(Alnus cordata)*
• Japanese red cedar *(Cryptomeria japonica)*
• Lenga *(Nothofagus pumilio)*
• London plane *(Platanus × hispanica)*
• Macedonian pine *(Pinus peuce)*
• Maritime pine *(Pinus pinaster)*
• Oriental spruce *(Picea orientalis)*
• Pacific silver fir *(Abies amabilis)*
• Red alder *(Alnus rubra)*
• Shining gum *(Eucalyptus nitens)*
• Silver maple *(Acer saccharinum)*

Emerging species: characteristics and value

Lancaster (1966) proposed that the value an individual places on a product is derived from the value placed on the separate characteristics it possesses. For example, an individual does not value a plank of wood per se but rather the characteristics it has, such as strength, durability, weight, ease of working, aesthetics and sustainable certification. The relative value placed on each characteristic will vary depending on the intended use of the wood/tree and individual taste, and it is important to note that these values may extend beyond timber properties. This also applies to intermediate processing, such as at sawmills, where the ease at which a type of sawlog can be cut will be a key determinant of demand for that type of sawlog. For softwood used in construction, strength grading is often regarded as a key characteristic (and determinant of value) as certain thresholds must be met for the timber to be safe to use. In theory, where wider factors (e.g. harvesting access) are the same, if two species of tree had exactly the same characteristics then they would have exactly the same value, and those with similar characteristics are likely to have similar values (assuming these characteristics are key determinants of value). Therefore, understanding and measuring key characteristics for emerging species may provide a useful avenue to estimating their potential value and how they may fit into existing UK markets and supply chains.

There have been few studies conducted to measure the timber properties of emerging species that would allow comparisons to be made both between emerging species and with species that are already well established in the UK.

From those that do, the results are generally based on small sample sizes because of the limited scale at which many of these species are currently planted in the UK. Research carried out by Gil-Moreno, Ridley-Ellis and Mclean (2016) tested the strength, stiffness and wood density of four species including the emerging species noble fir, western red-cedar and western hemlock. Of the species tested, all were found to be capable of producing structural timber, but western red-cedar timber was found to perform more poorly than the other species.

Wilson (2011) provides guidance to foresters on what to consider before planting a wide number of less common forestry species in Scotland, including emerging species of particular interest such as western red-cedar, coast redwood, giant sequoia, western hemlock, grand fir, noble fir, European silver fir, Caucasian silver fir, Lawson cypress, Leyland cypress, Japanese red cedar and Macedonian pine. Wilson's report covers many aspects of these species in relation to forestry, including useful summaries of what wood products were being produced from these species in Great Britain at the time. While the descriptions provide a useful indicator of the perceived characteristics of the timber, it should be noted this does not necessarily reflect the true characteristics of wood from these species measured through methodical testing. Further research into timber properties for minor species (including emerging species) is ongoing and as further results are published it may become clearer where these will fit within the UK timber market.

Current UK growing stock and wood product use

In statistics published as part of the National Forest Inventory, conifer species that are reported separately (Sitka spruce, Scots pine, Corsican pine, Norway spruce, larch species, Douglas fir and lodgepole pine) are not among the emerging species. The 4.3% of Great Britain growing stock classified as 'other conifers' covers both emerging species as well as less frequently stocked conifer species not currently regarded as emerging species (Forest Research, 2021a, Table 1.10c); however, no further breakdown of this category is provided. For broadleaves, the equivalent statistics are less clear as the species reported separately (oak, beech, sycamore, ash, birch, sweet chestnut, hazel, hawthorn, alder and willow) could potentially include some emerging species, for example, red oak and Italian alder. Approximately 9.3% of the Great Britain growing stock of broadleaves is categorised as 'other broadleaves', covering those species not reported separately including any emerging species (Forest Research, 2021a, Table 1.11c). This review aims to cover all the species listed in Table 1, while recognising that existing studies and separate data available may be restricted to only a few.

In 2020, the volume of softwood imports of 'industrial roundwood' was equivalent to 10.2% of domestic production (Forest Research, 2021b) and softwood imports accounted for only 4.3% of the total softwood consumed by UK sawmills (Forest Research, 2021a, Table 2.7a). However, in 2020, 68.3% of the total UK apparent consumption of softwood sawnwood (the primary end product) consisted of imports (Forest Research, 2021a, Table 3.2). This indicates that although UK sawmills largely process domestically grown softwood, there is a huge shortfall in the supply of sawnwood that is filled by imports.

The volume of 'industrial roundwood' hardwood imports in 2020 accounted for 43.8% of apparent domestic consumption (Forest Research, 2021b), with 84.4% of domestically produced hardwood being used as woodfuel (Forest Research, 2021a). Consumption of domestically produced hardwood sawnwood is dwarfed by imports, which account for 97.5% of apparent consumption (Forest Research, 2021a, Table 3.2). A large proportion of UK imports of hardwood sawnwood consists of oak (29.0%), with birch (5.5%), poplar/aspen (4.6%), beech (2.2%) and ash (1.7%) comprising the next largest share of these imports (Forest Research, 2021b, 'ECE-EU Species' workbook).

Of solid woodfuel imported into the UK, the market is dominated by birch, ash, oak and alder originating from the European Union (EU), predominately from Latvia (66%) (Forest Research, 2020). There has also been an increase in recovered wood being used as woodfuel in recent years, with approximately 2.5 million tonnes used in 2020 (Forest Research, 2021c). Most wood pellets consumed in the UK are imported and in 2020 imports of wood pellets totalled 9.1 million tonnes, with around 80% imported from North America. A further 0.3 million tonnes of wood pellets were produced in the UK (Forest Research, 2021c). From 2008 to 2015, consumption of wood pellets in the UK increased by a factor of 9.1 (Thrän *et al*., 2019). The inputs used to make wood pellets can vary between countries, with approximately 90% of the input for wood pellets in Austria coming from sawmill residues (Kristöfel *et al*., 2015) compared with in the USA, where it was estimated that 38% comes from residues with the rest coming from harvested wood (Franco, 2022).

The UK market

Forest products

In this report forest products have been categorised based upon the United Nations Economic Commission for Europe (UNECE) classification used in the Joint Forest Sector Questionnaire Definitions (UNECE, 2020); see the Glossary for full definitions. This categorisation is used for the largest source of international trade statistics for forestry, including those submitted by the UK as well as major trading partners in the EU and North America. Its clear definitions and conversion factors make incorporating other sources of data straightforward. Where products have been referred to using different terminology – for example, in many North American studies – the UNECE terminology has been used instead to facilitate comparisons.

Many forest products are inputs used in making other products. It is important to understand these links as they can affect market behaviour for each product. A simplified overview of the links between different forest products is presented in Figure 1. Many elasticities are determined to some degree by these links in production. For example, an increase in the price of one product may cause an increase or decrease in demand for another, depending upon whether the other is a complement or substitute for that good. Products that are directly or indirectly linked can also help guide which variables to include in any market analysis.

UK production

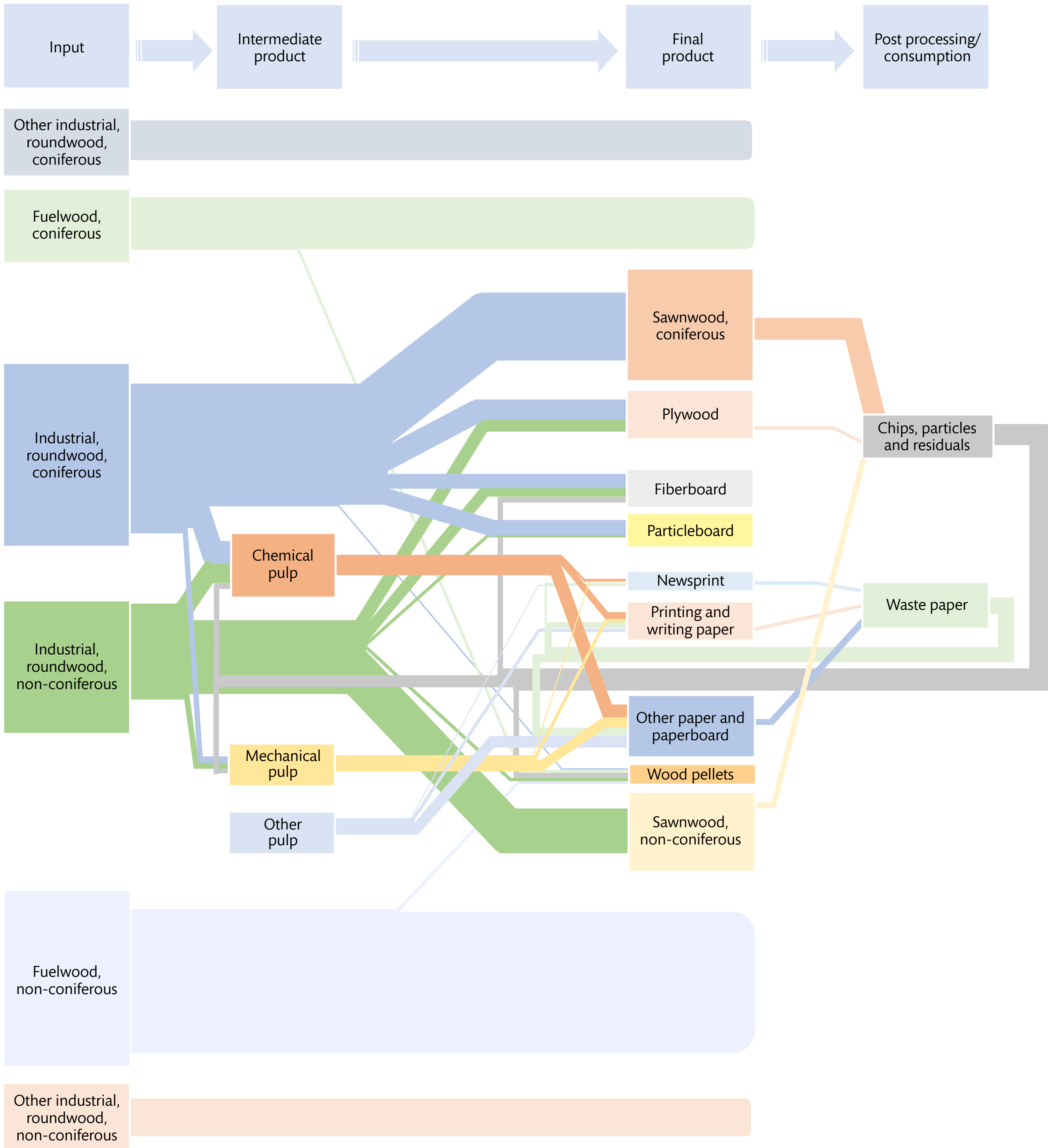
An overview of the most recent statistics on UK production, imports and exports of various wood products, and the links between them, is shown in Figure 2. These data illustrate how the bulk of UK imports come from processed wood products such as sawnwood and wood pellets/briquettes/logs, with the volumes of these far greater than volumes produced domestically (Forest Research, 2021a). It should be noted that the estimates for UK domestic production may be conservative as data are based on surveys of medium and large-scale producers and may therefore miss the contribution of small-scale forest and milling operations (Cooper, pers. comm.).

Comparable foreign markets

While the UK wood product market is unique, there are other nations that share some, or many, of the main characteristics that define it. These characteristics can be summarised as:

- **A low percentage of tree cover** (13% of the total land area in the UK): 10% in England; 19% in Scotland; 15% in Wales; and 9% in Northern Ireland (Forest Research, 2021a).
- **A mix of state and private forests:** 37.9% of woodlands in Great Britain woodland is owned or managed by Forestry England, Forestry and Land Scotland, or Natural Resources Wales, local authorities, or other public bodies. A further 8.2% is owned by voluntary subscription charities (Forestry Commission, 2020).
- **Non-coniferous woodland is mostly privately owned:** 55.6% of broadleaf woodland in Great Britain is owned by private personal or private business entities, with only 12.5% owned by the public forest estate compared with the 48.6% ownership of coniferous woodland (Forestry Commission, 2020).
- **Most harvested softwood is certified and just less than one-half of all woodlands is managed under a certification scheme:** in 2020, an estimated 82% of all softwood removals (including 67% of private sector removals) came from certified woodlands (Forest Research, 2021a, Table 2.28a); 44% of all UK woodlands in 2020 were certified to the UK Woodland Assurance Standard under the Forest Stewardship Council scheme or the Programme for the Endorsement of Forest Certification scheme, or both (Forest Research, 2021a, Table 1.4).
- **A high proportion of wood products are imported:** in 2020, 87.6% of the UK's apparent consumption of wood was accounted for by imports (Forest Research, 2021a, Table 3.1).
- **Most imports of finished 'value added wood products' are from the EU:** in 2020, 76.9% of furniture and 86.0% of wood for builders' joinery and carpentry was imported from EU countries (UNECE/FAO, 2021, Tables 7.1 and 7.2).
- **High gross domestic product (GDP) per capita:** ranked 29th globally (World Bank, 2022).
- **Significant demand for woody biomass met mostly by foreign imports:** in 2020, for example, the UK imported 9 million tonnes of wood pellets, with 81% imported from North America (Forest Research, 2021a, Table 3.4).

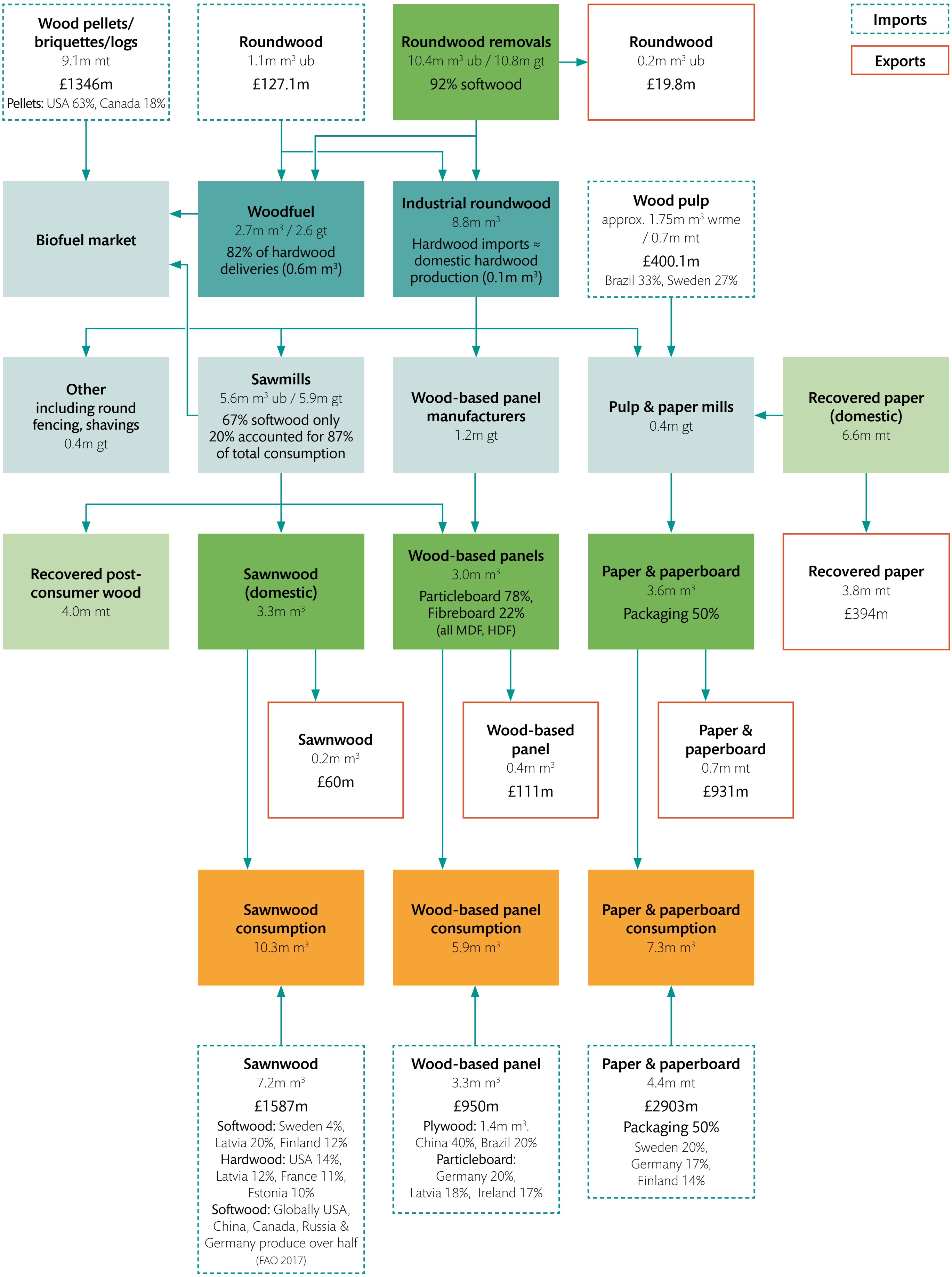
Figure 1 Pathways from harvesting to production of final wood products.



Source: Nepal, Johnston and Ganguly (2021).

Several wood product studies have used descriptive statistics to group countries. This is often done to provide larger sample sizes and to obtain more robust statistical results, while still accounting for structural differences between countries. An overview of the different countries that the UK has been grouped with in previous studies is shown in Appendix A. Those countries most frequently grouped with the UK are Denmark, Ireland, the Netherlands and Qatar. Countries that the UK has been grouped with for each product may provide data and elasticities that are comparable with those of the UK and therefore may provide insights when information is unavailable for the UK.

Figure 2 UK wood product pathways including imports and exports.



Data based on Forestry Statistics 2021 (Forest Research, 2021a) unless otherwise stated. Finanical figures from 2020. mt = metric ton, ub = underbark, gt = green tonnes.

Wood processing demand

A broad summary of the quality requirements of each sector of a given country's forestry supply chain, from harvesting to final product, is given by Manley (2002), who notes the following 'requirements for the forestry value chain to operate successfully':

1. Wood product performance requirements (based on such characteristics as strength, stiffness, stability, appearance and durability) must be clearly defined for different end uses.
2. Wood manufacturers need to process and grade products to meet these requirements.
3. Forest growers need to identify and segregate stands and logs based on log and wood properties.
4. Forest growers need to evaluate decisions about tree breeding and genetics deployment, species choice, the selection of location and site, and forest management, in terms of their impact on log and wood properties, as well as volume.

This summary clearly indicates the importance of quality and consistency throughout the value chain, and the interdependence of each sector (further information can be found in Appendix C: The role of sawmills in the supply chain). It is therefore important to consider how emerging species could fit within each of these sectors, as problems in one could have knock-on effects elsewhere and a breakdown at any point in this chain could make wood production using a particular species unviable, creating barriers to its use through a lack of supply. At the same time, the total volume of material will also be a key factor in whether growing a particular species is economically viable, with higher volumes allowing cost savings through economies of scale. Adjusting machinery is expensive, especially for larger sawmills, and a steady supply of similarly sized and shaped sawlogs may be necessary for such operations to be cost effective. An increase in transport costs may weaken the position of sawmilling companies and, as a result, they may be more likely to use locally sourced roundwood, even if this does not meet their usual size requirements. In this case we may expect to see an increase in demand and consequently an increase in price for smaller and lower quality roundwood.

There are many factors that may affect the supply of timber. Although no relevant UK studies were identified, factors cited in a Norwegian study – a country frequently grouped with the UK in previous studies based on similarities in the economy and forestry sector (see Appendix A) – identified some key issues. The study found that prices and expectation of prices were a key consideration, along with rate of return, and the costs of operation. Less obvious factors, such as off-farm income, education level, wealth and age, in addition to characteristics of the forest area in question such as size and the management plan, were also found to be important (Ranta *et al*., 2017). Some information on timber market supply and demand in the UK is available (mainly by paid subscription) from Timber Development UK (e.g. Market Data; Timber Development UK, 2023).

UK price data

The largest timber price dataset for the UK consists of import/export statistics from FAOSTAT (FAOSTAT, 2020). This dataset can be used to find the average import/export price of some wood products from as long ago as 1961 and for most products from 1991 onwards. The average import/export price gives an indication of the cost, insurance and freight price and therefore includes more than just the cost of the wood product itself. A study of FAOSTAT data from 2001 estimated that the average freight price (including insurance) was 20% of the import value for industrial roundwood, 12% for sawn timber, 4% for wood-based panels, 17% for waste paper, 8% for wood pulp, 7% for other paper and paperboard and 4% for newsprint (Turner and Buongiorno, 2001).

FAOSTAT data do not include a detailed breakdown by species, only distinguishing coniferous, non-coniferous and, in some cases, between tropical and non-tropical. Data published by UNECE are broadly in line with those of FAOSTAT; however, the Joint Forest Sector Questionnaire provides a more detailed breakdown of timber trade statistics for some species groups, including estimates for selected individual species, although this dataset only goes back as far as 2011 (UNECE, 2022). Caution is needed when using UK import and export data published by FAOSTAT to estimate average prices prior to 2012 as one study found that actual import and export volumes for the UK were probably far lower in 2011 (and probably in earlier years too) than had been reported by the UK (Moore, 2012). Use of the refined estimates implied a far higher estimate of the price of roundwood imports in 2011 (£84/m^3) than that implied (£47/m^3) by the official statistics (Moore, 2012, p. 13). Whether this is also an issue for other countries is unknown, but for the many studies that estimate elasticities of forest products using the FAOSTAT dataset – which is popular because of its length and ease of use – pre-2012 data quality needs to be considered.

UK timber price data for softwood sawlogs have been published by Forest Research since 1985, with data split between spruce and 'other conifers' since 2018, and for small roundwood from 2018. The relative price trends of coniferous standing sales, coniferous sawlogs and small roundwood are shown in Figure 3. Most UK companies involved in forestry presumably maintain records of timber prices for their sales and purchases, although price information for specific emerging species from these datasets is likely to be sparse in most cases. If these data on volumes sold and associated revenues could be collected and aggregated, possibly along with any relevant sales data for the public forest estate, then this would provide a useful guide to current timber prices for emerging species.

Comparisons of price data, both within and between different species, are complicated by several factors, with differences in size grade, quality, type of sale, local market and other factors creating a myriad of influences that could affect the price. Without an appreciation of the impact of these factors, incorrect conclusions may be drawn about the value of wood products expected from a given species and therefore its perceived suitability for future production. Differences in quality are seen within the industry as being especially influential for hardwood species, one example being oak, which could have prices as low as £45/m^3 for firewood and as high as £270/m^3 for the highest quality wood panels (Grown in Britain, 2022). In the UK context, production of hardwood is also more fragmented geographically compared with softwood, creating further differences in harvesting costs, market access and, consequently, prices. For more widely planted species categories such as spruce and pine, differences are generally less marked, although they can still be significant, especially for timber grown in different environments. Moving forward, disentangling these factors to help facilitate comparisons between prices for the principal existing species grown and those for emerging species is a key challenge.

Owners of small woodlands may be unable to meet scale demands that large purchasers require, a barrier that may restrict the total volume of wood coming to market. For example, because of transport costs, the main buyers are unlikely to take less than a lorry load of timber (e.g. 8–10 large trees) and if this threshold is not met then no sale will be made. Sellers will then only have the option of selling to small-scale wood processors in a less standardised market, often at lower prices.

UK species price data

Price data for Great Britain are published every 6 months by Forest Research for standing sales (where the purchaser is responsible for harvesting) from the public forest estate (i.e. land managed by Forestry England, Forestry and Land Scotland, and Natural Resources Wales). Together with associated price indices, these data provide useful indicators of the level, changes and volatility in coniferous standing sales prices in Great Britain.

There are sparse published timber price data for individual species available in the UK. In addition to standing sales data for conifers, the timber price data published by Forest Research also cover roadside prices for softwood sawlogs and small roundwood for sales from the public forest estate, with a breakdown of changes in associated softwood sawlog price indices provided for spruce and 'other coniferous' species (Table 2 and Figure 3).

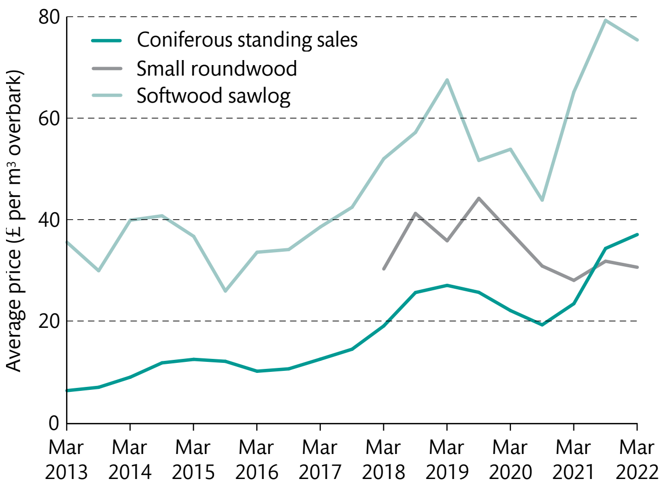
Where timber price data are published for other species in the UK, for example, by Grown in Britain and the Confederation of Forest Industries (Confor), this is generally either for a single point in time through a commissioned market assessment or included as a rough guide in monthly or quarterly sector bulletins. While the data used to estimate these may be of high quality, in contrast to the data published by Forest Research, there is little detail on how the figures were derived, making it difficult to assess how reflective they are of the market as a whole at that time or if the methodology had changed between assessments. Depending on how the data were collected, the figures may only be reflective of a certain area of the UK, and without knowing the exact location or locations of these estimates, their applicability to other areas may be limited. Nonetheless, figures derived from the same source might still be used as a tentative guide to overall trends (while bearing in mind that possible changes in methodology could make such an interpretation misleading).

Table 2 Timber price data for Great Britain.

Price data	Type of data	Period covering	Price in March 2014	Price in March 2018	Price in March 2020	Price in March 2022
Coniferous standing sales price	Real price (£ per cubic metre overbark at 2021 prices)	1986–current	17.96	26.78	29.42	42.51
Softwood sawlogs roadside price	Real price (£ per cubic metre overbark at 2021 prices)	2012–current	44.99	55.57	57.20	76.02
Small roundwood roadside price	Real price (£ per cubic metre overbark at 2021 prices)	2016–current	NA	36.59	42.91	36.88
Coniferous standing sales price	Index (real price (Sep 2021 = 100))	2012–current	45.6	68.0	73.2	105.1
Softwood sawlogs roadside price	Index (real price (Sep 2021 = 100))	2012–current	56.7	70.0	72.0	95.7
Spruce sawlogs roadside price	Index (real price (Sep 2021 = 100))	2016–current	NA	71.5	74.1	96.2
Non-spruce coniferous sawlogs roadside price	Index (real price (Sep 2021 = 100))	2016–current	NA	66.7	68.4	92.9
Small roundwood roadside price	Index (real price (Sep 2021 = 100))	2016–current	NA	96.4	113.1	97.3

Source: Timber Price Indices Data to March 2022 (Forest Research, 2022b).

Figure 3 Comparison of average prices (in real terms at 2021 prices) for different wood products in Great Britain.



Source: Forest Research (2022c).

Price data from other countries

A thorough search for available price data globally identified many sources of data that could be used either directly or indirectly to estimate and forecast emerging species prices and elasticities. It has been argued that the price of roundwood in a given market is rarely determined by the cost of production but is more likely set according to market prices in key countries or regions that act as price leaders (Bluďovský, 2005). Because the UK imports so many wood products, prices in other countries – especially in ones that are large producers – may serve as a useful proxy for UK prices. It is unlikely that future supply of emerging species in the UK would be large enough to significantly alter global supply and therefore prices in key supplier markets. With the addition of transport costs from the countries in question, price levels in these countries could be expected to provide a useful benchmark for prices in the UK, providing the quality of wood produced is equivalent.

Countries such as New Zealand and Chile for radiata pine, France for maritime pine and Austria for European silver fir, have established markets that may offer useful guides to benchmarking UK prices based upon those from elsewhere (Cooper, pers. comm.).

Elasticities

In economics, elasticities are a measure of the change in either the demand or supply of a good caused by a change in some other factor. The most frequently calculated elasticity is the price elasticity of demand, which indicates how much the quantity demanded is expected to change given a change in price. For example, a price elasticity of demand of −0.8 implies that a 1% increase in price would result in a 0.8% decrease in the quantity demanded. The price elasticity of demand is normally negative – with the exception of Giffen goods ('inferior goods') or Veblen ('luxury') goods – and although often reported without the negative symbol, in this report the sign will be included in all cases. An overview of own-price elasticity classifications is shown in Table 3. In the short run, the elasticity of demand is often determined by the availability of substitutes. If substitutes for the product are readily available then demand can shift easily in response to higher prices, whereas if there are no substitutes buyers will either continue buying at the higher price or stop buying entirely. Demand and supply are generally more elastic in the long term as changing to an alternative good or shifting behaviour is generally easier over a longer period, especially for industries that use the good as an input to produce other goods (Varian, 1992).

Other frequently reported elasticities are the income elasticity of demand (the change in the quantity demanded of the good associated with a change in the income of the consumer), the price elasticity of supply (the change in the quantity supplied associated with a change in price) and the cross-price elasticity (the change in demand when the price of a substitute good changes). A further explanation of each elasticity is provided in the Glossary. In this study the elasticities of most interest are the price elasticity of demand and the income elasticity of demand. However, as the price elasticity of supply is potentially also of interest in considering how timber prices for emerging species may evolve in future, these are also considered.

To find relevant wood product elasticities for both the UK and other countries, a search through the most recent literature (2010–22) was undertaken. The following summary information is based on the findings of this search together with input from industry experts. A full overview of the search and review process can be found in Appendix B.

Price elasticities for the UK

Tables 4 and 5 show estimates of elasticities covering the UK from studies published since 2010. In some studies, the UK is grouped with other countries with similar characteristics. While less focused than the forementioned 'UK group' estimates, estimates for Europe are more likely to reflect conditions in the UK than global estimates. In addition to the statistically significant results reported in Table 4 (with those significant at the 99% confidence level in bold), results from studies specifically focused on the UK, or where the UK has been grouped with other similar countries, are provided even where not statistically significant given the greater applicability of these studies.

No indication of the statistical significance of estimates of the elasticities for individual countries taken directly from the GFPM is provided. The elasticities are included in Table 4 for reference, although as their statistical significance is unknown, they are not included in the subsequent discussion of UK elasticities.

Table 3 Own-price elasticity classifications.

Value of own-price elasticity	Demand is	Example	Description
Less than −1 ($E_d < -1$)	Elastic	−1.1, −1.8, −100, −∞ (perfectly elastic)	Quantity demanded decreases by a larger percentage than the percentage increase in price
Equal to −1 ($E_d = -1$)	Unit elastic	−1	Quantity demanded decreases by the same percentage as the percentage increase in price
Between −1 and 0 ($-1 < E_d \leq 0$)	Inelastic	−0.8, −0.5, 0 (perfectly inelastic)	Quantity demanded decreases by a smaller percentage than the percentage increase in price
Greater than 0 (Ed > 0)	Special cases	Giffen good, Veblen good	Quantity demanded increases when price increases

Table 4 Own-price elasticities of demand for, or including, the UK.

Wood product	Own-price elasticity of demand	Long run own-price elasticity of demand	Country/ countries	Reference
Roundwood	No estimates found			
Industrial roundwood	No estimates found			
Sawlogs	No estimates found			
Sawnwood	−0.10		UK (GFPM)	Buongiorno (2014)
	−0.36*		UK (grouped)	Buongiorno (2015)
	−0.16		Global	Buongiorno (2019)
	−0.13**		Global	Morland *et al.* (2018)
(coniferous only)	−0.37*, 0.66*		Europe	Rougieux and Damette (2018)
(coniferous only)	**−0.30****		Global	Morland *et al.* (2018)
(non-coniferous only)	**−0.12****		Global	Morland *et al.* (2018)
Woodfuel and wood pellets	−0.10		UK (GFPM)	Buongiorno (2014)
(woodfuel only)	**−0.15****		Global	Morland *et al.* (2018)
(woodfuel non-coniferous)	−0.04*		Global	Morland *et al.* (2018)
Small roundwood (as 'other industrial hardwood')	−0.05		UK (GFPM)	Buongiorno (2014)
Plywood	**−0.73****	**−0.86** to−0.97****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	−0.29		UK (GFPM)	Buongiorno (2014)
(plywood and veneer)	**−0.62****		UK (grouped)	Buongiorno (2015)
(plywood and veneer)	**−0.35****		Global	Morland *et al.* (2018)
(plywood and veneer)	**−0.34****		Global	Buongiorno (2019)
Particleboard including OSB	**−0.70****	**−0.96** to−1.21****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	−0.29		UK (GFPM)	Buongiorno (2014)
	−0.55**		UK (grouped)	Buongiorno (2015)
	−0.25*		Europe	Rougieux and Damette (2018)
	−0.49**		Global	Morland *et al.* (2018)
	−0.42**		Global	Buongiorno (2019)
Fibreboard	−1.18*		UK	de Oliveira *et al.* (2011)
	−0.01	−0.03** to−0.40**	UK (grouped)	Michinaka, Tachibana and Turner (2011)
			UK (grouped)	Buongiorno (2015)
	−0.46		UK (GFPM)	Buongiorno (2014)
	−0.76,−1.42****		Europe	Rougieux and Damette (2018)
	−0.46**		Global	Morland *et al.* (2018)
	−0.50**		Global	Buongiorno (2019)
Wood pulp	No estimates found			
Newsprint	−0.04	**−0.14** to− 0.44****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
			UK (grouped)	Buongiorno (2015)
	−0.25		UK (GFPM)	Buongiorno (2014)
			Europe	Rougieux and Damette (2018)
	−0.12**		Global	Morland *et al.* (2018)
	−0.24**		Global	Buongiorno (2019)
Fibreboard	−1.18*		UK	de Oliveira *et al.* (2011)
	−0.01	−0.03** to−0.40**	UK (grouped)	Michinaka, Tachibana and Turner (2011)
			UK (grouped)	Buongiorno (2015)

Table 4 (continued) Own-price elasticities of demand for, or including, the UK.

Wood product	Own-price elasticity of demand	Long run own-price elasticity of demand	Country/ countries	Reference
Fibreboard (continued)	−0.46		UK (GFPM)	Buongiorno (2014)
	−0.76,−1.42** **		Europe	Rougieux and Damette (2018)
	−0.46 **		Global	Morland *et al.* (2018)
	−0.50 **		Global	Buongiorno (2019)
Wood pulp	No estimates found			
Newsprint	−0.04	**−0.14** to− 0.44** **	UK (grouped)	Michinaka, Tachibana and Turner (2011)
			UK (grouped)	Buongiorno (2015)
	−0.25		UK (GFPM)	Buongiorno (2014)
			Europe	Rougieux and Damette (2018)
	−0.12 **		Global	Morland *et al.* (2018)
	−0.24 **		Global	Buongiorno (2019)
Printing and writing paper	**−0.29** **	**−0.69** to −0.79** **	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	−0.54 **		UK (grouped)	Buongiorno (2015)
	−0.37		UK (GFPM)	Buongiorno (2014)
	−0.28*, −0.41*		Europe	Rougieux and Damette (2018)
	−0.52 **		Global	Morland *et al.* (2018)
	−0.54 **		Global	Buongiorno (2019)
Other paper and paperboard	**−0.16** **	**−0.15** to −0.31** **	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	−0.52 **		UK (grouped)	Buongiorno (2015)
	−0.23		UK (GFPM)	Buongiorno (2014)
	−0.44*, −0.30*		Europe	Rougieux and Damette (2018)
	−0.28 **		Global	Buongiorno (2019)

Significance: A: p<0.1, *: p<0.05, **: **p<0.01**, unknown statistical significance.

Table 5 Income elasticities of demand for, or including, the UK.

Wood product	Own-price elasticity of demand	Long run own-price elasticity of demand	Country/ countries	Reference
Roundwood	No estimates found			
Industrial roundwood	No estimates found			
Sawlogs	No estimates found			
Sawnwood	0.22		UK (GFPM)	Buongiorno (2014)
	0.55 **		UK (grouped)	Buongiorno (2015)
	0.27 **		Global	Buongiorno (2019)
	0.19 **		Global	Morland *et al.* (2018)
(coniferous only)	1.31* to 2.00*	2.13*	UK (grouped)	Skjerstad *et al.* (2021)
(coniferous only)	**1.04** **	**2.17** **	UK (grouped)	Hurmekoski, Hetemäki and Linden (2015)
(coniferous only)	0.36*, 0.21*		Europe	Rougieux and Damette (2018)
(coniferous only)	**0.44** **		Global	Morland *et al.* (2018)
(non-coniferous only)	0.22*		Global	Morland *et al.* (2018)
Woodfuel and wood pellets	0.22		UK (GFPM)	Buongiorno (2014)
(woodfuel only)	**0.57** **		Global	Morland *et al.* (2018)

Table 5 (continued) Income elasticities of demand for, or including, the UK.

Wood product	Own-price elasticity of demand	Long run own-price elasticity of demand	Country/ countries	Reference
(woodfuel non-coniferous)	**0.14****		Global	Morland *et al.* (2018)
Small roundwood (as 'other industrial hardwood')	−0.58		UK (GFPM)	Buongiorno (2014)
Plywood	**0.13****	**0.07****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.41		UK (GFPM)	Buongiorno (2014)
(plywood and veneer)	**0.97****		UK (grouped)	Buongiorno (2015)
(plywood and veneer)	**0.60****		Global	Morland *et al.* (2018)
(plywood and veneer)	**0.37****		Global	Buongiorno (2019)
Particleboard including OSB	0.25*	**0.11** to 0.38****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.54		UK (GFPM)	Buongiorno (2014)
	0.55**		UK (grouped)	Buongiorno (2015)
	0.73**, 0.99*		Europe	Rougieux and Damette (2018)
	0.75**		Global	Morland *et al.* (2018)
	0.30		Global	Buongiorno (2019)
Particleboard including OSB	0.25*	**0.11** to 0.38****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.54		UK (GFPM)	Buongiorno (2014)
	0.55**		UK (grouped)	Buongiorno (2015)
	0.73**, 0.99*		Europe	Rougieux and Damette (2018)
	0.75**		Global	Morland *et al.* (2018)
	0.30		Global	Buongiorno (2019)
Fibreboard	1.11*		UK	de Oliveira *et al.* (2011)
	0.32**	**0.95** to 1.00****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.79**		UK (grouped)	Buongiorno (2015)
	0.35		UK (GFPM)	Buongiorno (2014)
	0.32**, 0.39*		Europe	Rougieux and Damette (2018)
	1.07**		Global	Morland *et al.* (2018)
	0.55**		Global	Buongiorno (2019)
Wood pulp	No estimates found			
Particleboard including OSB	0.25*	**0.11** to 0.38****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.54		UK (GFPM)	Buongiorno (2014)
	0.55**		UK (grouped)	Buongiorno (2015)
	0.73**, 0.99*		Europe	Rougieux and Damette (2018)
	0.75**		Global	Morland *et al.* (2018)
	0.30		Global	Buongiorno (2019)
Fibreboard	1.11*		UK	de Oliveira *et al.* (2011)
	0.32**	**0.95** to 1.00****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.79**		UK (grouped)	Buongiorno (2015)
	0.35		UK (GFPM)	Buongiorno (2014)
	0.32**, 0.39*		Europe	Rougieux and Damette (2018)
	1.07**		Global	Morland *et al.* (2018)
	0.55**		Global	Buongiorno (2019)
Wood pulp	No estimates found			
Newsprint	**0.28****	**1.00** to 1.05****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.57*		UK (grouped)	Buongiorno (2015)
	0.58		UK (GFPM)	Buongiorno (2014)

Table 5 (continued) Income elasticities of demand for, or including, the UK.

Wood product	Own-price elasticity of demand	Long run own-price elasticity of demand	Country/ countries	Reference
Newsprint (continued)	0.48*		Europe	Rougieux and Damette (2018)
	0.24**		Global	Morland *et al.* (2018)
	0.31**		Global	Buongiorno (2019)
Printing and writing paper	**0.39****	**0.45** to 0.93****	UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.66**		UK (grouped)	Buongiorno (2015)
	0.45		UK (GFPM)	Buongiorno (2014)
	0.56*, 0.49*		Europe	Rougieux and Damette (2018)
	0.36**		Global	Morland *et al.* (2018)
	0.38**		Global	Buongiorno (2019)
Other paper and paperboard	0.08, **0.48** to 1.10****		UK (grouped)	Michinaka, Tachibana and Turner (2011)
	0.37**		UK (grouped)	Buongiorno (2015)
	0.43		UK (GFPM)	Buongiorno (2014)
	0.38*, 0.21*		Europe	Rougieux and Damette (2018)
	0.23**		Global	Buongiorno (2019)

Significance: A: p<0.1, **: p<0.05, ***: **p<0.01**, unknown statistical significance.

Estimates from a similar study using the methodology outlined in Buongiorno (2014) do provide statistical significance, although these estimates are for the larger grouping of 'high GDP' countries (Buongiorno, 2015). While the precise composition of this grouping is not explicitly stated, as it is likely that the UK is included, estimates for the 'high GDP' (top 20% of GDP per capita equivalent to the top 36 of 180 countries) group over the period covered (2004 to 2013) are included in Table 4.

Own-price elasticity of demand

The evidence mainly suggests that sawnwood as a whole is price inelastic in the short run, with estimates ranging from −0.13 to −0.36. The estimates for coniferous sawnwood are similar, with estimates ranging from −0.30 to −0.37. The exception to this is the estimate of 0.66, which, if accepted, would suggest that demand increases when prices increase, an anomalous result that runs counter to standard economic thinking and the results in all other studies. The single study that estimated a significant price elasticity for both coniferous and non-coniferous sawnwood found that non-coniferous sawnwood price elasticity was more inelastic (−0.12) than that for softwood sawnwood (−0.30).

From existing studies, the price elasticity of woodfuel is estimated to be highly inelastic in the short run, with estimates from −0.04 (for non-coniferous only) to −0.15 (for both coniferous and non-coniferous), although it should be noted that both these estimates come from a global study. As households in some parts of the world are mostly or entirely reliant on woodfuel for their energy needs (with few other options), it is unsurprising if global demand does not change readily. However, given that households in Great Britain generally have more choice regarding the type of energy they use, these results may be less likely to hold true for the UK.

Wood-based panels (plywood, particleboard and fibreboard) have a greater range of price elasticities, with these often estimated to be relatively elastic compared with other wood products. Plywood has estimated short-run elasticities of −0.34 to −0.73. For particleboard, estimated short-run elasticities range from −0.25 to −0.70, and for fibreboard from −0.46 to −1.18. Estimates of long-run elasticities are similar for plywood and particleboard, ranging from −0.86 to −0.97 for the former and from −0.96 to −1.21 for the latter, while demand for fibreboard is more inelastic, with estimated long-run elasticities ranging from −0.03 to −0.40. The results suggest that, compared with sawnwood, it is generally easier for consumers and businesses to find alternatives to plywood and particleboard if the price increases. (Results for fibreboard are less clear cut given the wide range of estimates found in the literature.) It is also possible that to some degree each of these products is itself a potential substitute for each of the others.

For paper-based products there is also a wide range of estimated elasticities of demand. Newsprint was estimated to have an elasticity of −0.12 to −0.24 in the short run, with a long-run elasticity of −0.14 to −0.44. For printing and writing paper, elasticities ranged from −0.28 to −0.54 in the short run, and from −0.69 to −0.79 in the long run. Finally, for other paper and paperboard, the short-run elasticity was from −0.16 to −0.52, and from −0.15 to −0.31 in the long run.

Income elasticity of demand

For all sawnwood, the estimated income elasticity of demand varied from 0.19 to 0.55. For coniferous sawnwood, estimates ranged from 0.21 to 2.00 in the short run and from 2.13 to 2.17 in the long run. For studies of coniferous sawnwood where the UK has been grouped with other countries based on certain characteristics, estimates of income elasticity were at the upper end of these ranges, with short-run estimates of 1.04 to 2.00 and of 2.13 to 2.17 in the long run. As might be expected, the estimates suggest that sawnwood demand increases as income increases, meaning it is a normal good (i.e. not an inferior good). Goods that have an income elasticity of demand of greater than one are sometimes described as 'luxury' goods, with the estimates for coniferous sawnwood more specific to the UK indicating that this product falls into this category. This suggests that as people have more disposable income then they are more likely to buy more coniferous sawnwood, for example, to undertake non-essential home improvement projects (see Elasticities from UK market reports). The income elasticity of demand for woodfuel is generally more inelastic, ranging from 0.14 to 0.57 at a global scale, suggesting that it is a necessity, the use of which does not change greatly with income. As with the results for the price elasticity of demand for woodfuel, this may not be representative of the UK, as many of the countries included in the dataset are heavily reliant on wood for all energy, thus for the UK we may expect to see a greater change in demand in response to income changes.

For wood-based panels, estimates suggest an inelastic response to changes in income, although this does depend on the type of wood-based panel, with an income elasticity for plywood (including veneer) of 0.13 to 0.97 in the short run and of 0.07 in the long run. Particleboard appears to be slightly more elastic, with estimates of 0.25 to 0.99 in the short run and of 0.11 to 0.38 in the long run, while fibreboard appears to be the most elastic, with estimates of 0.32 to 1.11 in the short run and of 0.95 to 1.00 in the long run. Similarly, the elasticities estimated are all positive, suggesting that demand increases as income increases.

Income elasticities estimated for paper products were also positive and mostly inelastic, although seemingly with more difference between short- and long-run estimates than for wood-based panels. Newsprint had a short-run income elasticity of 0.28 to 0.57 with a long-run estimate of 1.00 to 1.05, suggesting that while demand may not change much in the short term, in the long term it is more sensitive to changes in income. For printing and writing paper, in the short run the income elasticity estimates range from 0.36 to 0.66, and in the long run from 0.45 to 0.93, suggesting this product is less responsive in the short run and more responsive in the long run, albeit only slightly. The range of short-run income elasticity estimates of 0.21 to 1.10 appears to suggest that demand for other paper and paperboard may be more responsive to changes in income (less income inelastic) than printing and writing paper, although this interpretation depends upon the findings of a single paper.

Price elasticity of supply

Estimates of the price elasticity of supply (the change in the quantity supplied given a change in price) for the UK, or the groupings of countries including the UK, are inelastic for all wood products (Table 6). Estimates for the supply of roundwood and sawlogs were the most responsive to changes in prices, with estimates of 0.56 and 0.39, respectively, whereas estimates for woodfuel and wood pulp were less responsive, with estimates of −0.02 and 0.13. This suggests that forest managers and those holding timber stock increase the supply of timber more when the value of roundwood and sawlogs increases (possibly as these are the most valuable parts of the tree) than when the price of woodfuel or wood pulp increases (possibly as these provide a much smaller proportion of their income). The negative result for woodfuel, although counterintuitive, may be plausible if an increase in price for woodfuel is associated with an increase in other higher value wood products. A supplier may then shift supply away from woodfuel into the higher value product where this is possible, thus reducing the supply of woodfuel.

Elasticities from UK market reports

The most frequently found references to softwood timber-related elasticities of demand in UK industry reports relate to the private housing market and repairs, maintenance and improvement (RM&I) in the properties sector. The Timber Trade Federation (TTF), which accounts for two-thirds of the timber supply chain, uses the Builders Merchant Building Index as a key indicator in their

Table 6 Own-price elasticities of supply for wood products. Estimates in **bold** include the UK.

Wood product	Own-price elasticity of supply	Country/countries	Reference
Roundwood	**0.56**[A]	Global (meta-analysis)	Tian *et al.* (2017)
Industrial roundwood	**0.02***	Global (coniferous only)	Morland *et al.* (2018)
	0.23**	Global (plantation only)	Morland *et al.* (2018)
	0.28**, 0.37** (long run)	Switzerland	Borzykowski (2019)
(chip-n-saw)	0.59**	USA (chip-and-saw)	Tanger and Parajuli (2018)
Sawlogs	**0.39**[A]	Global (meta-analysis)	Tian *et al.* (2017)
	1.24**	Norway	Rørstad, Trømborg and Solberg (2022)
	0.91**	Norway	Bolkesjø, Buongiorno and Solberg (2010)
	0.49*	Southern USA (softwood)	Parajuli and Chang (2015)
	0.88*	Southern USA	Susaeta *et al.* (2013)
Sawnwood	0.16**	USA (softwood)	Song, Chang and Aguilar (2011)
Woodfuel and wood pellets	**-0.02***	Global (woodfuel)	Morland *et al.* (2018)
	1.16*	Austria (wood pellets)	Kristöfel *et al.* (2015)
Small roundwood			
Wood-based panels			
Plywood			
Particleboard including OSB			
OSB			
Fibreboard			
Wood pulp	**0.13**[A]	Global (meta-analysis)	Tian *et al.* (2017)
	0.89**	Norway	Bolkesjø, Buongiorno and Solberg (2010)
	0.51*	Southern USA	Susaeta *et al.* (2013)
Newsprint			
Printing and writing paper			
Other paper and paperboard			

Significance: A: p<0.1, *: p<0.05, **: p<0.01.

quarterly reports and base demand predictions on the forecasts of the Construction Products Association (Timber Trade Federation, 2022). A report by Gresham House in 2020 also pointed to the construction sector as a key driver of demand as well as wider economic growth within the economy (GHAM, 2020). No direct references to hardwood elasticities were found in UK industry reviews. This is probably because of the greater use of softwood materials in the UK, with an estimated 60% or more of timber and panel products consumed from both produced and imported sources, comprised of softwood (Moore, 2015).

UK emerging species studies

No estimated elasticities for emerging species in the UK were found in any of the studies reviewed.

Price elasticities for other countries

Applicability of elasticities from other countries to the UK

Because of the lack of studies focusing on the UK market it is useful to consider studies from other countries and gauge their potential applicability to the UK in terms of the characteristics outlined in 'Comparable foreign markets'. Were the timber market in another country fully or partially integrated with that in the UK (i.e. were prices to move together in both markets), price changes in the other country could be used as a proxy for price changes in the UK.

Furthermore, were the two markets fully integrated, then the price would be expected to be equal in both countries, apart from the cost of transportation and transactions costs (Chudy and Hagler, 2020). The degree to which this holds true for forest products between various countries has been tested in numerous studies, although not specifically between timber markets in the UK and those in other countries. Overall, there seems to be little evidence of forest product market integration between countries. However, for the well-established and more standardised softwood sawlog markets there is some evidence for other countries, mostly relating to Scandinavian markets.

A comprehensive global study by Ince, Kramp and Skog (2012) used quarterly data from 1995 to 2017 to assess the level of integration between the southern USA, Pacific Northwest USA, New Zealand, Brazil, South Africa, Sweden, Chile, Canada, Finland and Austria. The results suggested very little evidence of co-integration on a global scale; however, some evidence was found for co-integration of softwood sawlog prices between Sweden and Finland. A similar study focusing only on Nordic countries found very little evidence for this; however, it did find evidence of integration between Swedish and Norwegian pine sawlog markets (Eriksson and Lundmark, 2020). A study by Chudy and Hagler (2020) also found that softwood sawlog prices between Sweden and Finland were co-integrated, but found no evidence for other wood products and between other countries.

Another indicator of market integration between a country and other countries is the degree to which imported products are used as substitutes for domestic products. This can be measured by an Armington elasticity. This is effectively an elasticity of substitution, but rather than substitution effects between different products, it focuses on substitution effects between countries for the same product. An Armington elasticity of zero would indicate that foreign goods are not used at all as substitutes for domestically produced goods, whereas a high Armington elasticity would indicate that they are highly substitutable and that if domestic prices were to increase even a small amount, most or all demand would go to purchasing the imported product. One study that estimates this value for eight different countries was conducted by Lundmark and Shahrammehr (2012), who used FAOSTAT data for industrial roundwood from 1961 to 2007. Using an ordinary least squares (OLS) regression model, their results suggest an increasing level of differentiation in the first half of the data and then a decrease in the second half, indicating that this may be attributable to the formation of the EU free trade area. The results of this study suggest that we may expect to see a reduction in the substitutability of wood products between Great Britain and other countries if new trade agreements do not match the openness of previous agreements between the UK and the EU.

A similar study based in Sweden used an OLS regression with data from 1967 to 2007 to estimate Armington elasticities for pine and spruce sawlogs and pulpwood (Lundmark and Shahrammehr, 2010). For pulpwood, no significant results were found; however, for sawlogs the estimated elasticity was 3.2, suggesting that while not perfect substitutes, imports are easily substituted for domestically produced sawlogs, with greater levels of substitution found in the long run. This suggests that the level of differentiation, at least in the view of purchasers in Sweden, between domestic and foreign sawlogs is low. A test of significant structural breaks in the data was also performed, and found that both the fall of the Soviet Union, as well as Sweden joining the EU, caused significant increases in the substitutability of pulpwood imports for domestic pulpwood.

Price elasticities may differ not only between countries but also within countries. A study on Norwegian sawlog and pulpwood supply markets found that elasticities differed significantly in 12 of 15 pairs of regions (Rørstad, Trømborg and Solberg, 2022). The authors cite differences in regional policy, harvest intensity and average forest holding size as possible reasons for the differences in the estimated elasticities. Conversely, a study of Scots pine and Norway spruce sawlogs in Sweden found that regional markets were integrated (Chandr Jaunky and Lundmark, 2015). The authors used quarterly data from 1999 to 2012 in a vector error correction mechanism (VECM) model and identified and included structural breaks in the model to arrive at this conclusion, finding that the central region was a price leader in the long run.

One consideration when comparing timber markets in the UK with those in other countries is the level of state ownership involved in each. State ownership can be a key factor in how the timber market operates and reacts to changes. A study comparing the largely state-owned forests of Lithuania with the mostly privately owned forests of Finland found that in the Finnish case markets were able to adjust more quickly to changes in prices (Rinaldi and Jonsson, 2016). In the UK, 27% of UK woodlands are owned by the state, and these provide more than two-fifths of the total softwood produced (Forest Research, 2021a, Table 1.1 and Table 2.1a), although direct comparisons with timber markets in other countries are complicated by different levels of state involvement in timber markets. In Slovakia, for example, where the government manages 48% of all forests (UNECE, 2015), Gejdoš and Potkány (2017) argue that it largely determines the total volume of domestic timber supply, as well as influencing prices for primary wood products via its contracting arrangements with timber companies.

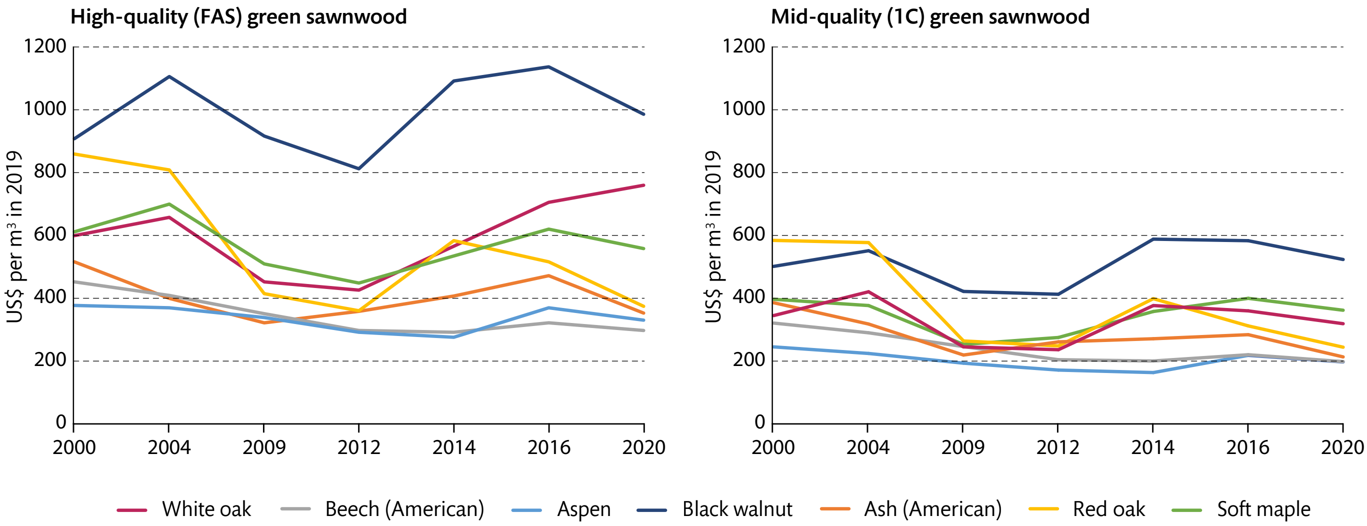
Depending on government priorities and policies, state ownership may lead to quite different market conditions from those assumed in standard economic models. To the extent that market prices do not purely represent interactions of market supply and demand conditions, the applicability of conventional economic analysis may be limited. This suggests that there are grounds for caution when considering the potential applicability of timber prices in countries with a very different mix of public and private forest ownership compared with the UK.

Elasticities for emerging species

There is a small pool of studies that estimate elasticities for individual emerging species. Only two studies include reference to a specific emerging species, both of which were for the USA. Luppold and Bumgardner (2021) studied high and medium quality sawnwood hardwood prices, including red oak, aspen, silver maple (soft maple) and black walnut in their analysis. Also included were nine other hardwood species, some of which (e.g. white oak) may be similar enough to species widely grown in the UK for associated estimates to be used to gauge timber price levels that could be anticipated for emerging species in Great Britain. Apart from calculating correlations between species there was no formal econometric analysis performed and no elasticities estimated, but relative price levels and trends identified for the different species are still of interest. Figure 4 illustrates the price levels for the different species, providing an insight into their relative standing in US timber markets during 2000–20. Black walnut, for example, consistently commanded a higher price in both quality categories over this period, although its prices were fairly volatile. By contrast, aspen was consistently one of the lowest value species, but with far less variance in price. The value of red oak appears to have decreased during the period covered, with its value shifting from above that of white oak to below. The price of soft maple (inclusive of the emerging species silver maple) was fairly stable and largely followed the price of white oak, both for high- and mid-quality sawnwood.

Although in the absence of better data these relationships may offer some indication of potential prices that may be expected in the UK timber market, an important caveat to bear in mind is that characteristics specific to the USA market may also affect these prices. As prices for white oak timber in the UK are widely available (and approximately equivalent to English oak prices), it may be possible to estimate the price of species that are not widely sold in the UK by multiplying the price of white oak by the proportion of the price it is in the USA. For example, the price of high-quality aspen is consistently around 56% of the price of white oak and for mid-quality it is around 61%, while high-quality black walnut is around 168% of the price of white oak and for mid-quality it is around 156%. This approach relies on some key assumptions – most notably

Figure 4 Price trends of USA hardwood sawnwood, including emerging species from 2000 to 2020.



FAS: 'First and second grade' timber, 1C: Lower quality 'Number 1 Common grade' timber. Source: Luppold and Bumgardner (2021).

that past results are relevant for predicting future results and that price relationships between species are more than coincidental – however, in the absence of better data it may offer useful insights in combination with any available UK data for these species.

The other study looks into the standing timber prices of six species and includes two emerging species of interest, red oak and Weymouth pine (referred to as white pine in paper) (Wagner, Rahn and Cavo, 2019). Yearly data from 1972 to 2012 were used to develop three price forecasting models that adopt different approaches but all use prices in previous periods to predict prices for the next year. While this study is rigorous with a high-quality dataset, the results are based solely on historic prices and therefore do not provide much indication of other influences on the price, such as the quantity demanded and the price of substitutes.

Elasticities for wood products from other countries

Studies that focus on other countries can provide useful insights relevant to considering UK timber elasticities, especially where the country focused upon has similar characteristics to the UK (as outlined in 'Comparable foreign markets'). For those wood products for which no elasticities were found in studies that included UK data, wider studies covering countries with similar characteristics could potentially help shed light on elasticities that might be expected in the UK.

Table 7 shows elasticities estimated for wood products in other countries, with instances shown in bold where the elasticity is calculated for a country that the UK has been grouped with in a previous study for that specific product and where no significant results for the UK were identified in the literature. A relevant finding identified for a country grouped with the UK in other studies is an estimated own-price elasticity of demand of −0.95 for wood-based panels in Germany. This result is almost unit elastic, implying that a change in price causes an opposite and close to equal change in demand, suggesting that even in the short run there are likely to be substitutes available.

Results for other wood products, for which no statistically significant estimates were identified for the UK that may also be relevant, include a price elasticity of demand for industrial roundwood in Switzerland (Switzerland was grouped with the UK for other wood products in Michinaka, Tachibana and Turner (2011), although not for industrial roundwood). This was estimated to be elastic at −1.89, suggesting that demand changes considerably in response to a change in prices. An estimate of −1.18 for 'chip-n-saw' (25 to 30 cm diameter at breast height (DBH) roundwood inclusive of material suitable for chipping) in the southern USA market also suggests that roundwood combined with other woody debris is own-price elastic. As the UK has not been grouped with Switzerland or USA for industrial roundwood in any of the studies reviewed, the applicability of this to the UK is unclear. OSB demand in the USA construction sector was estimated to be highly inelastic in the short run, with elasticities of −0.06 and −0.11, but elastic in the long run with an elasticity of −1.16. Wood pulp demand was found to be price inelastic in the short run in Brazil and the southern USA, with estimates of −0.23 and −0.46, respectively.

Table 7 Elasticities for other relevant countries/regions.

Wood product	Own-price elasticity of demand	Income elasticity of demand	Country/regions	Reference
Roundwood				
Industrial roundwood	–1.89[C]		Switzerland	Borzykowski (2019)
(coniferous chip-and-saw)	–1.18[A]		USA	Tanger and Parajuli (2018)
Sawlogs	–0.85[B]		USA (hardwood)	Parajuli and Zhang (2017)
		0.76[C]	Slovakia (softwood)	Gejdoš *et al.* (2020)
		0.30[C]	Slovakia (hardwood)	Gejdoš *et al.* (2020)
	–0.44[B]		Southern USA (softwood)	Parajuli and Chang (2015)
	(–)1.00[B]*		Southern USA	Susaeta *et al.* (2013)
Sawnwood	–0.13[C] to –0.24[C], –0.20[B] to –0.97[B] (long run)		USA (coniferous)	Haim, Adams and White (2014)
	–0.51[B]		Slovakia (hardwood)	Paluš *et al.* (2018)
	–0.14[C]		USA (softwood)	Song, Chang and Aguilar (2011)
Woodfuel and wood pellets	–0.90[B]		Southern USA (biomass)	Susaeta *et al.* (2013)
	–0.67[B]		Austria (wood pellets)	Kristöfel *et al.* (2015)
	–0.64[C]		USA (wood pellets)	Sun and Niquidet (2017)
Small roundwood				
Wood-based panels	**–0.95[C]**		Germany	Jochem, Janzen and Weimar (2016)
Plywood				
Particleboard including OSB				
OSB	–0.06[C] to –0.11[C], –1.16[B] (long run)		USA	Haim, Adams and White (2014)
Fibreboard				
Wood pulp	–0.46[A]		Southern USA	Susaeta *et al.* (2013)
	–0.23[B]		Brazil	Angelo *et al.* (2020)
Newsprint				
Printing and writing paper				
Other paper and paperboard				

Significance: A: $p<0.1$, B: $p<0.05$, C: $p<0.01$. *The table in which this is reported in Susaeta *et al.* (2013); this result is given as positive, although in the text it is described as negative and 'unit elastic'.

Forecasting

Numerous models for forecasting prices in forest product markets have been presented in the scientific literature. These models can be split roughly into two categories:

- Short-term forecasting generally focuses on the effect of changes in quantity, season, patterns in past prices (e.g. any trends) and past prices of linked products, but does not seek to predict changes in the overall structure of the market in question. Predictions will frequently only be made for up to one year into the future and may use finer timescales such as months or quarters.
- Long-term forecasting generally looks further into the future and, in addition to the variables included in the short-term forecasting, attempts to incorporate wider structural changes using indicators such as GDP, or by modelling interactions of national and foreign markets. Predictions may be made up to 100 years into the future using intervals of one to five years.

It should be noted that this is a generalisation with some models covering both, although most forecasting models in forestry sit largely, if not wholly, in one or the other category. Chatfield (1988) proposes some key considerations when deciding what forecasting approach to take, such as the objective of the forecast, how far into the future the forecast will project and how far back previous data go. There is little information on the degree to which UK firms forecast prices and, where they do, over what period. It is likely few, if any, UK companies make forecasts of future timber prices beyond a 12-month horizon due to increasing uncertainty over time (Cooper, pers. comm.).

A breakdown of the models used for making forecasts from the literature covered is given in Tables 8 and 9. The majority of short-term forecasts use autoregressive integrated moving average (ARIMA) time series models or a modified version of this (e.g. the seasonal ARIMA with exogenous factors (SARIMAX)) to make their forecasts, with the GFPM the most frequently used model for long-term forecasts.

Forecasting of timber prices has also been conducted utilising machine learning through artificial neural networks, with promising results (Lamichhane, Mei and Siry, 2023). With advancements in artificial intelligence, such approaches may become more common in the future. However, given the high data requirements of such approaches, their application to timber price forecasting may currently be limited for many markets. This may change as and when more data become available. While predictions made from such models may be more accurate, it is often difficult, if not impossible, to infer the underlying drivers of market behaviours based on their results.

Table 8 Models used for short-term forecasting.

Forecasting model used in publication	Number of publications used in
ARIMA/SARIMA/SARIMAX model	8
Regression analysis	2
Johansen cointegration/VECM	1
Vector autoregression (VAR)/autoregressive distributed lag (ARDL)	1

Table 9 Models used for long-term forecasting.

Forecasting model used in publication	Number of publications used in
GFPM	5
Modified version of GFPM	4
French Forestry Sector Model	1

A key consideration when making predictions using historical data is whether those data are considered a valid indicator of future trends. For many short-term forecasting models to be regarded as valid and useful, the data need to be stationary, that is, the data do not just move randomly from one period to the next. There are numerous tests that can be completed to test stationarity. However, Niquidet and Sun (2012) argue that often this is neglected in studies that offer timber price forecasts. They assessed the stationarity of sawnwood and pulpwood prices in the USA using monthly average prices from 1964 to 2010 for Douglas fir, southern yellow pine and the combination of white spruce, Engelmann spruce, lodgepole pine and alpine fir. They found that the price data for these products are not stationary and suggest that often similar datasets in other studies have been assumed to be stationary, either without this being explicitly tested, or based upon less thorough methods than are used in their own paper. As a result, they urge caution when assessing the results of predictive models in the literature, especially over longer time horizons.

Forecasting prices of emerging species

One study was found in the literature forecasting prices of emerging species, with short-term predicted prices of standing sales of red oak and Weymouth pine (white pine) (Wagner, Rahn and Cavo, 2019). The authors used New York State Department of Environmental Conservation yearly data from 1972 to 2012 as an input into three different price forecasting models and evaluated the accuracy of each by comparing the predictions for 2013 to 2017 with observed prices. The authors found the exponential weighted moving average method to be more robust than the linear weighted or simple moving average, and the simple moving average to be the least robust. Based upon these findings, the authors recommend using the exponential weighted moving average method for forecasting. While this study is rigorous with a high-quality dataset, the results are based solely on historic prices and therefore do not provide much indication of other influences on the price, such as the quantity demanded and the price of substitutes.

Forecasts covering the UK

A projection of UK wood product consumption and forest planting in three different timber demand scenarios estimated that UK demand for softwood sawnwood could increase from 32 000 m^3 to 670 000 m^3 from 2020 to 2060 in a conservative scenario, or from 301 000 m^3 to 1 290 000m^3 over the same period in an extreme scenario. The UK price of softwood sawnwood in 2060 is predicted to be US$339 per m^3 (~£251 per m^3 at 2021 prices) (Nepal, Johnston and Ganguly, 2021). This was estimated using the Forest Resource Outlook Model (FOROM) and covered 12 selected countries, forecasting global price increases of 2% to 23%.

The impact of Brexit on forest products was analysed using the GFPM, estimating projections for up to 2030 in two different scenarios (Johnston and Buongiorno, 2017). The first scenario was if Brexit had relatively little impact on UK GDP and the other if Brexit had a large impact, using predictions made by the Centre for Economic Performance. The model also uses inputs of historical data taken from FAOSTAT on each country's consumption, GDP, import/export values, population growth and wood stock. The study predicts that in 2030 the consumption of sawnwood in the UK will be 1.0 to 2.1% lower than it would have been otherwise, consumption of wood-based panels 2.9 to 6.1% lower, and for paper and paperboard 1.9 to 4.1% lower. Price effects were estimated to be negligible for all products.

In a study conducted by Skjerstad *et al*. (2021), long-term estimates for European coniferous sawnwood demand were estimated for five different future states. Forestry and wood product data were taken from FAOSTAT and combined with GDP and population projections taken from previous studies, with prices assumed to be constant at 2015 levels. The results suggest that annual consumption of coniferous sawnwood in Europe will increase from 102.0m m^3 to 114.1–122.3m m^3 in 2025, then to 118.7–136.5m m^3 in 2035.

In addition to estimating elasticities (covered in 'Elasticities'), the study by Rougieux and Damette (2018) provides projections of consumption in the EU (at the time including the UK) based upon these elasticities using the GFPM. By 2032, consumption of coniferous sawnwood is projected to be 85.3m m^3, for particleboard 43.9–52.8m m^3, for fibreboard 10.1–12.0m m^3, for printing and writing paper 29.8–30.6m tonnes, and for other paper and paperboard 51.7–53.7m tonnes. These results were generally lower than those estimated with the default elasticities in the GFPM, with the exception of the projected demand for particleboard, which was much higher (i.e. 17.9m m^3).

Short-term forecasting (other countries)

A short-term timber price forecasting model was created by Banaś and Utnik-Banaś (2021) to make predictions of pine, spruce, beech, birch and alder roundwood prices in Poland. They used data from the Polish State Forest Information System along with the Construction Confidence Index (CCI), covering a period from 2005 to 2020, testing three different models using in-sample comparisons to find the most accurate model. They found that the most accurate model was the SARIMAX, which accounted for seasonality as well as an exogenous variable, in this case construction activity represented by the CCI. This model was able to offer good predictions without requiring a large amount of different data, offering a good example that could be explored further if emerging species prices were to be forecast using historical data.

A model for predicting the volumes and prices of industrial roundwood imports and exports was created by Kolo and

Tzanova (2017). Using quarterly import/export data from EUROSTAT for 1995 to 2012 with Johansen co-integration and VECM, they were able to provide accurate estimates using export volume, export price and GDP as dependent variables for forecasts up to one year. Using import volume, import price and the exchange rate provided less accurate predictions. Many potentially influential variables are initially included, and numerous statistical tests are performed before arriving at the best forecast model.

A model for forecasting pine sawlog standing timber prices was specified for the southern USA by Mei, Clutter and Harris (2010). The authors used quarterly data for 12 regions from 1977 to 2008 and used a single variable ARIMA model as a base before specifying more complex multi-variate models to see if these gave more accurate predictions. Several statistical tests were performed, and an in-sample forecast test was used to compare the different models. For all ARIMA models the historic price data had to be first-differenced to account for issues of non-stationarity. Results suggested that the multi-variate vector autoregressive model, which included historic prices in other regions, offered better predictions of pine sawlog prices for the next year than when only including the historic prices of that region. For short-term forecasts the authors found little difference between regions. However, for long-term predictions, accuracy was improved by focusing on regional price leaders.

A relatively simple prediction model was created by Adamowicz and Górna (2020) using yearly data on Polish timber prices (exact wood product not specified) from 2006 to 2017. Using a simple linear regression of the previous five years, timber price predictions in the range of 0.83–1.15% of the observed values were achieved for three in-sample tests. While the results of this analysis are promising, it should be noted that this method is heavily reliant on historical data and the in-sample tests have only been completed three times, which may not give an accurate representation of effectiveness. However, this analysis does show that even very simple models can offer some guidance for predicting future prices, provided that the necessary data are available.

Long-term forecasting (other countries)

Given the long-term nature of many decisions made in the timber industry, it is unsurprising that numerous models have been created to make predictions that match the time horizons needed for tree planting. It is not only tree planting that requires long-term planning, but also the investments needed in processing trees at sawmills and other facilities which, given the initial investment cost, often take many years to achieve a positive return.

As woodfuel is used as an alternative to other available fuel sources, changes in the markets for these alternatives may influence woodfuel demand. A study in the USA analysed the effect of fossil fuel prices on the demand for wood bioenergy by modifying the GFPM and using elasticities taken from the literature as parameter inputs (Zhang, Gilless and Stewart, 2014). Incorporating macroeconomic projections from the USDA Economic Research Service, the authors predict a steady increase in woodfuel demand from around 360 petajoules in 2013 to 899 petajoules in 2050. A large increase in demand for woody cellulose ethanol was also predicted, provided that high oil prices persist.

Typology of models used

Tables 10–12 provide a summary of the types of models used and the variables included in analysis in the literature reviewed. A very basic overview of the relative advantages and disadvantages of each model is given in Appendix D. The choice of model is largely dependent on the research question being explored. However, identifying those models that have most frequently been used could also provide a useful indicator as to which are considered the best suited in the literature.

The high number of VAR co-integration models used compared with standard VAR models is indicative of the large proportion of studies finding that available data are non-stationarity, a characteristic that makes results from standard VAR models invalid. In terms of robustness, models that use panel data (multiple observations over time for a number of individuals/entities), such as fixed effects, random effects and pooled OLS, are generally regarded as generating more reliable results than models that use either time series data (the same individual/entity over time) or cross-sectional data (numerous individuals/entities at a fixed point in time), such as OLS regression, two-stage least squares (2SLS), three-stage least squares (3SLS) and ARIMA models. However, as with all models, the quality of the output is dependent on many factors beyond the type of model used (e.g. data quality and choice of variables).

Table 10 Models used for economic analysis.

Model used for analysis	Number of publications used in
VAR co-integration: Engle–Granger Two-Step/ Johansen's co-integration test/VECM	15
ARIMA/SARIMA/SARIMAX	10
OLS regression	9
Fixed effects	8
Random effects	7
VAR model: VAR/Granger causality/ARDL	6
Seemingly unrelated regression (SUR)	5
Pooled OLS	4
2SLS	3
3SLS	1
System generalised method of moments (GMM)	1

Table 11 Dependent variables used in models..

Dependent variable	No. of times used in models
Quantity consumed/demanded	22
Price	22
Import quantity consumed/demanded	4
Import price	2
Ratio imports/domestic consumption	2
Export quantity	1
Export price	1

Table 12 Independent variables used in models..

Independent variable	No. of times used in models
Own-price lagged	21
Own-price (domestic)	20
Income/GDP	15
Price of complementary/substitute product	14
Lagged quantity consumed	7
Time trend	7
Season	6
Lagged price in other countries/regions	6
2008 recession	6
Price in other countries/regions	5
Lagged price of complementary/ substitute product	5
Interest rate	4
Construction activity	4
Exchange rate	4
Export quantity	3
Standing stock	3
External supply disruption event dummy	3
Import quantity	3
Import price	2
Domestic production	2
Economically active population	2
Unemployment rate	2
Business cycles	2
Transaction cost of trade (including tariff)	2
Other	18

Variables used within models

For each of the studies reviewed where either elasticities of demand were estimated or future prices predicted, the dependent variable and explanatory variables used were identified. Table 11 provides a summary of the dependent variables used. Most frequently, this was the quantity consumed/demanded in studies estimating elasticities of demand, with the price mainly used in studies seeking to forecast future prices. Table 12 provides a summary of the variables used to explain variations in the dependent variable. This can be regarded as a useful guide to the most important factors involved and therefore which should be considered in future studies estimating elasticities for emerging species or different wood products. Equally, they would be useful in constructing a model to predict future prices for emerging species, although in this case it is frequently suggested that including too many variables risks 'overfitting' the model, which can hinder the reliability of future predictions.

In most cases, models where the quantity demanded of a product is the dependent variable, the explanatory variables include the price of that product, some measure of income (e.g. GDP), as well as the price of complementary or substitute goods. For models using price as the dependent variable, explanatory variables include prices from previous periods in most cases, with time and seasonal trends also frequently included. Dummy variables for one-off events were also frequently used, such as the financial crisis of 2008 or events that impacted supply significantly, such as windthrow or pest outbreaks.

Forest models

An overview of economic modelling of the forest sector is provided by Rivière and Caurla (2020), who cover the development of such models from the 1970s to 2020, describing forest sector models as 'partial equilibrium, mathematical models of the forest sector enabling the determination of products prices, supply and demand quantities'. Numerous forest sector models have been created with varying scope and complexity, with an overview of the development of various models from 1998 to 2007 provided in a review by Toppinen and Kuuluvainen (2010). Focusing on Europe, the authors find that there has been a shift away from using time series econometric methods to derive estimates of economic parameters such as elasticities, stating that structural changes and a lack of availability of high-quality data are potential reasons for this. Despite this, the number of studies using econometric methods still comprised three-quarters of the 49 papers they assessed, with the remaining papers using larger forest sector models. Considering the shift away from econometric studies, because many of the larger multi-market models such as the GFPM use parameters estimated in these studies as inputs, the authors call into question the accuracy of some of these larger models, as the initial inputs may no longer be up to date. The authors recommend that more studies on the structure of forest products markets are needed to support the relatively advanced forecasting models that have been created for predicting short-term timber prices. They also state that smaller simple models focused on one issue can often offer as much or more analytical power as larger and more complex models.

Hurmekoski and Hetemäki (2013) offer a more critical view of forestry models, suggesting that current approaches often miss the increasingly interconnected nature of the timber industry with other industries and policy. They also cite the amount of uncertainty in many inputs such as elasticities, as well as the dynamic nature of many of the inputs, which can change considerably over time. An example they give is that estimates of income elasticity of demand for newsprint changed from 0.95 during 1980–99 to –0.51 from 2000 to 2012. The authors are keen to point out that such models are still useful, but caution is needed not to place too much weight on individual results, especially over longer time periods and wider geographical areas.

One of the most popular models for projecting global trade in wood products is the GFPM (Buongiorno, 2014). This model uses trade data from FAOSTAT and includes most of the forest products available from this dataset to estimate shifts in demand and supply and the effect they consequently have on prices, consumption, production, imports and exports, as well as forest area and growing stock (including estimated carbon stock). The model uses historical data for 180 countries along with a validation procedure to ensure that estimates are consistent and to estimate price elasticities, which are used as parameters in the model.

An alternative to the GFPM is the GFPMX model, which uses a cobweb theorem to make predictions regarding international forest product market performance (Buongiorno, 2021). Rather than all markets reaching equilibrium each year, markets take time to adjust and therefore equilibrium is not necessarily reached. It could be argued that this is a more realistic representation of the world, as often it can take time for shocks to move through different markets and for adjustments to be made. No other study uses this model, with the simpler GFPM often used either as is, or as a base model to build upon. Both models can provide estimates of future UK consumption and prices using country-specific data from FAOSTAT.

A different model not used in any studies reviewed but that may be of interest is the Global Forest Trade Model (Joint Research Centre Institute for Environment and Sustainability *et al*., 2015) (Cooper, pers. comm.). This model has a greater focus on EU member countries, with 48 countries or regions of the world included (the UK being one). Just as with the GFPM, FAOSTAT data are used, with an equilibrium of supply and demand for each forest product market estimated for each period. There are some differences in terms of the parameters used, however, with more frequent use of elasticities from country-specific studies rather than those estimated from FAOSTAT data (as with the GFPM). When trade values for sawlogs or pulpwood were unavailable, the value for sawlogs was assumed to be two-thirds the value of industrial roundwood. This model may be interesting to explore further, although its limited use in the scientific literature makes it more difficult to compare results with other studies.

The European Forest Institute Global Trade Model (EFI-GTM) is another forest sector model for predicting market behaviour of the industry on a global scale, albeit with a focus on the possible impact of policy changes rather than for forecasting, although it can be used to make forecasts (Kallio, Alexander and Solberg, 2004). The model can compute year-on-year estimates of production, consumption, import and export quantities for 36 wood products in 61 regions (including the UK), and projections can be made up to 2030 and 2050. EFI members, including Forest Research, are permitted access to use the model.

Conclusions and recommendations

There currently exists very little information or research regarding future UK prices of different emerging species, with sparse publicly available data or guidance on the returns that could be achieved through their planting. The little information available is for a small number of species in North American markets, which benefit from relatively rich historical price datasets and for which a few academic studies forecasting future prices exist. No estimates of elasticities for individual emerging species were found in the literature, possibly because of a lack of available data and the general focus on wood products rather than species when estimating elasticities.

For wood product categories, data are more widely available and more research has been conducted, with price and income elasticities of demand for the UK (or small groups of countries including the UK) estimates available for sawnwood, most wood-based panels and most paper-based products. Price elasticities estimated for sawnwood were inelastic in the short run, with prices having little effect on demand. Small roundwood was also found to be inelastic, although this is based on only one study and as part of the wider grouping 'other industrial roundwood'. Demand for wood-based panels was mainly found to be inelastic, albeit slightly more responsive to prices than demand for sawnwood. Demand for woodfuel was found to be highly inelastic based upon estimates from global studies (although whether this holds in the UK with a greater choice of energy sources than in many lower income countries, is unclear). Demand for printing and writing paper is generally more responsive to prices (less inelastic) than demand for other paper and paperboard, and is also less inelastic in the long run than demand for newsprint. From UK industry reports, the most frequently reported factors influencing demand for wood products were the private housing market and the RM&I market.

The key recommendations from this review are:

1. Collection, synthesis and publication of more data on timber sales of individual species in the UK. Data that exist for emerging species in the UK should be collated and average price trends estimated to allow these to be compared with those for more commonly planted species (e.g. Sitka spruce). Once such data become available, research to estimate associated elasticities and forecast future prices could be undertaken. The findings of Variables used within models provide some guidance on variables to consider when developing new models. Such information may provide greater confidence to landowners considering woodland creation or restocking. As ongoing and future research into key characteristics of emerging species is completed, more focus may be placed on those with the highest potential timber and non-timber values. Priority may also be given to emerging species that are already the subject of current UK research to create synergies in undertaking future studies. For example, species already covered in Forest Research's CARBINE carbon model, such as grand fir, noble fir, roble, western hemlock and western red-cedar (BEIS, 2020), could be focused on initially, with these species then used as benchmarks for the remaining emerging species in the model based on expert judgement.

2. Collection, synthesis and publication of price data for key more commonly planted tree species in the UK would also be useful where not done already, especially for species where the characteristics of the timber are similar to those of the emerging species of most interest. Potentially, prices of wood products from the more commonly planted tree species could then be used as a benchmark to help guide prices expected for the emerging species. For example, price reports for certain regions of the USA provide information regarding what prices for more widely planted species can be used as a guide for less commonly planted species. For those unfamiliar with respective timber properties, a clear guide upon what emerging species are similar to more well-known species in terms of timber quality and the likely end uses of the timber would be useful (research that could contribute to this is currently being carried out under Forest Research's Research Programme on Markets for forest products and services). This could help landowners to understand those markets they are most likely to be selling to in the future if they choose to plant a particular emerging species, and to gauge which emerging species are best suited to their plans.

3. Further analysis of the data for emerging species from other countries could be conducted to estimate relative prices in each market, with prices for species common to both the UK and the other country being used to gauge the likely extent of differentials in emerging species prices between those countries. Although

estimates for the UK using an indirect method like this would be less reliable than actual sales prices, if the volume of sales in the other country was substantial, they could help gauge the level of prices more representative of a situation where the market for the emerging species had matured, rather than being a 'fringe' or 'niche' species.

4. Use relatively simple models for short-term forecasting. Existing evidence indicates that there are often relatively small gains in accuracy when using more complex models compared with a simple average of previous prices. A potentially useful and relatively simple model for predicting prices is the SARIMAX model, which uses historical price data and time of year, and which can incorporate a measure of construction activity to make future predictions of roundwood prices. This model was shown to be more accurate at predicting prices than simpler models, while still having relatively modest data inputs (Banaś and Utnik-Banaś, 2021).

5. For forecasting long-term demand and prices, the GFPM appears to be the best starting point and is the most frequently used in studies of this type. Both the model and the data needed are publicly available, and while the latest version only provides data up to 2018, it would be possible to update this manually using FAOSTAT data.

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Appendix A: Countries grouped with the UK in studies reviewed

Paper	Wood product	Criteria	UK grouped with
Skjerstad *et al.* (2021)	Coniferous sawnwood	GDP, forest coverage, import consumption ratio	Denmark, Iceland, the Netherlands, Qatar (Bahrain, Cyprus, Israel, Italy, Saudi Arabia, Barbados and Kuwait met the same criteria except GDP, which was classified as 'medium-high' instead of 'high')
Hurmekoski, Hetemäki and Linden (2015)	Sawnwood	GDP, change in demand patterns	Denmark, Ireland, the Netherlands, Spain, Switzerland
Michinaka, Tachibana and Turner (2011)	Plywood	Per capita GDP, forest coverage, per capita consumption	Bahrain, Barbados, Ireland, Kuwait, the Netherlands, Norway, Qatar, United Arab Emirates
Michinaka, Tachibana and Turner (2011)	Particleboard	Per capita GDP, forest coverage, per capita consumption	Australia, France, French Polynesia, Iceland, Ireland, Kuwait, the Netherlands, New Zealand, Norway, Qatar, Switzerland, United Arab Emirates
Michinaka, Tachibana and Turner (2011)	Fibreboard	Per capita GDP, forest coverage, per capita consumption	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Kuwait, the Netherlands, New Zealand, Norway, Qatar, Spain, Sweden, Switzerland, United Arab Emirates, USA
Michinaka, Tachibana and Turner (2011)	Newsprint	Per capita GDP, forest coverage, per capita consumption	Australia, Austria, Belgium, Denmark, Finland, Germany, Iceland, Ireland, Japan, the Netherlands, Norway, Qatar, Sweden, Switzerland, USA
Michinaka, Tachibana and Turner (2011)	Printing and writing paper	Per capita GDP, forest coverage, per capita consumption	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Malta, the Netherlands, New Zealand, Norway, Croatia, Spain, Sweden, Switzerland, United Arab Emirates, USA
Michinaka, Tachibana and Turner (2011)	Paper and paperboard	Per capita GDP, forest coverage, per capita consumption	Australia, Denmark, France, Iceland, Ireland, Kuwait, the Netherlands, Norway, Switzerland, United Arab Emirates, Austria, Belgium, Canada, Finland, Germany, Italy, Japan, Korea, Rep., New Zealand, Slovenia, Spain, Sweden, USA

Appendix B: Literature search

Search terms

The core part of this review was based on a search through recent academic literature to find relevant studies. The search terms used were broad to ensure that any studies forecasting prices or estimating elasticities for timber or other forest products were not missed. Those identified were then analysed to pick out information, methodologies or information on datasets that may not only be useful for this review, but also for any subsequent research on emerging species. The search terms used were as follows, resulting in 3963 hits.

Price/elasticity	W/6* economic	AND products/species	AND year
elastic OR price*	***Include 'or' between each term** income demand supply *forecast* import* export* grant certif* segment* integrat* 'time series' 'law of one price' 'partial equilibrium' consumption 'financial assessment' 'cluster analysis' 'panel data analysis' 'exchange rate' market diversif* segregat* econom* future predict* 'dynamic model' 'static model' trade competit* trend 'rate of change' domestic sales value	***Include 'or' between each term** veneer particleboard fibreboard hardboard mdf hdf packaging *forest* sawlog 'saw log' sawnlog *timber *wood* lumb?r stumpage broadlea* oak *conifer* beech pine spruce aspen poplar **((emerging OR introduced OR exotic OR novel OR alien OR foreign) PRE/4 (forest OR *conifer* OR *tree* OR *species))** **full list of common and latin names of UK emerging species according to Forest Research criteria)** **AND NOT** **'random forest'**	>2009

*Must be within six words of price/elasticity.

First screening

From the initial results of the above search, a screening process was adopted using the following criteria, resulting in 112 publications identified for further review.

Criteria	Limited to
Geography	UK, Europe, North America, Chile, New Zealand
Products	Industrial roundwood/logs, woodfuel, wood chips, wood pellets, sawnwood/lumber (sometimes timber in UK), veneer sheets, wood-based panels/panels, plywood, particleboard (MDF, HDF, oriented strand-board), fibreboard, wood pulp/pulpwood.
Language	English
Industry	Must have reference to forestry sector in title or source, or one of the 'products' above. Where the industry is unclear the document will be passed as 'uncertain' and checked further in the second screening.
Economics	Must have some reference to price and/or elasticity or other economic indicators. Where this is unclear the document will be passed as 'uncertain' and checked further in the second screening.

Second screening

Following the first screening, any papers identified as 'uncertain' in their relevance were screened a second time by reading the abstract to remove any publications clearly not relevant to the review; 86 publications were selected for full review.

Information to extract from academic literature

Following the screening process, the following categories of information were extracted from relevant studies.

Title	Example
Date	
Published in	Forest Science/BioResources/CONFOR Market Report April 2021
Access	Open/unavailable
Type	Journal article/report/thesis
Relevance	Clearly relevant/uncertain
Description	
Author/s	
Source (weblink to the literature)	
Location	The country/region that the data are describing
Data source	FAOSTAT/Forest Research
Sample size (no. of observations used for analysis and modelling)	
Period covered	
Species covered	Red oak/beech spp./redwood spp./ conifer spp.
UK emerging species?	Y/N/included but grouped with other species/unknown
Non-native species in study location?	Y/N/mixed/unknown
Wood product	Sawlog/sawnwood/wood pellets
Size of wood product	<15 cm DBH/>3 m length, 26–32 mm thickness/unspecified
Quality of wood product	Grade I/II/III/unspecified
Sale type	Standing sale/roadside
Unit	£ per m^3 underbark/$ per tonne
From natural forest?	Yes, if not taken from plantation forestry
Private/public forest owner	Private/public/mixed/unspecified
Forecast made?	Short-term/long-term
Forecast model used	VAR/ARIMA/NA

Other sources covered

The review also covered grey literature such as market and policy reports, in addition to documents suggested by steering group members (17 documents). The following sources were identified as additional resources to investigate further:

Source
Confederation of Forest Industries (CONFOR)
United Nations Economic Commission for Europe (UNECE)
Forest Research/Forestry Commission
Forestry and Land Scotland
Department of Agriculture, Environment and Rural Affairs (DAERA)
Timber Trade Federation (TTF)
Grown in Britain
Timber Auctions UK
European Forest Institute (https://efi.int/publications)

Appendix C: The role of sawmills in the supply chain

Sawmills are a key part of the forest industry because they purchase many of the higher value products as well as supplying their waste by-products as inputs in the manufacture of other products. There has been a shift from a mix of small, medium and large sawmills, to mostly large, with many small and medium sases the influence and importance of the remaining sawmills within the UK market. As with other sectors, transport costs of getting raw materials to their plants is an important consideration, and this could be expected to become even more important as fuel prices rise. Some analysts have predicted a shift to smaller diameter logs when sourcing locally to counter this (John Clegg Consulting, 2016). Klepacka, Siry and Bettinger (2017) suggest that, at least in the USA market, the price paid for sawlogs is largely determined by the willingness of the sawmills to pay, rather than by aspects of production, with exceptions made to meet contractual obligations or to maintain a local pool of labour.

The shift away from smaller sawmills may also present a challenge for the future use of emerging species, with many larger sawmills currently designed to maximise the production of more standardised softwood sawlogs coming from a relatively small group of species. As these larger sawmills cannot quickly adjust their production processes, there may be a need for more small diverse sawmills that can cope with different species (Wilson, 2011). Research carried out in 2015 and 2016 regarding alternative species found a range of views among sawmill managers in the UK (Lawrence, 2020). The interviews revealed that many sawmill managers accepted that they needed to be prepared for more diverse species, especially considering a predicted increasing reliance on private sector supply, with at least one smaller sawmill manager seeing diversification as a strategic opportunity. However, one large sawmill suggested that any incentives to improve diversification needed to be on a large-scale, stating: 'I want 8 million alternative conifer, not a few thousand.'

Sawmill production is limited by capacity, with any measures to increase capacity generally requiring large investments and longer time periods than would be required to react to short-term changes in the market. Sawmills may be able to increase capacity in the short term by reducing downtime and holidays for staff. However, this would only provide a small increase in capacity and for short time periods. Some large sawmills have targets to meet regarding sustainability certification, which can further restrict the ability of sawmills to react to changes in supply. For example, after a storm event leading to an oversupply of roundwood, it may not be possible for sawmills to take wood from non-certified woodlands, as to do so would risk them missing their targets for that year.

The output of sawmills can be severely disrupted by storm events, causing a short-run oversupply of timber – especially small roundwood – associated with the trees that have been blown down. Aside from any potential damage to the mills themselves or disruption to felling operations from access being blocked, such short-term oversupply requires a reorganisation of operations to process the additional input. Contracts for planned felling may need to be delayed and applications must be completed for felling permits in the affected areas; resources must be reallocated from planned felling to fallen trees. If the species affected is different from that being currently processed then adjustments will also have to be made to machinery, and markets must be found for the new output. The length of time a given species can remain on the ground without the timber degrading is a key determinant of the impact these events have, with those that degrade slowly giving far more flexibility than those that do so quickly. The susceptibility of a species to disease and discoloration when left grounded is therefore a key consideration given the expected increase in windthrow events.

Appendix D: Advantages and disadvantages of models used

Model	Primary data type	Advantages	Disadvantages
OLS linear regression	Cross-sectional	• Simple • Widely used • Flexible (can accommodate many different variables)	• Susceptible to bias if dependent variables are not carefully chosen • Requires dependent and independent variables to be uncorrelated with the error term • Sensitivity to outliers
2SLS	Cross-sectional	• Extension of OLS • Flexible (can accommodate many different variables) • Allows estimation when one or more independent variables is correlated with the error term	• More complex than linear regression (requires more steps and expertise than OLS) • Susceptible to bias if dependent variables are not carefully chosen • Requires identification of additional data outside of the original model to use in extra steps
Seemingly unrelated regression (SUR)	Cross-sectional	• Extension of OLS • Flexible (can accommodate many different variables) • Can accommodate links between more than one OLS model	• More complex than linear regression • Susceptible to bias if dependent variables are not carefully chosen
3SLS	Cross-sectional	• Combination of SUR and 2SLS, therefore has the advantages of both	• Combination of SUR and 2SLS, therefore has the disadvantages of both • If the SUR equations are mis-specified, the results of 3SLS will be less consistent than for 2SLS
ARIMA/SARIMA/ SARIMAX	Time series	• Simple • Widely used • Use of historical values means causal factors are indirectly included in the model without the need to identify them • Can allow for some flexibility in variables (for SARIMAX)	• Requires time series data to be stationary • Assumes future will look similar to the past • Cannot account for large changes in individual causal factors (unless included via SARIMAX model)
VAR model: VAR/ Granger causality/ ARDL	Time series	• Use of historical values means causal factors are indirectly included in the model without the need to identify them • Can include more than one dependent variable and the correlations between them	• Requires time series data to be stationary • Assumes future will look similar to the past • Cannot account for large changes in individual causal factors
VAR co-integration model: Engle–Granger Two-Step/Johansen's co-integration test/VECM	Time series	• Does not require time series data to be stationary • Use of historical values means causal factors are indirectly included in the model without the need to identify them • Includes both short-run and long-run effects • Can include more than one dependent variable and the correlations between them	• More complex than the VAR model • Requires strong co-integration relationship/s for results to be valid
Pooled OLS	Panel	• Simple	• Differences between subjects/groups not accounted for
Fixed effects	Panel	• Accounts for differences between subjects/ groups • These differences are quantified	• Assumes full exogeneity, which is rarely valid
Random effects	Panel	• Accounts for differences between subjects/ groups • Still valid in the presence of endogeneity	• Accounts for differences between subjects/ groups
System generalised method of moments (GMM)	Panel	• Can include lagged levels of the dependent variable (dynamic)	• Complex (requires more steps than other panel data methods above)

Glossary

Apparent consumption A basic measure of the amount of a good consumed in a country, defined as domestic production plus imports minus exports.

ARIMA Autoregressive Integrated Moving Average model: a type of linear model often used for forecasting that uses data for previous periods to predict future points in a time series. See Chatfield (2003) for more information.

Economic good A product or service that provides value to people through its use (consumption) and therefore they would be willing to pay for (Collins, 2024). This includes both market goods, which typically have a price, and non-market goods, which do not (e.g. access to a public park).

Fibreboard A panel manufactured from wood fibres or fibres of other ligno-cellulosic materials, with the primary bond deriving from the felting of the fibres and their inherent adhesive properties. It includes MDF and HDF (UNECE, 2020).

Hardwood Wood derived from non-coniferous trees.

HDF High-density fibreboard.

Income elasticity of demand The degree to which the quantity of an economic good demanded changes in response to a change in consumer income.

Industrial roundwood All roundwood ('wood in the rough') apart from woodfuel. It includes sawlogs, pulpwood and small roundwood (UNECE, 2020).

MDF Medium-density fibreboard.

Newsprint Paper mainly used for printing newspapers, made largely from mechanical pulp and/or recovered paper, with or without a small amount of filler (UNECE, 2020).

OLS Ordinary least squares: a basic method for estimating the coefficients for the unknown parameters in a linear regression. See Wooldridge (2015) for more information.

OSB Oriented strand board: a structural board in which layers of narrow wafers are layered alternately at right angles to provide greater elastomechanical properties, thereby creating a solid, uniform material with high strength and water resistance for use in construction (UNECE, 2020).

Other industrial roundwood Industrial roundwood ('wood in the rough') not including sawlogs, veneer logs and pulpwood. It includes roundwood used for poles, piling, posts, fencing, pitprops, shingles and shakes, wood wool, tanning, distillation and match blocks (UNECE, 2020). Small roundwood fits within this category.

Other paper and paperboard Paper and paperboard, apart from printing and writing paper. It includes construction paper and paperboard, household and sanitary paper, special thin paper, wrapping and packaging paper, as well as some other types of paper and paperboard (UNECE, 2020; codes 12.2, 12.3 and 12.4).

Particleboard A panel ('chipboard') manufactured from small pieces of wood or other ligno-cellulosic materials (e.g. chips, flakes, splinters, strands, shreds and shives) bonded together by the use of an organic binder together with heat, pressure, humidity or a catalyst (UNECE, 2020).

Plywood A panel consisting of an assembly of veneer sheets bonded together, with the direction of the grain in alternate plies and generally at right angles (UNECE, 2020).

Price elasticity of demand The degree to which the quantity of an economic good demanded changes in response to a change in its price.

Price elasticity of supply The degree to which the quantity of an economic good supplied changes in response to a change in its price.

Printing and writing paper This comprises paper suitable for printing or other graphic purposes, including paper coated on one or both sides with carbon or minerals, and uncoated mechanical and wood-free papers (UNECE, 2020; codes: 12.1.2, 12.1.3, and 12.1.4). It excludes newsprint.

Roundwood All wood that is harvested ('wood in the rough') in all forms (i.e. branches, stumps and roots). It includes wood with and without bark. It covers wood used for fuel and wood used for other wood products (UNECE, 2020).

SARIMAX Seasonal Autoregressive Integrated Moving Average with eXogenous factors: a method applied to time series data and based on the ARIMA model. It also accounts for seasonal effects and can include one or more exogenous variables that may affect the dependent variable.

Sawlogs Roundwood suitable for the manufacture of sawnwood and veneer. Generally, the largest and highest quality roundwood, including the most valuable wood harvested. It is estimated that in fully grown trees 70% of the value is in the sawlogs (GHAM, 2020), with sawlog prices considered a key driver of management decisions.

Sawnwood Wood that has been cut into lengths with a thickness of more than 6 mm using either domestic or imported sawlogs. It includes many products that are used in construction such as beams and planking (UNECE, 2020). In the UK it is sometimes referred to as 'timber' and in North America it is often referred to as 'lumber'.

Small roundwood There is no set definition for small roundwood. According to a definition adopted by Forest

Research, it constitutes roundwood of 7–14 cm diameter at breast height, which is too small to be used as sawlog (Forest Research, 2022a). The minimum size differentiates it from wood that has more limited uses, such as for pulping. Small roundwood often comes from thinning as part of ongoing management.

Softwood Wood derived from coniferous trees.

Value added wood products Wood products processed into furniture, builders' joinery and carpentry products, profiled wood and engineered wood products (UNECE/FAO, 2021).

VECM Vector Error Correction Mechanism: a model used to fit past data points and forecast future data points in a time series when two or more dependent variables have a long-run relationship (i.e. are 'co-integrated') influencing outcomes. See Kilian and Lütkepohl (2017) for more information.

Wood chips Wood reduced to small pieces that are suitable for pulping, for particleboard and/or fibreboard production, or for use as a fuel or other purposes. It excludes chips produced from roundwood or wood residues in the production of pulp, particleboard and fibreboard, or as part of another continuous industrial process, as well as chips made in the forest itself from roundwood as pulpwood or woodfuel (UNECE, 2020).

Wood pulp Fibrous material prepared from pulpwood, wood chips, particles or residues by a mechanical and/or chemical process for further manufacture into paper, paperboard, fibreboard or other cellulose products (UNECE, 2020).

Wood-based panels This includes plywood, particleboard, OSB and fibreboard. As most wood-based panels are used in construction and repair, they are often categorised based upon whether they are structural or non-structural. Structural panels include plywood, OSB and veneers, whereas non-structural boards include particleboard and MDF (GHAM, 2020).

Woodfuel and wood pellets Woodfuel is roundwood ('wood in the rough') that is used as fuel for purposes such as cooking, heating or power production (UNECE, 2020). It includes wood pellets produced using (often relatively low quality) roundwood. Wood pellets can also be made as by-products of other wood-processing activities (e.g. using the sawdust from sawnwood production). Wood pellets generally have a standardised size (diameter up to 25 mm, length up to 100 mm) and moisture content (8%), facilitating comparisons between datasets (UNECE, 2020).

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This research report reviews existing studies estimating future timber prices and price elasticities of demand for emerging species and different product categories, focusing on studies most relevant to UK timber markets. This report was produced as part of Forest Research's 'Research Programme on Markets for forest products and services', and aims to provide information to support the transition to a low carbon economy in the context of a changing climate and to help inform decisions on planting alternative emerging species.

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