

**How the Russia-Ukraine Conflict is Shaping U.S. Wood Pellet Exports
and EU Import Demand**

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ABSTRACT

The EU's Renewable Energy Directive (RED) classifies wood pellets as carbon neutral, which has resulted in their increased use in commercial heat and electricity generation. Consequently, the EU is heavily reliant on imports to satisfy this growing demand.

The U.S. is the world's largest wood pellet exporter, reaching a value of \$1.9 billion in 2024, and a major exporter to the EU. Russia and Belarus are also major exporters to the EU. As a result of Russia's invasion of Ukraine, the EU imposed trade sanctions on Russia and Belarus (for supporting the invasion) causing imports from these countries to plummet.

The goal of this study is to estimate the demand for imported wood pellets in the EU across exporting countries and to assess how these trade sanctions have impacted U.S. wood pellet exports to the EU, as well as exports from other competing countries. The QUAIDS model was used for the analysis, which is an extension of the more popular AIDS model, and uses a quadratic term to allow a more flexible total expenditure effect. Uncompensated elasticities, compensated elasticities, and expenditure elasticities were estimated. The price elasticities were used to establish substitution and complementary relationships between exporting countries in the EU market.

Before the sanctions, EU wood pellet demand favored U.S. exports. Additionally, the QUAIDS elasticities indicated that wood pellet demand was elastic and price sensitive overall, with U.S. wood pellet exports being the least sensitive to own-price changes. After the sanctions, Russia and Belarus suffered significant losses in export value, while the remaining countries experienced substantial export gains. The U.S. maintained its rank as the top wood pellet exporter to the EU.

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CHAPTER 1

INTRODUCTION

Wood pellets are often derived from forest byproducts, commonly referred to as secondary feedstocks and residues. These include materials such as excess bark, sawdust, chips, shavings, and branches, which are processed and converted into a small, cylinder-shaped energy source. Their use is rising due to several unique characteristics such as low moisture content and high energy density (Sgarbossa et al., 2020). Wood pellets are utilized in two main sectors: industrial markets for electricity and commercial heating, and residential markets for stoves and hot water preparation (Schipfer et al., 2020b). When compared to other forms of wood-based energy such as wood chips (3,100 megajoules per cubic meter, MJ/m³), stackable log wood (5,200 – 7,400 MJ/m³), and oven-dry wood (7600 – 11,400 MJ/m³), wood pellets produce 11,000 MJ/m³ while also providing easier transport than solid wood (Bioenergy Europe, 2023; Forest Research, 2025). The rising interest in sustainable practices to address escalating environmental challenges is driving international efforts to incorporate wood pellets into renewable energy goals (Catanoso, 2022; Drouin, 2015).

Wood pellets are being recognized as a renewable energy source and an alternative to fossil fuels (Parish et al., 2018). However, there are contrasting views on the benefits and disadvantages of wood pellet use. Supporters view wood pellets as a carbon-neutral energy source that will help achieve sustainability goals. Although the burning of wood pellets release carbon dioxide (CO²) into the atmosphere, their production (via tree growth) sequester and capture carbon (Hanssen et al., 2017; Ireland, 2024; Schlesinger, 2018).

Critics of wood pellets challenge the claim that wood pellets are a clean, renewable energy, and often cite problems from increased air and noise pollution from wood pellet plants,

carbon emissions that may exceed those from fossil fuels, heightened deforestation, and the practice of using whole tree biomass for production rather than forest-byproducts (Drouin, 2015; Speare-Cole, 2021). More concerns include slow forest regrowth which can take up to 40 years, the premature cutting of trees that cannot sequester efficient carbon, and increased carbon emissions from transportation driven by the growing international wood pellet trade (Schlesinger, 2018). However, supporters counter that when sourced and managed correctly, wood pellets can reduce greenhouse gas emissions (Hanssen et al., 2017). Furthermore, researchers maintain that forest stock has remained stable despite the increase in global demand (Fitts, 2024; Hanssen et al., 2017).

Controversies aside, the EU considers wood pellets to be carbon neutral and a critical resource to achieve its climate goals (Parish et al., 2018). The EU is a leader in sustainability efforts given its renewable energy initiatives and increasing its demand for wood pellets (Parish et al., 2018). In 2022, the EU emerged as the largest global wood pellet market, consuming 24.8 million metric tons (MMT) (importing 5.89 MMT), followed by a slight decrease (1.2 percent) to 24.5 MMT (importing 4.88 MMT) in 2023 (Flach & Sophie, 2023, 2024). Wood pellet use is forecasted to rebound to 25.4 MMT due to prices and government incentives, with imports reaching 5.3 MMT in 2024 (Flach & Sophie, 2023, 2024).

The primary driver of EU wood pellet demand is the Renewable Energy Directive (RED), established in 2009 (European Commission, 2025). This legal framework is aimed at improving the development of clean energy in all sectors of the EU economy. The first target was to achieve a 20 percent share of renewable energy by 2020. This initiative has proven effective as the share of renewable energy in the EU was 12.5 percent in 2010 compared to 24.5 percent in 2023 (European Commission, 2025). Countries such as Sweden have renewable energy shares as high

as 66.0 percent, while Luxembourg has the lowest share at 11.6 percent (Eurostat, 2024). In 2018, the EU revised the RED (now REDII) to a higher target of 32 percent renewable energy by 2030 (European Commission, 2025). The directive was further updated in 2023 (REDII+) to 42.5 percent by 2030 (Flach & Sophie, 2024). In addition to RED strategies, the ‘Clean Energy for all Europeans’ package was introduced in 2019 to strengthen the infrastructure to handle the transition towards cleaner energy (Büscher et al., 2022).

The European Green Deal, which set a goal for the EU to be carbon neutral by 2050 (Flach & Sophie, 2023), was also introduced in 2019. Additionally, the EU implemented the REPowerEU plan in 2022, whose goal is to expand renewable energy use and reduce energy dependence on Russian fossil fuels (European Commission, 2022; Parajuli et al., 2024). Another main reason for the increase in wood pellet imports and demand is the rising cost of fossil fuels (Flach & Sophie, 2023).

European countries struggle to fulfill their wood pellet demand and find it challenging to trade with other European countries, so their priorities are to fulfill their energy requirements by maintaining and increasing imports to satisfy demand (Verhoest & Ryckmans, 2012). **Figure 1.1** shows the overall changes in wood pellet imports into the EU, in total and by exporting country. Since 2012, total wood pellet imports in the EU grew from nearly \$560 million to a little over \$1 billion by 2024. Belarus and Russia experienced growth in both value and quantity during this period. However, due to economic sanctions, imports from Belarus and Russia have fallen to zero. Note that imports from the remaining countries (Ukraine, U.S., and the *Rest of World*) increased when the sanctions were first imposed. Imports from the rest of the world continued to increase, reaching its highest value in 2024.

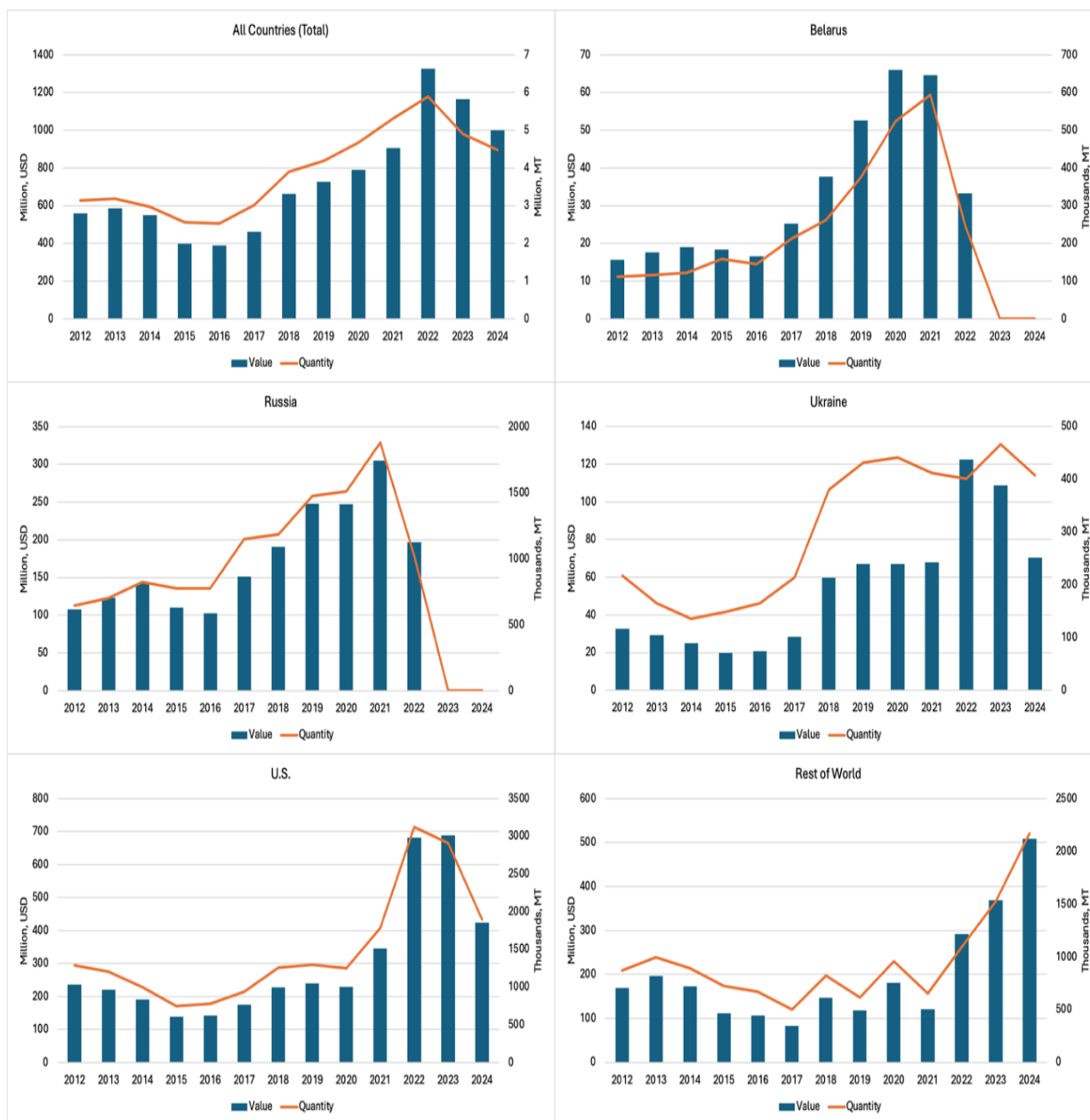


Figure 1.1. Values and Quantities of Top Wood Pellet Exporters to the EU: 2012-2024.

Source: Trade Data Monitor ® (2025), Eurostat (2025)

Note: Wood pellets are defined according to the Harmonized System (HS) for classifying traded products: HS 4401.31 *wood pellets*. MT is metric tons and USD is U.S. dollars.

The United States is the world's largest wood pellet exporter and one of the leading suppliers of wood pellet exports to the EU (International Trade Commission, 2025). In 2024, U.S. wood pellet exports reached a value of almost \$1.9 billion, nearly a 620 percent increase since 2012 (Foreign Agricultural Service, 2025). The top U.S. wood pellet export destinations are the United Kingdom (UK) (which held 58 per cent of the export market in 2023), followed by the EU, Japan, and Canada (Foreign Agricultural Service, 2025). Considering the U.S. has held a market share between 62 percent and 74 percent in the UK wood pellet import market since 2016, this study will focus on the next largest market, the EU, as the U.S. faces more competition from other exporting countries (Trade Data Monitor, 2024).

The U.S. produced 9.5 MMT of wood pellets in 2023, with 8.1 MMT produced in the Southeastern U.S. (Fitts, 2024). The Southeastern U.S. is the primary region for wood pellet production due to its abundant forest resources, specialized infrastructure for the wood pellet supply chain, and multiple ports (Parajuli et al., 2024). The U.S. has only about 24 export-oriented wood pellet processing mills in the South, with 21 having a capacity of over 100 metric tons per year (Fitts, 2024; Ireland, 2022). From 2012 to 2015, the value of U.S. wood pellet exports to the EU decreased by 41 percent due to several reasons such as increased competition. However, there was a 22 percent recovery in 2016 from \$142.7 million to \$174.8 million in 2017 (Trade Data Monitor, 2024). The positive year-over-year growth trend continued until 2019 to \$239.9 million. However, there was a slight 4.3 percent decrease in 2020 to \$229.5 million. Exports rebounded by 50.8 percent in 2021, growing to \$346.3 million, followed by a significant 96.8 percent increase to \$681.7 million in 2022. As of 2023, the export value reached a record high of \$694 million (**Figure 1.1**). Since the majority of wood pellets are produced in the Southeastern U.S., there is potential for economic growth and additional financial support for

rural forestry communities, with over 10,000 jobs being related to the wood pellet industry in the past decade (Fitts, 2024; Masum et al., 2019).

Figure 1.2 shows the import share of the top wood pellet exporters in the EU market from 2012 to 2024. As noted in the figure, the U.S. is the major supplier of wood pellets to the EU, but it is not the sole supplier. Two major competitors are Russia and Belarus, with Belarus playing a prominent role due to its close ties to Russia through a bilateral union and geographic proximity to the EU (Welt, 2023). While the U.S. did have a majority share in the EU wood pellet market at 38.3 percent in 2021 (prior to the Russian invasion of Ukraine), the combined market share for Russia (33.7 percent) and Belarus (7.1 percent) surpassed the U.S. market share (Trade Data Monitor, 2024). These two countries combined have exceeded the U.S. market share in the EU since 2017 (Trade Data Monitor, 2024). Ukraine has maintained less than ten percent of market share since 2012. The rest of the world's import share averaged nearly 25 percent since 2012. However, since 2021, the import share for rest of the world has steadily increased to 50 percent in 2024.

The Russian invasion of Ukraine, which began in February 2022, deepened tensions between Russia and the EU, affecting the industrial and energy-related sectors (Meissner, 2024). Although there are ongoing debates over the effectiveness of these measures (Giumelli, 2024), sanctions have become the primary response by the EU (Pertiwi, 2024). Additionally, the EU has a long history of supporting Ukraine, as seen previously during Russia's 2014 annexation of Crimea, a peninsula governed by Ukraine (Pertiwi, 2024; Price, 2023). Since 2022, the EU placed four types of sanctions on Russia and supporters of the invasion: individual sanctions, economic sanctions, diplomatic measures, and visa measures (European Council, 2024). These sanctions included trade restrictions, and since the invasion, EU customs authorities banned 91.2

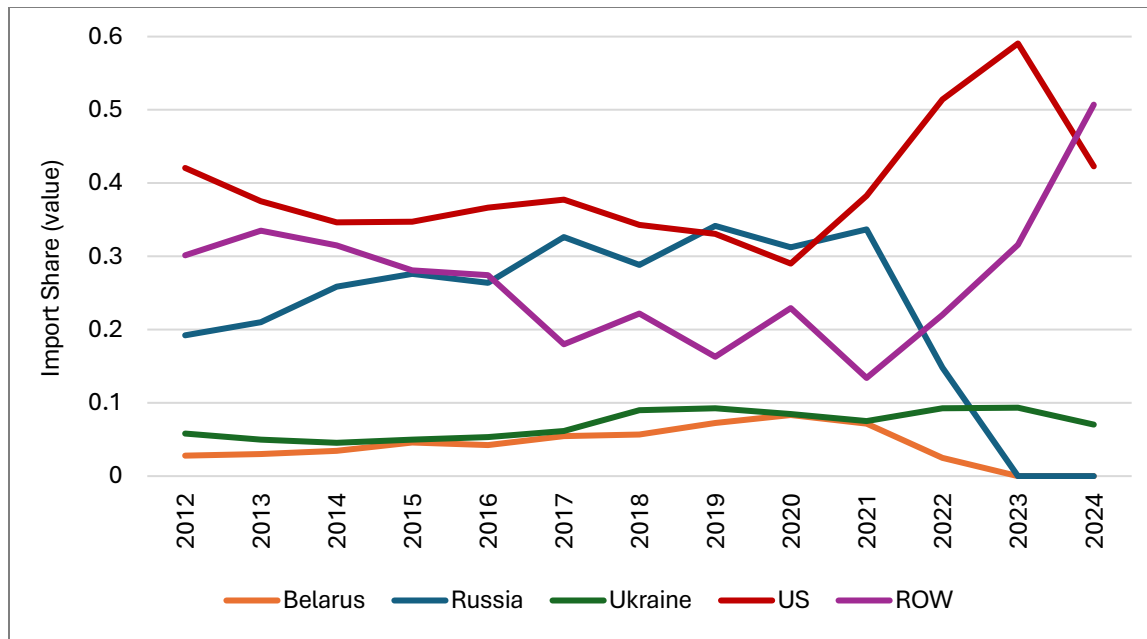


Figure 1.2. Import Share of Top Wood Pellet Exporters to the EU: 2012-2024.

Source: Trade Data Monitor ® (2025), Eurostat (2025)

Note: Wood pellets are defined according to the Harmonized System (HS) for classifying traded products: HS 4401.31 *wood pellets*.

billion euros worth of imports from Russia (European Council, 2024). Although not directly involved, Belarus supported the invasion and the sanctions were extended to include Belarus (Welt, 2023). The banning of wood pellets is included in the fifth package out of a total of 15 packages of sanctions against Russia and Belarus adopted since April 2022 (European Council, 2024). As shown in **Figure 1.1** and **Figure 1.2**, EU imports of wood pellets from Belarus and Russia significantly fell in 2022 and were zero in 2023 and 2024, respectively.

Problem Statement and Study Overview

The Russian invasion of Ukraine and following EU sanctions raise questions about the consequences of the future of EU wood pellet demand and U.S. exports. The purpose of this study is to evaluate the impact of the Russia-Ukraine conflict on the U.S. and competing wood pellet exporters in the EU market. This study will employ a demand system approach to model EU import demand. To assess the competition across exporting countries, EU demand is assumed

to be differentiated by source. Based on their importance to EU wood pellet demand, the following countries will be considered for the analysis: U.S., Ukraine, Russia, and Belarus. Additionally, less prominent wood pellet exporters such as Brazil and Canada will be aggregated with all remaining countries.

This paper will answer the following questions. How has the Russian-Ukraine conflict affected the top wood pellet exporter in the EU market? Will exporters gain or lose market share in the EU wood pellet market? How did wood pellet prices change, and how did that affect competing countries in the EU? What would have happened to imports had the invasion not occurred? Which exporting country mostly benefited from the sanctions? What are the projected losses and gains for each exporting country from the sanctions?

The issue of economic sanctions and trade outcomes is important because competing countries feel their direct effects within the market, whether it is through trade losses or trade gains. When trade flows shift, U.S. wood pellets exporters and their broader economic environment are affected. For the EU, the sanctions could lead to overall import loss, shrinking its wood pellet market, and making sustainability goals more difficult to achieve. The findings of this research will show how the demand for imported wood pellets in the EU responded after the shock from the economic sanctions, and which countries benefit the most in the aftermath.

Study Goal and Specific Objectives

The goal of the study is to estimate the demand for wood pellet imports in the EU from top exporters such as the U.S. and its competitors. Additionally, the study will assess how the Russia-Ukraine conflict and following sanctions have impacted wood pellet demand in the EU. The specific objectives of the study are as follows:

- (1) Estimate source-differentiated EU demand to determine how exporting countries compete in the EU market. For this objective, the Quadratic Almost Ideal Demand System (QUAIDS) model is used to determine how competing exporters' import shares change in the EU wood pellet market in response to changes in the exporters' wood pellet prices and total import expenditures.
- (2) Using the model estimates, derive the uncompensated, compensated, and expenditure elasticities to evaluate the EU wood pellet market. Additionally, I will analyze the own-price and cross-price elasticities to assess demand changes for an exporting country and capture complementary or substitution effects between competitors.
- (3) Estimate total import demand using a dynamic regression framework to determine EU imports had the invasion not occurred.
- (4) Using the estimates from the modeling framework, assess the difference between the actual trade and projected trade assuming the invasion did not occur to determine the losses and gains for each exporting country from the economic sanctions on Russia and Belarus.

Overview of Thesis

The remainder of this thesis proceeds as follows. In Chapter 2, I discuss global wood pellet production and exports. EU wood pellet demand is also discussed in this chapter. In Chapter 3, I review the literature on wood pellet import demand and also consider research on trade and economic sanctions. Lastly, the implications of the literature on this research and how this paper will strengthen EU wood pellet demand research are considered. In Chapter 4, I introduce the methodology and present the QUAIDS model and dynamic regression framework for estimating total import demand. Additionally, I show how the uncompensated, compensated,

and expenditure elasticities are derived from the QUAIDS model estimates. Estimation and elasticity results are reported in Chapter 5. I also present the findings of the dynamic regression framework to show the impacts of the invasion and sanctions on EU wood pellet imports. Chapter 6 concludes the research where I provide a summary and closing remarks.

CHAPTER 2

BACKGROUND

U.S. Wood Pellet Production and Exports

The U.S. is one of the largest producers of industrial roundwood, wood pulp, and wood pellets (Brandeis et al., 2021). Within the forestry sector, wood pellets have become a key international commodity due to global green energy initiatives, reduced fossil fuel dependency, and rising demand for renewable energy alternatives (Flach & Sophie, 2024; Kline et al., 2021). U.S. wood pellets are typically made from pulp-wood, a low-quality roundwood that is whole wood or chipped logs (Brandeis et al., 2021). Although the demand for wood pellets is growing, they remain a small part of broader pulp-wood consumption, which accounts for 46 percent of all U.S. roundwood consumption (Brandeis et al., 2021). In 2017, wood pellets accounted for less than 3.0 percent of roundwood use in the Southern U.S. (Brandeis et al., 2021).

There are two main types of wood pellets: premium wood pellets and industrial pellets. Premium wood pellets, which are used in small-scale residential settings, have a lower ash content (≤ 1.0 percent) and lower moisture content (≤ 8.0 percent), resulting in a cleaner burn and more heat production (Pellet Fuels Institute, 2022). These pellets typically cost more than utility pellets (U.S. Energy Information Administration, 2025). Standard pellets are similar but have a slightly lesser quality than premium. Both premium and standard pellets are subject to strict grading regulations set by the Pellets Fuels Institute and approved by the U.S. Environmental Protection Agency in 2015 (Environmental Protection Agency, 2020). Industrial wood pellets are used in industrial settings such as power plants. They have higher ash content (≤ 6.0 percent), higher moisture content (≤ 10.0 percent), and use lower-quality wood, which

reduces their cost (Ireland, 2022; Pellet Fuels Institute, 2022). Additionally, utility pellets are typically purchased in bulk, further reducing costs.

The U.S., specifically the Southern U.S., produces wood pellets for export, with little production going towards domestic use (Ireland, 2022). Wood pellet exports currently account for a large share of U.S. wood pellet production. In 2012, exports only accounted for 54.6 percent of U.S. production, however, exports have steadily increased to 97.2 percent of production in 2023 (FAO, 2025). Domestic consumption is relatively low due to price competitiveness with other residential heating options such as oil and propane (Lamers, 2017). The demand for residential wood pellets is, in part, due to incentives such as the Energy Efficient Home Improvement tax, where a consumer can claim 30.0 percent of the cost of an energy-efficient project, such as the installation of wood pellet stoves (Atasoy et al., 2023; Energy Star, 2025; Ireland, 2022). There are no incentives for industrial pellet use in the U.S. However, due to woody biomass favorable policies in foreign markets, seasonal preferences, incentive programs, competitive wood pellet pricing, and fluctuating fossil fuel prices, the U.S. has emerged as a major exporter of industrial wood pellets (Flach & Sophie, 2024).

Figure 2.1 compares global and U.S. wood pellet production. The U.S. is the largest contributor to global wood pellet production, representing nearly 21 percent of wood pellet production in 2023 (FAO, 2025; Johnston et al., 2022). Between 2012 and 2023, U.S. wood pellet production steadily increased by 183 percent, from 3.5 MMT to 9.8 MMT. Although production slightly decreased in 2016 and 2020, the sector was able to quickly recover. As production increased, domestic wood pellet prices rose. (U.S. Energy Information Administration, 2025).

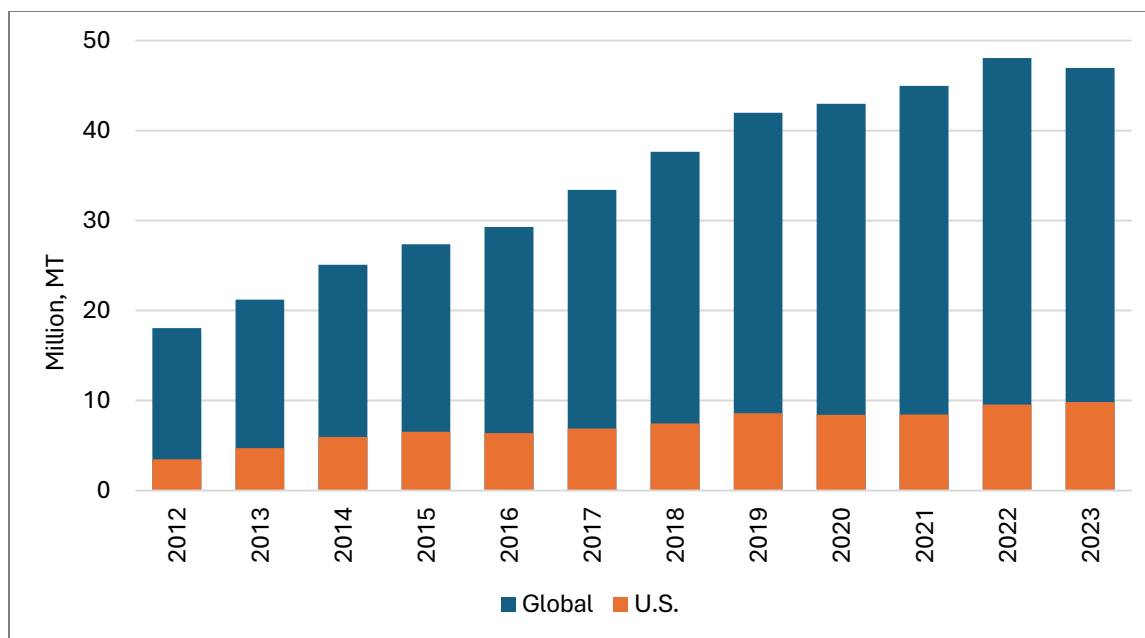


Figure 2.1. Wood Pellet Production (U.S. and Global): 2012 to 2023.

Source: FAOSTAT (2025)

Note: Wood pellets are defined according to the Harmonized System (HS) for classifying traded products: HS 4401.31 *wood pellets*. MT is metric tons.

U.S. wood pellet exports have increased significantly in comparison to other forest products since 2012 (**Figure 2.2**). In 2012, U.S. wood pellet exports accounted for three percent, \$258 million, of total U.S. forest product exports (\$7.8 billion) (Foreign Agricultural Service, 2025). By 2018, the share of wood pellet exports increased by 8.0 percent, reaching \$809 million. Although there was a slight decrease in 2021, U.S. wood pellets experienced a strong recovery in 2022, reaching 15.0 percent of total forestry exports (\$1.5 billion) (**Figure 2.3**). As of 2024, U.S. wood pellet exports represented 20 percent of all forest product exports, as defined by the U.S. Department of Agriculture. From 2012 to 2018, U.S. wood pellets exports increased by nearly 214 percent, from a value of \$258 million to \$810 million. After steady growth, wood pellet exports experienced a notable 48 percent increase from 2021 to 2022, reaching a value of \$1.5 billion, with continued growth to \$1.9 billion in 2024 (**Figure 2.4**).

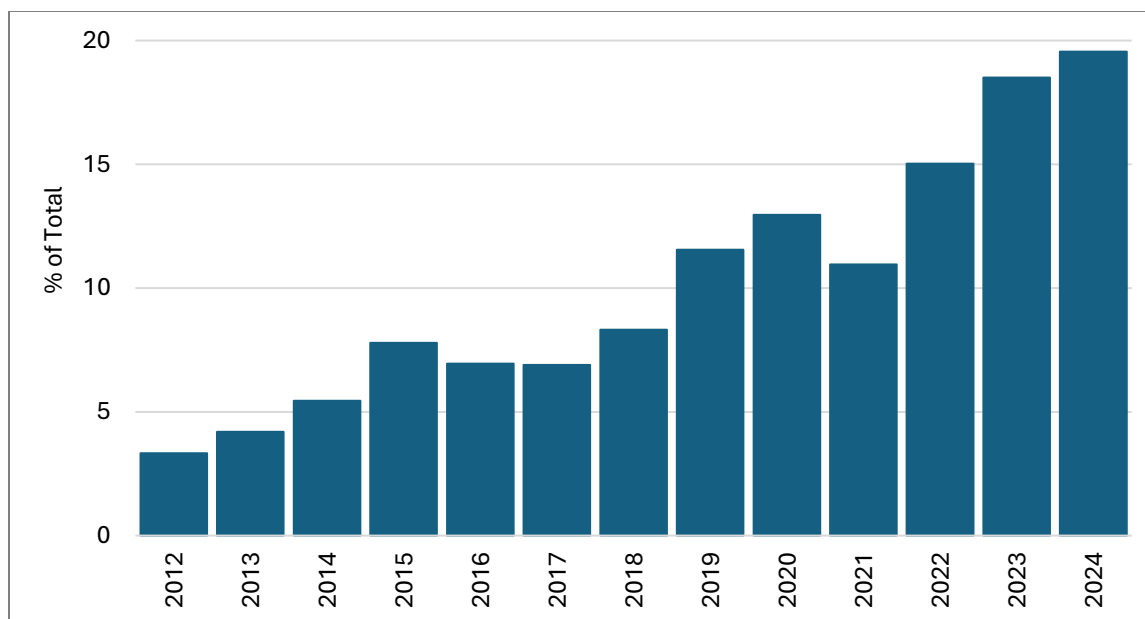


Figure 2.2. Share of U.S. Global Wood Pellets Exports in Total U.S. Global Forest Products Exports: 2012-2024.

Source: U.S. Department of Agriculture (2025)

Note: Wood pellets are defined according to the Harmonized System (HS) for classifying traded products: HS 4401.31 *wood pellets*.

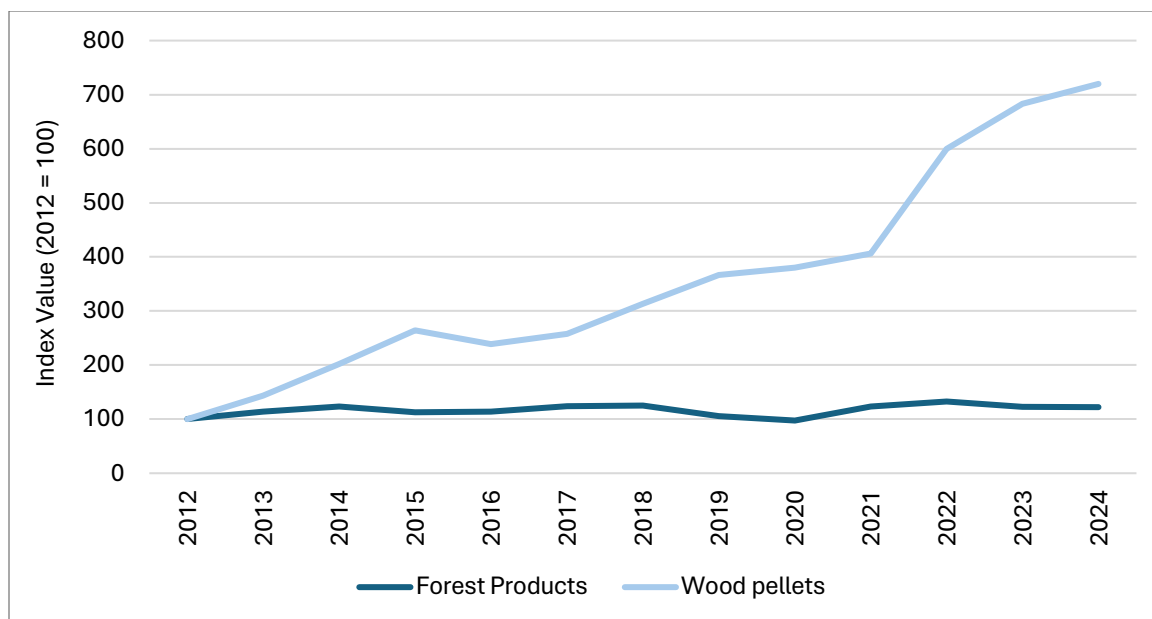


Figure 2.3. U.S. Wood Pellets Export versus U.S. Forest Products Exports: 2012 – 2024.

Source: U.S. Department of Agriculture (2025)

Note: Wood pellets are defined according to the Harmonized System (HS) for classifying traded products: HS 4401.31 *wood pellets*. Forest Products are defined according to the U.S. Department of Agriculture.

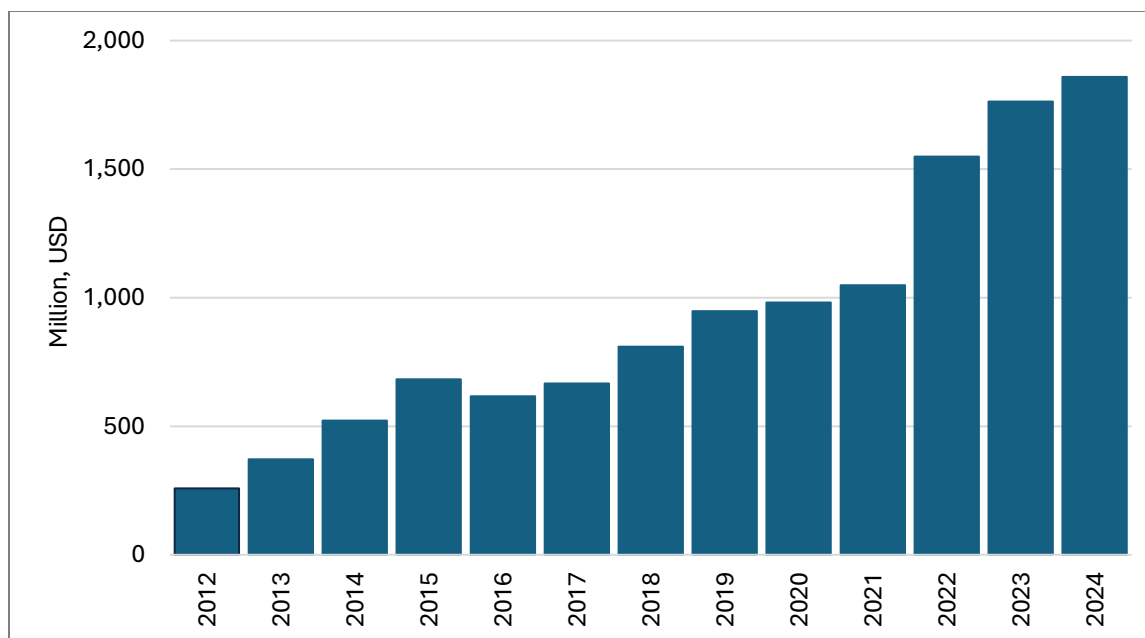


Figure 2.4. U.S. Wood Pellet Exports to All Global Partners, Value, 2012-2024.

Source: U.S. Department of Agriculture (2025)

Note: Wood pellets are defined according to the Harmonized System (HS) for classifying traded products: HS 4401.31 wood pellets. USD is U.S. dollars.

As of 2024, the primary export destinations for U.S. wood pellets were the UK, the EU, Japan, and Canada. The UK and the EU are the largest markets due to favorable woody biomass policies. Since the UK was once a part of the EU, many of the EU environmental policies still apply to the UK. Combined, the EU and UK made up 97.0 percent of the U.S. wood pellet exports in 2018 and had a slight decline to 86.0 percent in 2024. The decrease could be due to other competitors, such as Brazil, increasing their wood pellets exports to the EU. Although the UK made up 58.1 percent of U.S. exports in 2023, the U.S. faces limited competition in the UK market. In this paper, I focus solely on the EU, the second largest market for U.S. wood pellets (26.2 percent of U.S. exports in 2023), as the U.S. faces more competition from other exporting countries in this market (Trade Data Monitor, 2024).

EU Wood Pellet Production and Import Demand

EU wood pellet consumption has steadily grown in recent years due to policies in the Renewable Energy Directive (RED) and the rising price of fossil fuels (Flach & Sophie, 2024). From 2015 to 2023, EU wood pellet consumption increased by an annual average of 6.5 percent, reaching 25 MMT in 2023, with the same forecasted value for 2024 (Flach & Sophie, 2024). From 2015 to 2021, EU wood pellet production increased by 34.0 percent from 15 MMT to nearly 20 MMT and has remained relatively stagnant up to 2024 at 21 MMT. However, the EU cannot produce enough wood pellets to meet its consumption needs, as shown in **Figure 2.5**. The gap is due to several countries within the EU suffering from softwood shortages, logistical constraints, and high input costs, leading to a dependence on wood pellet imports to fulfill demand (Flach & Sophie, 2024; Von Wood, 2024). As a result, EU wood pellet imports increased by 108.0 percent from 2015 to 2021, rising from 2.6 MMT to 5.3 MMT (Flach & Sophie, 2024). Imports continued to grow by 11.0 percent between 2021 and 2022, followed by a nearly 17.0 percent decrease in 2023 to 4.9 MMT. However, there is a forecasted recovery of an 8.0 percent increase in imports, bringing the total to 5.3 MMT in 2024.

The top EU countries for wood pellets imports are Germany, France, and Italy (mainly for residential use) while the top wood pellet importers for industrial wood pellet use are the Netherlands and Denmark (Flach & Sophie, 2024). Fifty percent of wood pellet consumption is for small and medium-scale residential use (domestic stoves, residential buildings, and public buildings) and the remaining consumption is for industrial use. While wood pellet use differs across EU countries, the ability to produce wood pellets varies from country to country. Some EU countries, such as Germany, can support their wood pellet consumption, while other countries, such as the Netherlands, rely solely on imports (Flach & Sophie, 2024). National

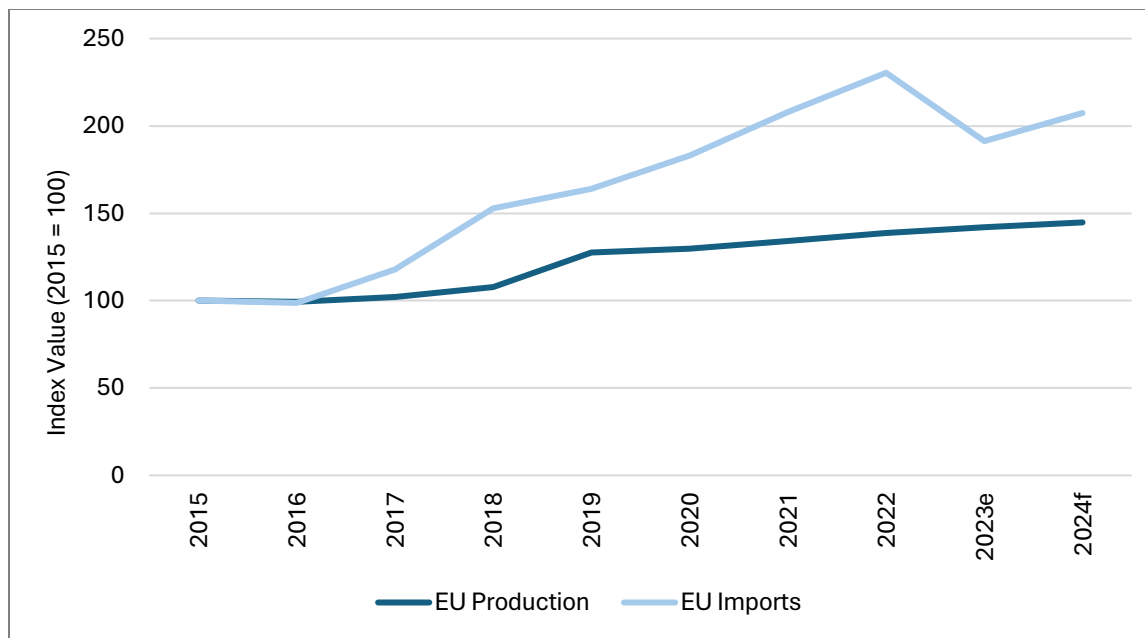


Figure 2.5. The EU's Growing Reliance on Imports: EU Wood Pellet Production vs EU Wood Pellet Imports, 2015 to 2024.

Source: Flach and Bolla (2024).

Note: e represents an estimated value and f is a forecasted value.

Note: Wood pellets are defined according to the Harmonized System (HS) for classifying traded products: HS 4401.31 wood pellets.

policies further influenced the production and consumption of wood pellets. Apart from the broad sustainability policies, many countries have specific standards and programs about wood pellet use such as Austria subsidizing wood pellet replacement over fossil fuels, Poland's Clean Air program, and Germany's programs to financially support the transition from coal to wood pellets. As a result, several wood pellet-importing EU countries rely on non-EU countries to satisfy their consumption (Flach & Sophie, 2024).

The main exporting countries that supply the EU are the U.S., Russia, Ukraine, and Belarus. Russia and the U.S. have consistently been the top wood pellet exporters in the EU market. The U.S. held the largest share from 2012 to 2018, then Russia briefly overtook the U.S. in 2019 and 2020. However, the U.S. regained the top position in 2021 and has held it since. Prior to the economic sanctions, each country has experienced significant growth in the EU.

From the period between 2016 to 2020, U.S. wood pellets exports to the EU increased by 61.0 percent (\$230 million), Russian exports by 141.0 percent (\$247 million), Ukrainian exports by 225.0 percent (\$67 million), and Belarusian exports by 301.0 percent (\$66 million) (Trade Data Monitor, 2024). **Table 2.1** shows the market share for the top exporting countries to the EU in 2021.

The Russian invasion of Ukraine occurred in February 2022, and the EU placed sanctions in April 2022 during the fifth package of sanctions against Russia and its supporter, Belarus (European Council, 2024). Russia and Belarus were significant wood pellet exporters to the EU as shown in **Table 2.1**, where Russia and Belarus combined for 41.0 percent in 2021. However, due to the sanctions, their exports to the EU decreased significantly and trade flows changed for the remaining competitors (Trade Data Monitor, 2024; Welt, 2023).

In closing, the demand for U.S. wood pellet exports in the EU is dependent on the implementation and enforcement of EU green energy policies (Ireland, 2018). Recent growth is most likely due to the 2018 modification of the Renewable Energy Directive (REDII) (Flach & Sophie, 2024). REDII set renewable energy targets to 32.0 percent by 2030. This directive was once again updated in 2023 to align with the EU Green New Deal goals, which included a 55 percent reduction of greenhouse gas emissions by 2030 and carbon neutrality by 2050 (European Commission, 2025; Flach & Sophie, 2024). However, ongoing debates about the renewable nature of woody biomass as an industrial energy could affect future EU demand. New EU deforestation regulations, i.e., the EU Deforestation-free Supply Chain Regulation, which took effect in December 2024 could restrict imports of wood pellets in the future (Flach & Sophie, 2024).

Table 2.1. Value, Quantity, and Share of Wood Pellet Exporters to the EU in 2021.

Countries	Value USD	Quantity Kg	Share
Belarus	\$64,653,237	593,694	7.1
Russia	\$304,802,868	1,880,627	33.7
Ukraine	\$68,018,527	411,347	7.5
U.S.	\$346,346,049	1,781,158	38.3
ROW	\$121,294,074	651,304	13.4

Source: Trade Data Monitor ® (2025)

CHAPTER 3

LITERATURE REVIEW

Wood Pellet Import Demand

Research on wood pellet demand is growing due to increased trade, related policy initiatives, increasing interest in renewable fossil fuel alternatives, and environmental concerns. In this section, the international demand for wood pellets is explored to gain a better understanding of this growing market. Although the literature is growing, research on international wood pellet demand is limited; however, several studies have investigated demand and trade in regions such as the EU and Southeast Asia.

Sun and Niquidet (2017) examined the demand for imported wood pellets in the EU. They estimated expenditure, price, and cross-price elasticities using the Almost Ideal Demand System (AIDS) model. In their analysis, they assume that wood pellets were differentiated by source to examine how exporting countries competed in the EU market. They also analyzed how import demand responded to EU policies and renewable fuels targets. They used monthly import data from 2009 to 2015 and focused on the top wood pellet sources: U.S., Canada, Russia, and ROW. The study found that the EU's demand for imported wood pellets is mostly inelastic. The results also showed that the U.S. benefited more from rising imports. For example, when total import expenditures increased by 1 percent, imports from the U.S. grew by 1.41 percent, compared to only 0.74 percent and 0.43 percent for Canada and Russia, respectively. They concluded that non-price attributes, such as quality and sustainability, are also essential determinants of demand.

Atasoy and Zhang (2025) also estimated the expenditure, price, and cross-price elasticities for imported wood pellets in the EU. They also used the AIDS model and focused on

demand from different sources. However, they also considered other functional forms such as the Rotterdam model, another popular demand model. The study used a longer period for analysis: 2007 to 2021. Despite its exit from the EU in December 2020, the UK was included due to it being a large wood pellet importer. Similar results were found for U.S. wood pellets. This was primarily due to the U.S. being favored over its competitors, resulting in lower market share for Canada and Russia. This study also identified significant cross-price elasticities compared to the previous study, indicating more competition within the EU wood pellet market.

The EU is a dominant region of interest for global wood pellet demand and the two studies reviewed this far focused on the entire region. Kristöfel et al. (2016), however, estimated the supply and demand for wood pellets in an individual country, Austria. They noted that production, consumption, and production capacity in Austria have steadily increased since 2000 due to wood pellets being used for residential heating. The study utilized a two-stage least-squares (2SLS) regression and simultaneous equation model to estimate short-run supply and demand elasticities. Two estimated models used annual wood pellet data based on quantity, prices, consumption, production, and more attributes from 2000 to 2014. Their final model used monthly data based on wood pellet prices, consumption, and production from 2009 to 2014. Their results indicated that the elasticity of demand is inelastic in Austria. The supply elasticity for all models was unit elastic, a 1.0 percent increase in price led to a 1.0 percent increase in wood pellet production. Their study contributes to a better understanding of wood pellet demand, as well as the inelastic nature of own-price responsiveness within the EU region.

Unlike the previous studies, Oh and Suh (2024) examine the wood pellet imports in Southeastern Asia. Due to renewable energy policies around the world, Vietnam, Malaysia, and Indonesia experienced a surge in wood pellet production and exports with a majority of

production being exclusively exported between 2012 and 2021. In the same period, South Korea experienced a significant increase in imports. Using a differential import allocation model, the study examined South Korean import demand by analyzing price effects and policy factors and exploring the impact of a mandated renewable energy policy. The source-differentiated model included monthly quantities and prices for Vietnam, Malaysia, Indonesia, and the remaining countries all aggregated (*rest of world*). They consider import during the period 2013 to 2022. The study found that the own price elasticities for wood pellets from Vietnam, Malaysia, and Indonesia were significant and inelastic. Their cross-price elasticity estimates indicated a substitute relationship between Vietnam and Malaysia, as well as between Vietnam and ROW. However, the demand for wood pellets from Vietnam changed minimally with respect to wood pellet prices in Malaysia and other countries. Additionally, the renewable portfolio standard (a mandated policy in South Korea to blend renewable energy sources with fossil fuel energy) led to an increase in South Korea's import demand from Vietnam and Indonesia, while decreasing imports from all remaining countries.

Lamica and Parajuli (2024) examined the drivers of U.S. wood pellet exports using a stochastic frontier gravity trade model, a model commonly used to analyze trade flows. Their approach allowed for estimating the maximum trade possible for a given set of inputs. The objective of the study was to determine drivers such as forest area, biomass consumption and consumption incentives, and sustainability criteria that affect U.S. wood pellet exports. They also considered the broader societal impacts such as COVID-19 and the Russia-Ukraine conflict. The data consisted of monthly U.S. wood pellet exports to its top ten export destinations: the UK, the Netherlands, Denmark, Belgium-Luxemburg, Canada, Italy, South Korea, France, Japan, and Germany. The results indicated that consumption incentives and biomass consumption policies

increased U.S. wood pellet exports to export destinations by 0.2 and 37.0 percent, respectively. Most notably, the Russia-Ukraine conflict caused U.S. wood pellet exports to major destinations to increase by 50.0 percent, all else held constant. Their study concluded that the average efficiency of trade between the U.S. and its top destinations was 40.5 percent.

A recurring trend influencing wood pellet research is the implementation of the EU's renewable energy policies or incentives as the main drivers of wood pellet demand. Jonsson and Rinaldi (2017) assessed how increased demand for wood pellets in the EU affected global markets. The authors simulated how the market would behave in response to two of the EU's target goals. The study utilizes the Global Forest Trade Model (GFTM), a model based on spatial equilibrium theory. The model covers 48 regions with values and quantities from the year 2014. The study uses two scenarios: a scenario where EU wood pellet consumption is forced to increase to 22.2 million tons by 2030 and a second scenario where wood pellet consumption is increased to 40.1 million tons by 2030. The results show that in the alternate scenarios, as EU consumption increases, EU wood pellet production will also increase, although not equally among all EU countries. However, once consumption exceeds production, the EU will rely on imports from the U.S., Russia, and Canada. Demand in the U.S., Russia, and Canada will decrease in favor of wood pellet exports to the EU.

Russia-Ukraine Conflict

This section describes studies of how the Russia-Ukraine conflict and resulting sanctions affected global markets. To capture potential economic effects, Mahlstein et al. (2022) used a computer general equilibrium modeling framework (Global Trade Analysis Project or GTAP) to estimate simulated economic effects within a mocked sanctioned environment. The data includes geographical data from 32 regions and 65 sectors from 2017 to 2019. The most notable results

were the percentage changes in real income and total exports under the total effect and import embargo. U.S. and the rest of the EU real income decreased by only -0.1 and -1.37 percent, respectively. Similarly, the U.S. and the rest of the EU total exports decreased by only -0.52 and -0.27 percent, respectively. This indicates that the Allied embargo had a limited effect on the ally economies. Conversely, for the non-allies, such as China, the study reported positive changes in both real income and total exports, which supports the notion that Russian exports are being redirected to alternative markets. The study also found that Russian forest exports to the world increased by 30.26 percent, supporting the alternative markets narrative. This could allow U.S. forest products, which compete with Russian forest products, to expand their market share in foreign markets.

Nepal et al. (2024) studied the projected effects on global forest product markets in the aftermath of the Russia-Ukraine conflict. Using the Global Forest Products Market (GFPM) model to evaluate the effects of trade policies, the study considers scenarios where there was no invasion, a short-term invasion resulting in restricted trade flows of Russia and Ukraine wood products between 33 percent and 95 percent between 2021 and 2025, and a long-term scenario (2050) where the trade ban is assumed to be lifted by 2025. The data in their study contain wood product exports from multiple sources and imports for multiple destinations, assuming 2020 as the base year. The results indicate that in the short-term scenario, Russia and Ukraine were severely affected in terms of consumption, trade, production, and higher prices in the wood products market and suffered for two decades afterward. However, in the long-term scenario, there is less overall disruption, and the global wood products market is expected to recover to pre-invasion levels. This study contributes to the understanding of market welfare impacts for

wood products and the shifting trade flows. It also indicates that recovery after a market shock is possible.

Implications for Current Research

Previously mentioned studies lacked coverage of large market shocks such as COVID-19, significant policy updates, and the Russia-Ukraine conflict. Additionally, some studies covered the wood pellet sector, while others focus on wood products in general.

The study conducted by Sun and Niquidet (2017) is similar to the current study. The authors delve into the import demand for wood pellets in the EU, however, they are missing key components. In terms of capturing more recent market shocks, their data period stops at 2015, excluding data from the COVID-19 period. Additionally, the UK is included with the EU (EU-28), without considering the effects of Brexit in December 2020. This is important due to the potential bias towards the U.S. in the model. Note that the U.S. is the primary supplier of wood pellets to the UK but faces significantly more competition in the EU (minus the UK). Since the UK imports mostly from the U.S., regardless of competition, the UK will more likely than not continue to favor U.S. wood pellets. Additionally, since the effects of the Russia-Ukraine conflict are not included, major exporters to the EU are excluded. Key exporters, such as Belarus and Ukraine, are vital to EU wood pellet imports and the overall analysis interpretation. Another related wood pellet demand study was conducted by Atasoy and Zhang (2025). Although the study had a larger range up to 2021, the effects of the Russia-Ukraine war were not included. Additionally, the UK was included, while key exporters were excluded. Additional research considering the effects of the sanctions placed on Russia and Belarus is beneficial to the changing trade dynamics of the wood pellet trade.

This paper will include several components to enhance EU import wood pellet demand research. A larger monthly dataset including market shocks, such as Covid-19, will better capture demand effects. The inclusion of other top wood pellet exporters, such as Belarus and Ukraine, will provide a clearer understanding of the competitive nature of the EU wood pellet market. Additionally, the omission of the UK will deter strict EU demand preference towards the U.S. Most notably, the QUAIDS model will capture more flexible expenditure effects and complex import relationships.

CHAPTER 4

DATA AND METHODS

Data Overview

Data on EU wood pellet imports were obtained from the Trade Data Monitor® (2025). The data include monthly values and quantities for wood pellet exporting countries in the EU from 2012 to 2024. As previously mentioned, the exporters considered in this study are Belarus, Russia, Ukraine, and the U.S. All remaining countries are aggregated together into the *rest of world* (ROW). Wood pellets are defined according to the Harmonized System (HS) classification HS 4401.31 *wood pellets* (Schipfer et al., 2020a). Import shares and prices are derived from the data and used in estimating the QUAIDS model and total import model. The descriptive statistics are presented in **Table 4.1**. The countries with the smallest average import shares are Belarus (5 percent) and Ukraine (7 percent). ROW has a moderate average import share of 24 percent. EU wood pellet demand mainly relies on imports from the U.S. (34 percent) and Russia (29 percent). For prices, the average price on the lower end for Belarus was \$133 per ton. Ukrainian and Russian prices follow with average prices of \$153 and \$158, respectively. The average price for ROW is on the higher end at \$181, while the U.S. has the highest average price at \$188. Despite the high price, the U.S. still has the largest average import share. Additionally, the U.S. has a wider variation between its minimum price (\$152) and maximum price (\$408).

Models and Methods

In this section, I present the methods used to address the study's goal: to estimate the demand for wood pellet imports in the EU from major exporters such as the U.S. and its competitors, and to assess how the Russia-Ukraine conflict and following sanctions have impacted wood pellet demand in the EU. I will discuss the model used to estimate source-

Table 4.1. Descriptive Statistics

Variable	Mean	Std. dev.	Min	Max
Belarus import share	0.054	0.025	0.014	0.127
Russia import share	0.294	0.094	0.092	0.706
Ukraine import share	0.069	0.027	0.023	0.170
U.S. import share	0.343	0.125	0.003	0.631
ROW import share	0.240	0.106	0.044	0.499
Belarus price (\$ per MT)	133.11	19.35	92.86	190.09
Russia price (\$ per MT)	158.05	17.29	118.24	187.48
Ukraine price (\$ per MT)	153.53	21.36	120.03	220.58
U.S. price (\$ per MT)	188.97	26.41	152.46	408.40
ROW price (\$ per MT)	181.51	20.77	121.53	278.57
Total Expenditure (\$ mill.)	50.30	18.00	12.10	90.80

Source: Author's calculations using data from Trade Data Monitor ® (2025), Eurostat (2025)

differentiated EU demand (QUAIDS demand system) and resulting uncompensated, compensated, and expenditure elasticities, and will also discuss the dynamic total import demand estimation and forecasting. Both modeling frameworks will be used to forecast EU demand and assess the impact of the Russia-Ukraine conflict on each exporting country.

Quadratic Almost Ideal Demand System Model

The Almost Ideal Demand System (AIDS) model was developed by Deaton and Muellbauer (1980). Although originally intended for consumer demand analysis, the model has been used in trade analysis to assess a country's expenditure on a good(s) from various exporting countries (Sun & Niquidet, 2017).

An extension of the AIDS model is the QUAIDS model developed by Banks, Blundell, and Lewbel (1997). Engel curves describe how the quantity demanded changes with a change in income. The QUAIDS Engel curves are non-linear, compared to the linear Engel curves in the traditional AIDS model. The QUAIDS model is consistent with utility theory and the quadratic expenditure term allows for nonlinear responses between total expenditure and imports.

Define the total expenditure on imported wood pellets as E and the expenditure on wood pellets from country i as E_i , such that $\sum_i E_i = E$. The QUAIDS model can be expressed as follows (Banks et al., 1997):

$$w_i = \alpha_i + \sum_{j=1}^n \gamma_{ij} \ln p_j + \beta_i \ln \left[\frac{E}{a(P)} \right] + \frac{\lambda_i}{b(P)} \left\{ \ln \left[\frac{E}{a(P)} \right] \right\}^2 \quad (1)$$

The term, $w_i = \frac{E_i}{E}$, represents the import (expenditure) share for wood pellet from country i . p_j is the price of wood pellets from country j . As mentioned, total import expenditure is represented by E . The intercept is α_i and γ_{ij} represents the price effect of good j on good i . β_i

represents how EU wood pellet demand changes when overall wood pellet expenditures change.

λ_i represents the quadratic expenditure effect. $\ln a(p)$ and $b(p)$ are prices indexes that are expressed as follows (Banks et al., 1997):

$$\ln a(P) = \alpha_0 + \sum_{i=1}^n \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij} \ln p_i \ln p_j \quad (2)$$

$$b(P) = \prod_{i=1}^n p_i^{\beta_i} \quad (3)$$

Additionally, restrictions can be imposed on the model parameters to satisfy the following demand theory properties: adding up, homogeneity, and symmetry (Banks et al., 1997; Deaton & Muellbauer, 1980; Poi, 2012). The adding up restriction is due to the summation of the import shares being equal to one. The homogeneity restriction is due to prices in the demand model being homogenous of degree zero. This implies that if all prices change by equal proportion, the budget shares should be constant. Symmetry indicates that the cross-price effects should be symmetric. That is, the effects of the price of wood pellets from country i on the demand for wood pellets from country j is equal to the effect of the price of wood pellets from country j on the demand for wood pellets in country i . These restrictions can be expressed as follows:

$$\text{Adding up:} \quad \sum_{i=1}^n \alpha_i = 1, \sum_{i=1}^n \beta_i = 0, \sum_{i=1}^n \lambda_i = 0, \sum_{i=1}^n \gamma_{ij} = 0 \quad (4)$$

$$\text{Homogeneity:} \quad \sum_{j=1}^n \gamma_{ij} = 0 \quad (5)$$

$$\text{Symmetry:} \quad \gamma_{ij} = \gamma_{ji} \quad (6)$$

The model estimates could also be used to derive the uncompensated, compensated, and expenditure elasticities.

$$\text{Uncompensated:} \quad e_{ij}^u = \left(\frac{\mu_{ij}}{w_i} \right) - \delta_{ij} \quad (7)$$

$$\text{Compensated:} \quad e_{ij}^c = e_{ij}^u + e_i w_i \quad (8)$$

$$\text{Expenditure:} \quad e_i = \left(\frac{\mu_i}{w_i} \right) + 1 \quad (9)$$

δ_{ij} represents the Kronecker Delta, which is one for own price ($i = j$), but 0 otherwise. The terms μ_{ij} represents the marginal effect of the import share with respect to logarithm of price,

$\frac{\partial w_i}{\partial \ln p_j}$ (Onyeneke et al., 2020). μ_i represents the marginal effect of the import share with respect

to logarithm of expenditure, $\frac{\partial w_i}{\partial \ln E}$ (Onyeneke et al., 2020). Uncompensated elasticities measure the percentage change in demand in response to changes in price, where the substitution effect and income effect of a price change are both accounted for in this relationship. Compensated elasticities estimate the percentage change in demand in response to changes in price but excludes the income effect of a price change (only the substitution effect in considered).

Expenditure elasticities measure the percentage change in demand in response to a change in total expenditure.

Dynamic Regression Framework

A dynamic framework is used to determine EU import demand if the invasion had not occurred. This equation is expressed as follows:

$$X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 X_{t-12} + \beta_3 \log PE_t + \beta_4 \log P_{t-1} + \beta_5 RED2_t + \epsilon_t \quad (10)$$

The same data and time period used to estimate equation (1) is used to estimate equation (10).

The dependent variable, $X_t \cong \log \frac{E}{a(p)}$, is a measure of the real value of total wood pellets

imports in the EU where X_t is calculated as the log of the total import value (E) deflated by an import price index ($\log P$): $X = \log \left(\frac{E}{P} \right)$. Note that this is similar to the real expenditure term in equation (1). The price index is defined as the summation of each country's import share multiplied by its corresponding price in logs, $\log P_t = \sum_{i=1}^5 s_{it} \log p_{it}$ (Stone Price Index) (Deaton & Muellbauer, 1980). The model includes lagged dependent variables as explanatory variables. X_{t-1} is a one-period lagged term to determine if past import demand affects current import demand. The variable X_{t-12} is a 12-period or annual lag to capture seasonal dynamics. The variable $\log PE_t$ is included to capture the effects of global energy prices on total imports. Additionally, the Stone Price Index, $\log P_{t-1}$, is included to capture the impact of average import prices on total import demand. This term is lagged one period to control for potential price endogeneity. The variable, $RED2_t$, is a binary variable that represents the period before and after the implementation of the EU's renewable energy policies that were updated in December of 2018. The values before December 2018 were 0, while values from December 2018 onward were 1. Lastly, ϵ_t represents the random error term. Once the estimated coefficients are determined, the model will be used to forecast total import demand for 2022, 2023, and 2024 assuming the invasion did not occur.

Forecasting Importing Demand

The forecast values for total import demand can be used to derive projections for each exporting country. For this procedure, I use the expenditure elasticity and the forecasted change in total imports. Elasticity-based forecasting is well established in the literature and often results in forecasts more accurate than model-based forecasts (Gustavsen, 2003; Kastens & Brester, 1996; Muhammad, 2007).

The expenditure elasticities and forecasted total import demand for 2022, 2023, and 2024 are used to calculate forecasts for each exporting country. The elasticity-based forecasting equation is as described below.

$$e_i = \frac{\% \Delta E_i}{\% \Delta X} = \frac{\frac{\Delta E_i}{E_i}}{\frac{\Delta X}{X}} = \frac{\frac{E_{i1} - E_{i0}}{E_{i0}}}{\frac{X_1 - X_0}{X_0}}$$

$$\frac{E_{i1} - E_{i0}}{E_{i0}} = e_i \left[\frac{X_1 - X_0}{X_0} \right]$$

$$E_{i1} = e_i \left[\frac{X_1 - X_0}{X_0} \right] E_{i0} + E_{i0} \quad (11)$$

The term E_i describes the expenditure the EU allocates on importing wood pellets from country i . The expenditure elasticity is denoted as ε_i . E_{i0} represents the allocation of EU expenditure on wood pellets to country i in the base period (0), which is used to forecast the new values, E_{i1} . X_1 represents the total EU expenditure on wood pellet imports in the year 2022, 2023, or 2024, while X_0 represents total EU expenditure the previous year.

CHAPTER 5

RESULTS AND DISCUSSION

Estimation Procedure

The model estimates, uncompensated elasticities, compensated elasticities, expenditures elasticities, and forecast results are discussed in this section. Stata (version 18) was used to obtain model estimates, elasticity values and standard errors, and trade forecasts. The Stata code and results can be found in the Appendix. The *demandsys* procedure was used to estimate the QUAIDS model using the import shares, wood pellet prices (unit prices derived from value and quantity), and total EU expenditure. The procedure uses a iterative nonlinear multiple-equation estimator (Stata, 2025a). The command, *regress*, was used to estimate the coefficients for the total import demand regression. This procedure uses basic linear regression (Stata, 2025b). Once the coefficients were estimated, Stata's forecast command (*forecast* procedure) was used to forecast X_t from 2022 to 2024. The monthly trade forecasts results were summed to get annual forecast values for 2022, 2023, and 2024.

QUAIDS Model Estimates

The QUAIDS model estimates alpha (α), beta (β), gamma (γ), and lambda (λ) for each country are reported in **Table 5.1**. The α estimates are constant terms. The β estimates represent demand changes when total expenditure changes. The γ estimates represent the effect of prices on expenditure shares across goods. The λ estimates account for the quadratic expenditure effect on import shares, capturing the nonlinear curvature in the total expenditure effect on imports. Belarus, Russia, Ukraine, and the U.S. all had significant alpha, beta, or lambda estimates, while ROW had no significant estimates. Only Belarus and the U.S. had significant estimates for

Table 5.1. QUAIDS Model Estimates

	Belarus	Russia	Ukraine	U.S.	ROW
α	0.219** (0.074)	0.996*** (0.259)	0.289*** (0.086)	-0.404* (0.226)	-0.101 (0.333)
β	0.087** (0.033)	0.399*** (0.114)	0.109** (0.038)	-0.460*** (0.091)	-0.135 (0.155)
γ_1	-0.052*** (0.018)	0.063 (0.044)	0.026 (0.017)	-0.080* (0.043)	.044 (0.036)
γ_2		0.083 (0.184)	0.097* (0.052)	-0.327** (0.154)	0.084 (0.036)
γ_3			-0.038 (0.024)	-0.147*** (0.051)	0.062 (0.044)
γ_4				0.558*** (0.191)	-0.004 (0.166)
γ_5					-0.186 (0.179)
λ	0.010* (0.004)	0.054*** (0.013)	0.013** (0.004)	-0.069*** (0.009)	-0.007 (.018)

Standard errors in parenthesis. Significance: ***p < 0.01; **p < 0.05; *p < 0.1

gamma. Note that these estimates are best understood as elasticities. The estimates for lambda indicate that a quadratic model is appropriate for this analysis.

Import Demand Elasticities

The uncompensated price elasticities are reported in **Table 5.2**. All own-price elasticities are statistically significant and highly elastic, showing that the EU wood pellet market is price-sensitive. Note that this is different from previous findings, which is likely due to a wider data range, inclusion of more major exporters, and the increased flexibility because of the quadratic expenditure term in the QUAIDS model. For example, Belarus's estimate is -2.27, indicating a one percent increase in the price of wood pellets from Belarus will cause the EU to decrease wood pellets imports from Belarus by 2.27 percent. U.S. wood pellets have the lowest own-price responsiveness (-1.29).

The cross-price elasticities, which are also reported in **Table 5.2** indicate substitution across exporting countries. A one percent increase in the price of wood pellets from the rest of the world will cause the EU to increase wood pellet imports from Belarus, Russia, and Ukraine by 0.30 percent, 0.84 percent, and 0.40 percent, respectively. Conversely, the U.S. and Ukraine are complementary. A one percent increase in the price of U.S. wood pellet prices will cause the EU to slightly decrease wood pellet imports from Ukraine by 0.15 percent. Conversely, the EU will decrease wood pellet imports from the U.S. by 0.84 percent given a percentage increase in Ukraine prices.

The compensated price elasticities also show statistically significant and highly elastic own-price estimates (**Table 5.3**). Notably, the U.S. has the lowest own-price elasticity estimate, indicating less price sensitivity in the EU market. A one percent increase in the price of U.S. wood pellets will cause the EU to decrease wood pellet imports from the U.S. by 0.84 percent.

Table 5.2. Uncompensated Price Elasticity Estimates

	Belarus	Russia	Ukraine	U.S.	ROW
Belarus	-2.27*** (0.24)	0.00 (0.08)	0.13 (0.17)	0.00 (0.05)	0.30*** (0.09)
Russia	-0.04 (0.43)	-1.68*** (0.26)	0.25 (0.40)	0.18 (0.18)	0.84*** (0.32)
Ukraine	0.16 (0.22)	0.07 (0.09)	-1.89*** (0.28)	-0.15** (0.06)	0.40*** (0.10)
U.S.	-0.18 (0.30)	0.08 (0.20)	-0.84*** (0.27)	-1.29*** (0.25)	-0.32 (0.28)
ROW	1.23*** (0.39)	0.64** (0.25)	1.31*** (0.36)	-0.63*** (0.20)	-1.90*** (0.46)

Standard errors in parenthesis. Significance: ***p < 0.01; **p < 0.05; *p < 0.1

Table 5.3. Expenditure and Compensated Price Elasticity Estimates

Country	Belarus	Russia	Ukraine	U.S.	ROW	Expenditure Elasticity
Belarus	-2.21*** (0.24)	0.05 (0.08)	0.18 (0.17)	0.12** (0.05)	0.33*** (0.09)	1.10*** (0.12)
Russia	0.27 (0.42)	-1.42*** (0.26)	0.54 (0.39)	0.91*** (0.19)	1.04*** (0.31)	0.90*** (0.08)
Ukraine	0.23 (0.22)	0.13 (0.09)	-1.81*** (0.27)	-0.02 (0.06)	0.45*** (0.10)	1.04*** (0.11)
U.S.	0.21 (0.31)	0.39* (0.20)	-0.47* (0.28)	-0.84*** (0.26)	-0.09 (0.29)	1.87*** (0.15)
ROW	1.49*** (0.39)	0.85*** (0.25)	1.56*** (0.36)	-0.17 (0.19)	-1.73*** (0.46)	0.68*** (0.12)

Standard errors in parenthesis. Significance: ***p < 0.01; **p < 0.05; *p < 0.1

This is less elastic in comparison to the 2.2 percent decrease for imports from Belarus or a 1.8 percent decrease for imports from Ukraine.

Regarding the cross-price estimates, the U.S. and Ukraine continue to show a complementary relationship. A one percent increase in the price of wood pellets from Ukraine will cause the EU to slightly decrease wood pellet imports from the U.S. wood pellets by 0.47 percent. Belarus, Russia, and the U.S., on the other hand, are all substitutes. A one percent increase in wood pellets from the U.S. will cause the EU to increase imports from Belarus and Russia by 0.12 percent and 0.91 percent, respectively. Additionally, if Russia's price increases by one percent, EU demand for U.S. wood pellets increases by 0.39 percent.

These elasticities are essential for understanding EU wood pellet import behavior. The own-price elasticity estimates highlight the EU's preference for both the U.S. and Russia. Additionally, considering the substitution between the two countries help to explain the observed outcome from the economic sanctions.

The expenditure elasticities are also reported in **Table 5.3**. All estimates are positive and significant, indicating that the wood pellets from all countries are normal goods, regardless of the exporting source. The expenditure elasticities for the imports of wood pellets from Belarus, Ukraine, and U.S. are greater than one, which are luxury goods. The U.S. has the highest expenditure elasticity (1.87), indicating a one percent increase in the EU's total import expenditure leads to a 1.87 percent increase in imports of U.S. wood pellets. The next highest expenditure elasticity is Belarus, followed by Ukraine, Russia, and ROW.

Dynamic Regression Results

The total import demand results show that all the independent variables are all highly significant and have the expected sign based on economic intuition (**Table 5.4**). The variables,

Table 5.4. Total Import Demand Regression Estimates

Variable	Estimate (SE)
Intercept	7.77 (1.80)***
X_{t-1}	0.44 (0.09)***
X_{t-12}	0.24 (0.09)***
$\log PE_t$	0.21 (0.09)***
$\log P_{t-1}$	-0.93 (0.33)***
$RED2_t$	0.22 (0.07)***

Standard errors in parenthesis. Significance: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. R-square = 0.584. Standard error = 0.229. Total observations = 108.

X_{t-1} , and X_{t-12} demonstrates that past import demand positively affects current import demand. A one percent increase in the import demand of the previous period will cause the EU to increase import demand by 0.44 percent. The coefficient on $\log PE_t$ is 0.21, which reflects that higher energy prices lead to greater wood pellet imports. The coefficient on $\log P_{t-1}$ is consistent with economic theory as a one percent increase in the average price leads to a 0.93 percent decrease in the real value of total wood pellet imports. Lastly, the coefficient on the binary policy variable ($RED2_t$) indicates that implementation of the REDII policy in December 2018 caused the EU to increase wood pellets by 0.22 percent on average.

Forecast Comparison Results

The forecast results show how some countries benefited from the conflict and resulting economic sanctions and how Russia and Belarus experienced severe losses in the EU market. **Figure 5.1** shows an overview of the total and country-by-country breakdown of actual import values and projected import values. Note that the projections represents trade without the sanctions. **Figure 5.1** show the losses experienced by Belarus and Russia, especially in 2024. Conversely, Ukraine, the U.S., and the rest of the world experienced trade gains. **Table 5.5** reports the actual and projected values. The difference between these two values determines the losses or gains in total and for each year: 2022, 2023, and 2024. Belarus had a total loss (all years) of nearly \$69 million, while Russia lost a significant \$353 million over the three-year period. Both countries experienced their largest loss in 2023. If the invasion and sanctions had not occurred, Belarus and Russia would have gained a total of \$102 million and \$550 million, respectively.

The U.S., Ukraine, and the rest of the world all experience gains over the three-year period: \$1.5 billion, \$190 million, and \$913 million, respectively (**Table 5.6**). Ukraine and the



Figure 5.1. Actual vs Projected Import Values of Total and Top Wood Pellet Exporting Countries to the EU if the invasion had not occurred, USD million.

Source: Trade Data Monitor ®, Stata (2025)

Table 5.5. Actual Values, Projected Values, and Difference Values for EU wood imports from Belarus and Russia in 2022, 2023, and 2024, including a Three-Year Total to Highlight Trade Losses.

	Belarus			Russia		
	Actual	Projected	Difference	Actual	Projected	Difference
2022	33.27	48.91	-15.64	196.56	244.52	- 47.96
2023	0.00	28.63	-28.63	0.06	162.21	-162.15
2024	0.07	24.53	-24.46	0.00	143.35	-143.35
3-Yr. sum	33.34	102.07	-68.73	196.63	550.08	-353.46

Note: Values are in million USD.

Table 5.6. Actual Values, Projected Values, and Difference Values for EU wood imports from Ukraine, the U.S., and the rest of the world in 2022, 2023, and 2024, including a Three-Year Total to Highlight Trade Gains.

	Ukraine			U.S.			ROW		
	Actual	Projected	Difference	Actual	Projected	Difference	Actual	Projected	Difference
2022	122.51	52.41	70.10	681.68	202.87	478.81	291.94	103.17	188.77
2023	108.84	31.94	76.91	694.40	59.83	634.57	363.33	76.93	286.40
2024	70.26	27.63	42.63	423.20	45.26	377.94	507.77	70.17	437.60
3-Yr. sum	301.61	111.97	189.64	1799.28	307.96	1491.32	1163.03	250.27	912.76

Note: Values are in million USD.

U.S. experienced the largest increase in 2023, while the rest of the world showed consistent increases, even in 2024 (\$437 million). Increases for the rest of the world could be influenced by the EU's desire to expand its wood pellet trade other partners and limiting dependence on the U.S. or Ukraine.

CHAPTER 6

CONCLUSION

The global wood pellet market is a growing sector due to specific policy initiatives supporting their use. The EU is the focus of this study because of its unique position of being the largest wood pellet importer due to renewable energy policies. Additionally, the EU set sanctions against Russia, one of its largest wood pellet sources, due to the Russia-Ukraine conflict, causing trade shifts in the EU wood pellet market.

The goal of the study was to estimate source-differentiated EU demand to determine how exporting countries compete in the EU market. Most notably, the own-price elasticities from the uncompensated and compensated results are elastic for all countries and align with the law of demand. The cross-price estimates for Belarus, Russia, and Ukraine indicate that wood pellets from these are substitutes in the EU market. Wood pellets from the U.S. and Ukraine are complements. Forecast results indicated that Russia and Belarus suffered significant losses due to the economic sanctions, while the other top exporters like the U.S. and Ukraine mostly benefited. Although the U.S. remains the most favored wood pellet exporter for EU demand, the considerable increase in imports from ROW countries indicates the EU's effort to diversify its wood pellet import sources.

Overall, the EU wood pellet market is a competitive export destination with the U.S. and Russia as the largest exporters. Before the sanctions, EU demand favored U.S. wood pellets synonymous with previous studies. The QUAIDS model elasticities determined that wood pellet demand was elastic and price sensitive with U.S. wood pellet exports being less sensitive to price changes. After the sanctions, Russia and Belarus suffered significant losses in export value, while the remaining countries experienced substantial export gains.

It is important to note that previous studies found EU import demand as mostly inelastic, while this study found EU import demand to be mostly elastic. The differences can be attributed to the quadratic form in the QUAIDS model being able to better capture flexible price and demand effects. Despite the different elasticity outcomes between past research and the current study, the U.S. maintains its ranking as the top wood pellet exporter to the EU and is expected to continue to gain import share in the EU wood pellet market.

More research is needed on wood pellet import demand. As previously mentioned, demand is also affected by other non-price variables, which requires further exploration to better understand the EU wood pellet market. Lastly, the main influence on the growth of wood pellet trade is renewable energy policies. However, upcoming policies that focus on greenhouse gas emissions, deforestation, and trade barriers are set to affect the global wood pellet market in contrasting ways, emphasizing the importance of ongoing research to understand the extent of shifting trade flows and relationships between top wood pellet exporters.

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APPENDIX

Stata Code

```
. tsset time

Time variable: time, 2012m1 to 2021m12
      Delta: 1 month

. demandsys quaid (isb isr isu isus isrow), prices(bp rp up usp rowp)
expenditure(wv) labels("Belarus" "Russia" "Ukraine" "US" "ROW")

Calculating NLS estimates:
Iteration 0:  Residual SS = 11.46758
Iteration 1:  Residual SS = 2.421346
Iteration 2:  Residual SS = 2.310917
Iteration 3:  Residual SS = 2.302792
Iteration 4:  Residual SS = 2.302764
Iteration 5:  Residual SS = 2.30276
Iteration 6:  Residual SS = 2.302759
Iteration 7:  Residual SS = 2.302759
Iteration 8:  Residual SS = 2.302759
Iteration 9:  Residual SS = 2.302759
Iteration 10: Residual SS = 2.302759
Iteration 11: Residual SS = 2.302759
Iteration 12: Residual SS = 2.302759
Iteration 13: Residual SS = 2.302759
Iteration 14: Residual SS = 2.302759
Iteration 15: Residual SS = 2.302759
Iteration 16: Residual SS = 2.302759
Iteration 17: Residual SS = 2.302759

Calculating FGNLS estimates:
Iteration 0:  Scaled RSS = 420.995
Iteration 1:  Scaled RSS = 420.1381
Iteration 2:  Scaled RSS = 420.1099
Iteration 3:  Scaled RSS = 420.1008
Iteration 4:  Scaled RSS = 420.0978
Iteration 5:  Scaled RSS = 420.0969
Iteration 6:  Scaled RSS = 420.0967
Iteration 7:  Scaled RSS = 420.0966
Iteration 8:  Scaled RSS = 420.0965
Iteration 9:  Scaled RSS = 420.0965
Iteration 10: Scaled RSS = 420.0965
Iteration 11: Scaled RSS = 420.0965
Iteration 12: Scaled RSS = 420.0965
Iteration 13: Scaled RSS = 420.0965
Iteration 14: Scaled RSS = 420.0965
Iteration 15: Scaled RSS = 420.0965
Iteration 16: Scaled RSS = 420.0965
Iteration 17: Scaled RSS = 420.0965
Iteration 18: Scaled RSS = 420.0965
Iteration 19: Scaled RSS = 420.0965

FGNLS iteration 2:
Iteration 0:  Scaled RSS = 477.8442
Iteration 1:  Scaled RSS = 477.8436
Iteration 2:  Scaled RSS = 477.8436
Iteration 3:  Scaled RSS = 477.8436
Iteration 4:  Scaled RSS = 477.8436
```

```

Iteration 5: Scaled RSS = 477.8436
Iteration 6: Scaled RSS = 477.8436
Iteration 7: Scaled RSS = 477.8436
Iteration 8: Scaled RSS = 477.8436
Iteration 9: Scaled RSS = 477.8436
Iteration 10: Scaled RSS = 477.8436
Iteration 11: Scaled RSS = 477.8436
Parameter change      = 2.13e-02
Covariance matrix change = 1.24e-04

```

FGNLS iteration 3:

```

Iteration 0: Scaled RSS = 479.9741
Iteration 1: Scaled RSS = 479.9739
Iteration 2: Scaled RSS = 479.9739
Iteration 3: Scaled RSS = 479.9739
Iteration 4: Scaled RSS = 479.9739
Iteration 5: Scaled RSS = 479.9739
Iteration 6: Scaled RSS = 479.9739
Iteration 7: Scaled RSS = 479.9739
Iteration 8: Scaled RSS = 479.9739
Iteration 9: Scaled RSS = 479.9739
Iteration 10: Scaled RSS = 479.9739
Iteration 11: Scaled RSS = 479.9739
Iteration 12: Scaled RSS = 479.9739
Parameter change      = 4.99e-03
Covariance matrix change = 1.73e-05

```

FGNLS iteration 4:

```

Iteration 0: Scaled RSS = 479.9997
Iteration 1: Scaled RSS = 479.9997
Iteration 2: Scaled RSS = 479.9997
Iteration 3: Scaled RSS = 479.9997
Iteration 4: Scaled RSS = 479.9997
Iteration 5: Scaled RSS = 479.9997
Iteration 6: Scaled RSS = 479.9997
Iteration 7: Scaled RSS = 479.9997
Iteration 8: Scaled RSS = 479.9997
Iteration 9: Scaled RSS = 479.9997
Iteration 10: Scaled RSS = 479.9997
Parameter change      = 8.29e-04
Covariance matrix change = 2.19e-06

```

FGNLS iteration 5:

```

Iteration 0: Scaled RSS =      480
Iteration 1: Scaled RSS =      480
Iteration 2: Scaled RSS =      480
Iteration 3: Scaled RSS =      480
Iteration 4: Scaled RSS =      480
Iteration 5: Scaled RSS =      480
Iteration 6: Scaled RSS =      480
Iteration 7: Scaled RSS =      480
Parameter change      = 1.12e-04
Covariance matrix change = 2.67e-07

```

FGNLS iteration 6:

```

Iteration 0: Scaled RSS =      480
Iteration 1: Scaled RSS =      480
Iteration 2: Scaled RSS =      480
Iteration 3: Scaled RSS =      480
Iteration 4: Scaled RSS =      480
Parameter change      = 1.40e-05
Covariance matrix change = 3.21e-08

```

FGNLS iteration 7:
Iteration 0: Scaled RSS = 480
Parameter change = 1.49e-06
Covariance matrix change = 3.42e-09

Quadratic AIDS model
Expenditure variable: wv

Number of obs = 120
Number of goods = 5
Price index constant = 16.31

Centered R2 of model for
Belarus = 0.2249
Russia = 0.2173
Ukraine = 0.0684
US = 0.2336
ROW = 0.1282

	Estimate	Std. err.	z	P> z	[95% conf. interval]	

alpha						
Good						
Belarus	.2186506	.0740742	2.95	0.003	.0734678	.3638334
Russia	.9961942	.2585935	3.85	0.000	.4893604	1.503028
Ukraine	.2892786	.0860037	3.36	0.001	.1207145	.4578427
US	-.4034662	.2263934	-1.78	0.075	-.8471891	.0402568

beta						
Good						
Belarus	.0873129	.0329155	2.65	0.008	.0227997	.1518261
Russia	.3985107	.1139414	3.50	0.000	.1751896	.6218317
Ukraine	.1094395	.0384139	2.85	0.004	.0341496	.1847293
US	-.4600435	.091231	-5.04	0.000	-.638853	-.2812341

Gamma						
Good_g#Good_h						
Belarus#Belarus	-.0523357	.0182269	-2.87	0.004	-.0880598	-.0166117
Belarus#Russia	.0625858	.043612	1.44	0.151	-.0228921	.1480637
Belarus#Ukraine	.0261704	.0166087	1.58	0.115	-.0063821	.0587229
Belarus#US	-.08011	.0432246	-1.85	0.064	-.1648288	.0046087
Russia#Russia	.0832565	.1841354	0.45	0.651	-.2776422	.4441552
Russia#Ukraine	.0968436	.0527121	1.84	0.066	-.0064702	.2001574
Russia#US	-.3266233	.1537662	-2.12	0.034	-.6279995	-.0252471
Ukraine#Ukraine	-.0376114	.0236797	-1.59	0.112	-.0840227	.0087999
Ukraine#US	-.1473448	.0508578	-2.90	0.004	-.2470242	-.0476654
US#US	.557953	.1911051	2.92	0.004	.183394	.9325121

lambda						
Good						
Belarus	.0100914	.003661	2.76	0.006	.002916	.0172668
Russia	.0535218	.0124545	4.30	0.000	.0291114	.0779322
Ukraine	.0131167	.0042839	3.06	0.002	.0047205	.021513
US	-.0693738	.009202	-7.54	0.000	-.0874094	-.0513383

Note: alpha estimates are constant terms in expenditure-share equations and also appear in the price index.

Note: beta estimates measure sensitivity of expenditure shares to changes in deflated expenditure and also appear in the price aggregator function.

Note: Gamma estimates measure the effect of price on expenditures shares across goods.

Note: lambda estimates measure the sensitivity of expenditure shares to changes in deflated expenditure.

Normalized parameters

		Estimate	Std. err.	z	P> z	[95% conf. interval]	
alpha							
	Good						
	ROW	-.1006573	.3331916	-0.30	0.763	-.7537008	.5523862
beta							
	Good						
	ROW	-.1352195	.154741	-0.87	0.382	-.4385062	.1680672
Gamma							
Good_g#Good_h							
	1#ROW	.0436896	.0360542	1.21	0.226	-.0269754	.1143545
	2#ROW	.0839374	.1538104	0.55	0.585	-.2175255	.3854003
	3#ROW	.0619421	.0438068	1.41	0.157	-.0239176	.1478019
	4#ROW	-.0038749	.1659978	-0.02	0.981	-.3292247	.3214749
lambda							
	Good						
	ROW	-.0073561	.0179209	-0.41	0.681	-.0424804	.0277682

Note: alpha estimates sum to 1.
Note: beta estimates sum to 0.
Note: Gamma estimates sum to 0 over goods.
Note: lambda estimates sum to 0 over goods.

Shares: isb isr isu isus isrow
Prices: bp rp up usp rowp
Expenditure: wv

. estat elasticities, expenditure

Expenditure elasticities Number of obs = 120

Expenditure	Elasticity	Std. err.	z	P> z	[95% conf. interval]	
Belarus	1.102272	.1245007	8.85	0.000	.8582547	1.346288
Russia	.8951052	.0827521	10.82	0.000	.7329142	1.057296
Ukraine	1.038658	.1124346	9.24	0.000	.8182901	1.259026
US	1.874892	.1519871	12.34	0.000	1.577003	2.172781
ROW	.6763257	.1197008	5.65	0.000	.4417164	.9109349

. estat elasticities, uncompensated

Uncompensated (Marshallian) price elasticities Number of obs = 120

Price	Elasticity	Std. err.	z	P> z	[95% conf. interval]	
Belarus						
Good						
Belarus	-2.271164	.2411727	-9.42	0.000	-2.743854	-1.798475
Russia	.0047497	.0759645	0.06	0.950	-.1441379	.1536374
Ukraine	.1262438	.1665305	0.76	0.448	-.2001501	.4526377
US	.0016564	.04832	0.03	0.973	-.093049	.0963617

ROW		.2970228	.0874569	3.40	0.001	.1256105	.4684351

Russia							
Good							
Belarus		-.0431528	.4281858	-0.10	0.920	-.8823816	.7960759
Russia		-1.681101	.2628069	-6.40	0.000	-2.196193	-1.166009
Ukraine		.2463926	.395714	0.62	0.534	-.5291927	1.021978
US		.1832729	.1819935	1.01	0.314	-.1734279	.5399736
ROW		.8417833	.3194006	2.64	0.008	.2157695	1.467797

Ukraine							
Good							
Belarus		.157135	.2163849	0.73	0.468	-.2669717	.5812416
Russia		.0685014	.091533	0.75	0.454	-.1108999	.2479027
Ukraine		-1.886202	.2753756	-6.85	0.000	-2.425928	-1.346476
US		-.1480588	.0588936	-2.51	0.012	-.263488	-.0326295
ROW		.400777	.1047729	3.83	0.000	.195426	.606128

US							
Good							
Belarus		-.1768807	.2979424	-0.59	0.553	-.7608371	.4070757
Russia		.0775962	.1994453	0.39	0.697	-.3133093	.4685017
Ukraine		-.8366757	.2739209	-3.05	0.002	-1.373551	-.2998007
US		-1.28505	.2492269	-5.16	0.000	-1.773526	-.7965745
ROW		-.3186502	.2837395	-1.12	0.261	-.8747695	.237469

ROW							
Good							
Belarus		1.231791	.3906672	3.15	0.002	.4660978	1.997485
Russia		.6351487	.2546046	2.49	0.013	.136133	1.134164
Ukraine		1.311583	.3616005	3.63	0.000	.6028595	2.020307
US		-.6267125	.2043092	-3.07	0.002	-1.027151	-.2262739
ROW		-1.897258	.4625211	-4.10	0.000	-2.803783	-.9907338

. estat elasticities, compensated

Compensated (Hicksian) price elasticities

Number of obs = 120

Price		Elasticity	Std. err.	z	P> z	[95% conf. interval]

Belarus						
Good						
Belarus		-2.211444	.2423889	-9.12	0.000	-2.686517 -1.73637
Russia		.0536469	.0757949	0.71	0.479	-.0949083 .2022021
Ukraine		.1825824	.1671539	1.09	0.275	-.1450331 .510198
US		.1178939	.0488211	2.41	0.016	.0222064 .2135815
ROW		.3333634	.0870752	3.83	0.000	.1626991 .5040276

Russia						
Good						
Belarus		.2743701	.417868	0.66	0.511	-.5446362 1.093376
Russia		-1.422562	.2570779	-5.53	0.000	-1.926425 -.9186983
Ukraine		.543038	.3885122	1.40	0.162	-.2184319 1.304508
US		.9130826	.1907517	4.79	0.000	.5392161 1.286949
ROW		1.042058	.3145233	3.31	0.001	.4256032 1.658512

Ukraine						
Good						
Belarus		.2333907	.215071	1.09	0.278	-.1881407 .6549221
Russia		.1305691	.0907526	1.44	0.150	-.0473028 .308441

Ukraine		-1.81432	.2741347	-6.62	0.000	-2.351614	-1.277026
US		-.0247117	.058809	-0.42	0.674	-.1399753	.0905519
ROW		.4471393	.1038192	4.31	0.000	.2436575	.6506211

US							
Good							
Belarus		.2094348	.3050432	0.69	0.492	-.3884388	.8073084
Russia		.3909715	.2035778	1.92	0.055	-.0080337	.7899766
Ukraine		-.4694339	.2807123	-1.67	0.094	-1.01962	.0807521
US		-.8392529	.261467	-3.21	0.001	-1.351719	-.3267871
ROW		-.089362	.2880469	-0.31	0.756	-.6539235	.4751996

ROW							
Good							
Belarus		1.494248	.3892711	3.84	0.000	.7312908	2.257205
Russia		.8473742	.2545029	3.33	0.001	.3485578	1.346191
Ukraine		1.558133	.3607683	4.32	0.000	.8510402	2.265226
US		-.1670119	.1940057	-0.86	0.389	-.547256	.2132322
ROW		-1.733198	.4595442	-3.77	0.000	-2.633888	-.8325082

VITA

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