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Impacts of Potential Aluminum Tariffs on the U.S. Economy

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Impacts of Potential Aluminum Tariffs on the U.S. Economy

Key Findings

- *Tariffs on aluminum would result in reductions in output, employment and personal income in the rest of the economy that would significantly exceed any gains in the aluminum sector.* A 30% across-the-board tariff, for example, would decrease economy-wide average annual employment by nearly 100,000 jobs while increasing average annual aluminum sector employment by just 3,700 jobs.

- *Aluminum tariffs would negatively affect manufacturing employment specifically.* Losses in other manufacturing sectors of the economy would far exceed gains in aluminum production. A 30% across-the-board tariff would reduce overall manufacturing employment by about 12,000 jobs annually on average.

- *A more targeted tariff may increase gains to overall aluminum sector employment.* Targeting a tariff on semi-finished products could increase the *overall* employment gains to the domestic aluminum sector. A more targeted tariff would also more directly address policy concerns about subsidies and over-capacity (primarily Chinese) in the market for semi-finished aluminum than would an across-the-board tariff.

Executive Summary

Methodology

- This study uses a state-of-the-art macroeconomic model developed by Regional Economic Models, Inc. ("REMI") to estimate the effects of "across-the-board" aluminum tariffs on primary and semi-finished aluminum products of 7% and 30%.

- We use the REMI model to estimate the full macroeconomic effects of such tariffs, including: (a) increased output and employment in the domestic primary and semi-finished products sectors; (b) the federal government revenues generated by the tariff; and, (c) reduced output and employment, and higher consumer prices, in the remainder of the economy. The REMI model incorporates the complex "multiplier effects" that arise as the positive and negative impacts of the tariff ripple through the economy.

- We also assess the likely effects of a targeted tariff focused on semi-finished aluminum products. While the REMI model does not allow us to formally disaggregate the effects of tariffs on the primary aluminum sector from those on the (downstream) semi-finished sector, we examine data on the relative sizes and labor intensities of the two sectors to assess the extent to which a tariff on primary products would result in job losses in the semi-finished sector, thereby offsetting any gains for the primary sector.

Results

- On average, a 7% across-the-board tariff on primary and semi-finished aluminum would increase aluminum sector employment by 1,000 jobs annually and increase annual aluminum output by $850 million. For the manufacturing sector as a whole (including aluminum), on average employment would decline by 3,040 jobs annually, and annual output would decline by $1.4 billion. For the economy as a whole, average annual employment would decline by 22,600 jobs, and total output would decline by $5.0 billion per year on average.

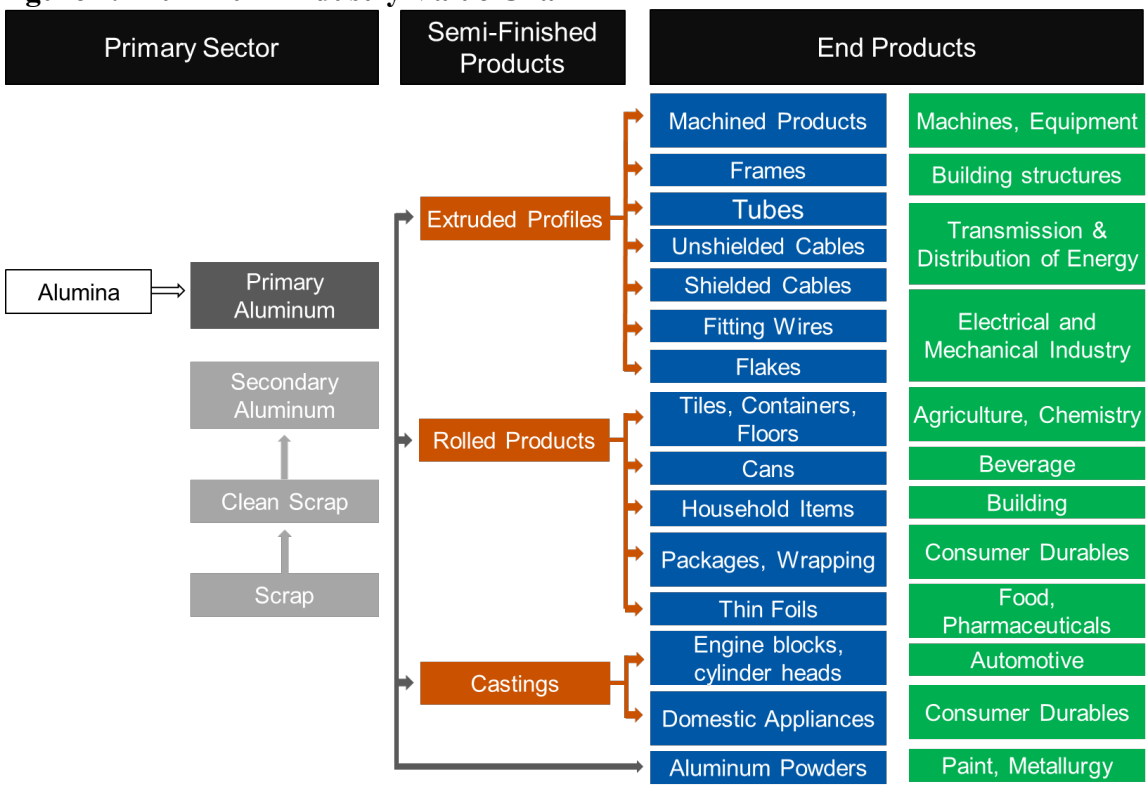
- On average, a 30% across-the-board tariff would increase employment in the aluminum sector by 3,720 jobs annually and increase annual aluminum output by $3.1 billion. For the manufacturing sector as a whole (including aluminum), on average, employment would decline by 12,430 jobs annually, and annual output would decline by $5.8 billion. For the economy as a whole, average annual employment would decline by 99,800 jobs, and total output would decline by $21.5 billion per year on average.

- The semi-finished aluminum sector is both larger and more labor intensive than the primary sector. About 43,500 people are employed in the semi-finished sector, compared with about 14,000 in the primary sector. The primary sector averages about 1.2 jobs per million dollars of domestic shipments, compared with about 1.7 jobs per million dollars of domestic shipments for the semi-finished sector. By definition, for any given proportional increase in output, more jobs would be created in the semi-finished sector than in the primary sector.

I. Introduction and Overview

This study assesses the economic impacts of imposing tariffs on imports of aluminum into the United States ("U.S."). Aluminum is a non-ferrous metal that is used in a wide variety of final products ranging from beverage cans to airplanes and automobiles. As illustrated in Figure 1, the aluminum industry is often characterized as having three major segments or categories of products: (1) primary sector products, including alumina (aluminum oxide refined from bauxite), primary aluminum produced by smelting of alumina, and secondary aluminum produced from scrap aluminum; (2) semi-finished products, including coils, foil and bars that are derived from primary sector products; and, (3) end products manufactured from semi-finished products, such as food and beverage cans, motor vehicle parts, frames and other products that are ultimately sold to consumers.

Figure 1. Aluminum Industry Value Chain



Source: Derived from LUISS (2015)

A. Objectives and Methodology

The purpose of this study is to estimate the economic impacts of tariffs on imports of primary and semi-finished aluminum into the U.S. We use a state-of-the-art macroeconomic model developed by Regional Economic Models, Inc. ("REMI") to estimate the effects of two levels of tariffs on output, employment, and personal income. The REMI model is used by numerous public agencies as well as private parties to evaluate the economic impacts of potential projects and policies. One of the sectors explicitly modeled in REMI is "aluminum production and

processing," which corresponds to a combination of the primary sector and semi-finished products categories shown in Figure 1.[1]

We use the REMI model to develop quantitative estimates of the U.S. economic impacts of two potential levels of a tariff on imported primary sector and semi-finished aluminum products: (1) 7% tariff on imports; and, (2) 30% tariff on imports.[2] The REMI modeling results reflect the full macroeconomic effects of such tariffs, including: (a) increased output and employment in the domestic primary and semi-finished products sectors (which result from the higher prices for imports that are the direct result of the tariff); (b) the federal government revenues generated by the tariff; and, (c) reduced output and employment, and higher consumer prices, in the remainder of the economy. The REMI model incorporates the complex "multiplier effects" that arise as the positive and negative impacts of the tariff ripple through the economy.

In addition to evaluating the overall economy-wide impacts of the two tariff levels, the study considers two other topics. First, we evaluate the effects of aluminum tariffs on various individual sectors within the U.S. economy. Specifically, we assess the effects of aluminum import tariffs on employment and output in the aluminum sector itself (i.e., primary and semi-finished aluminum), other manufacturing industries affected by the tariff as well as manufacturing as whole.

Second, in addition to assessing the effects of an *across-the-board* tariff on both primary and semi-finished aluminum, we consider the effects of a *targeted* tariff on imports of semi-finished aluminum products only. Our consideration of this alternative is motivated in part by the facts that: (a) tariffs on imports of primary aluminum would increase input costs for producers of semi-finished products, potentially offsetting increases in employment or output resulting directly from the tariff; and (b) output and employment in the semi-finished sector are significantly greater than for the primary sector, suggesting that any incremental gains from imposing a tariff on primary imports could actually be outweighed by losses in the semi-finished sector. While the REMI model does not allow us to formally model these effects (or their downstream consequences), we assess a variety of quantitative and qualitative evidence that bears on these issues. This information allows us to assess the relative impacts of a targeted tariff on semi-finished products, on the one hand, compared to an across-the-board tariff that also covers imports of primary aluminum.

We emphasize that this analysis is limited to the economic effects of the tariffs we analyze. It does not address foreign policy and national security implications, nor does it take into account potential responses to a U.S. tariff by other countries. Further, the economic measures we use—such as national output and employment—do not directly measure consumer welfare or capture the broader effects of international trade on society. That said, to the extent the goals of imposing

[1] Specifically, the REMI "aluminum and aluminum processing" sector corresponds to the four-digit NAICS code 3313.

[2] We chose these levels because they have been mentioned in the public policy debate on tariff levels (see United Steelworkers 2016). However, our results are easily generalized to any level of proposed tariff.

tariffs on aluminum are to increase U.S. output and, perhaps especially, employment, our results are directly relevant to assessing their effectiveness.

B. Estimated Impacts on the U.S. Economy

Table 1 summarizes the estimated impacts on the U.S. economy from an across-the-board tariff on primary sector and semi-finished products, expressed as average annual impacts over the decade from 2020-2029 as well as cumulative impacts over the same ten-year period. We examine the effects of tariffs on three specific measures of economic performance: (1) national output; (2) personal income; and, (3) employment. The cumulative dollar values are expressed as present values as of January 2020 in 2017 dollars, based upon a (real) discount rate of 3%. The cumulative employment values are summed in terms of job-years. Job-years aggregates job impacts over time. For example, if job impacts are 1,000 in 2020 and 2,000 in 2021, the sum for the two years would be 3,000 job-years. Note that jobs impacts in different years are not discounted.

These results indicate that an across-the-board tariff would result in reductions (compared to the no-tariff baseline) in all three measures of economic performance. As shown in the table, a 7% tariff would: reduce national output by $5 billion/year on average and by $43.6 billion over ten years; reduce personal income by $2.5 billion/year on average and by $22.0 billion over ten years; and reduce average annual employment by 22,600 jobs and cumulative employment by 225,900 job-years over ten years. Unsurprisingly, the effects of a 30% tariff would be significantly larger: The cumulative employment effect in the ten years following initiation of a 30% across-the-board tariff would approach one million lost job-years.

Table 1. Estimated U.S. Economic Impacts of Across-the-Board Tariffs on Imports of Primary and Semi-finished Aluminum Products

	7%	30%
National Output (Billions 2017$)		
Average Annual	-$5.0	-$21.5
Cumulative (3% DR)	-$43.6	-$188.6
Personal Income (Billions 2017$)		
Average Annual	-$2.5	-$10.9
Cumulative (3% DR)	-$22.0	-$96.3
Total Employment (Thousands)		
Average Annual (Jobs)	-22.6	-99.8
Cumulative (Job-years)	-225.9	-998.4

Note: Output and personal income values presented in 2017 dollars. Values are annual averages over the period from 2020-2029. Cumulative dollar values are present values over the same period calculated as of January 2020 at 3% (real) discount rate. Cumulative employment impacts are measured in job-years and are not discounted.

Source: NERA calculations as explained in text.

Table 2 summarizes the output and employment effects of the two levels of across-the-board aluminum tariffs for three individual sectors (or categories of sectors) of the U.S. economy: (1)

primary sector and semi-finished aluminum products (i.e., the categories subject to the tariff); (2) all other U.S. manufacturing; and, (3) all other U.S. industries. Unsurprisingly, the REMI model predicts that the combined primary and semi-finished aluminum sectors would see increases in both employment and output, gaining 1,000 jobs per year on average under a 7% tariff and 3,720 jobs per year on average if the tariff were set at 30%. However, as the table shows, these gains would be more than offset by losses in other manufacturing sectors: overall manufacturing employment would decline by about 3,000 jobs per year on average under the 7% tariff and more than 12,000 jobs per year on average under the 30% tariff.

Table 2. Estimated U.S. Economic Impacts on Aluminum and Other Manufacturing Industries

	Average Annual Economic Impacts			
	7%		30%	
	Employment (Jobs)	Output (Millions)	Employment (Jobs)	Output (Millions)
Primary Sector and Semi-finished Aluminum Products	+1,000	+$850	+3,720	+$3,130
Other Manufacturing	-4,040	-$2,250	-16,140	-$8,930
All Manufacturing	-3,040	-$1,400	-12,430	-$5,800
All Other Industries	-19,600	-$3,600	-87,400	-$15,700
Total	-22,600	-$5,000	-99,800	-$21,500

Note: Values may not sum to totals due to rounding.
Source: NERA calculations as explained in text.

As noted above, the REMI model does not permit us to formally estimate the differential effects of a targeted tariff (on semi-finished products only) as compared with an across-the-board tariff (including primary aluminum). We therefore present both a graphical framework for comparing the potential effects of these two approaches and some relevant data. The direct effect of imposing a tariff on primary aluminum would be to raise the domestic price, leading to increased output and employment in the primary aluminum sector. These gains, however, must be balanced against the effects of an increase in the cost of the key input for U.S. producers of semi-finished aluminum. That is, raising the price of primary aluminum would increase the marginal costs of domestic production of semi-finished aluminum, reduce domestic supply,[3] and lower both output and employment in the semi-finished sector.

As we explain, the sizes of these countervailing effects would depend on a number of factors—including elasticities of domestic and import supply at the various levels of the value chain—and we are not able with any reasonable degree of certainty to assess the net effects. However, we have examined data on the relative sizes and comparative labor intensities of the upstream (primary) and downstream (semi-finished) sectors. Other things equal, the larger and more labor-intensive the downstream sector is compared with the upstream sector, the more likely the downstream (semi-finished) job losses from higher primary aluminum prices are to exceed the upstream job gains.

[3] That is, shifting the supply curve for semi-finished aluminum upward and to the left.

Table 3 presents data comparing the relative sizes of the two sectors and their labor intensity. As the table shows, the semi-finished sector employs about three times as many workers as the primary sector in the U.S. and is more labor-intensive (as measured by jobs per million dollars of domestic shipments and jobs per million dollars of value added). These factors support the proposition that losses in semi-finished employment would exceed the gains in primary sector employment under a tariff on primary sector products. Put another way, these data suggest that a targeted tariff on semi-finished products could indeed result in larger employment gains in the aluminum sector than an across-the-board tariff.

Table 3. Sector Size and Employment Intensity for Aluminum Primary Sector and Semi-finished Products

	Primary Sector	Semi-finished Products
Employment (Thousands of Jobs)[a]	14.0	43.5
Total Value of Domestic Shipments (Millions of Dollars)[a]	$12,000	$26,000
Value Added (Millions of Dollars)[a]	$3,400	$7,700
Employment per Million Dollars of Domestic Shipments (Jobs)	1.2	1.7
Employment per Million Dollars of Value Added (Jobs)	4.1	5.6

Note: All dollar values in millions of 2015 dollars.
Source: U.S. Census Bureau Annual Survey of Manufacturers, 2015.

Again, this analysis does not allow us to reach a definitive conclusion with respect to the net employment and output effects of an across-the-board tariff relative to a targeted tariff limited to imports of semi-finished products. It does, however, suggest that, to the extent the objective of the policy is to increase employment in the aluminum sector, policy makers should consider the possibility of targeted tariff on semi-finished products only.

C. Summary of Conclusions

Our principal conclusions regarding the impacts of tariffs on imported aluminum products are as follows:

1. *Tariffs on primary sector and semi-finished aluminum products would lead to lower output, lower personal income, and lower levels of employment for the U.S. economy*. Our estimates indicate that the negative impacts on end product sectors (like beverage cans and automobiles) significantly exceed the gains for the domestic sectors covered by the tariff.

2. *Losses to the U.S. economy increase with the level of the tariff*. The estimated annual average job loss over the decade of the 2020's is about 23,000 jobs for the 7% tariff, compared to almost 100,000 jobs for the 30% tariff.

3. *Manufacturing employment as a whole would be reduced by the imposition of tariffs on aluminum.* The tariff would reduce annual average employment for manufacturing as a

whole, with our results indicating the losses would be about 3,000 jobs per year for the 7% tariff and about 12,000 jobs per year for the 30% tariff.

4. *A targeted tariff may increase gains to overall aluminum sector employment.* Targeting the tariff on semi-finished products could increase the *overall* employment gains to the domestic aluminum sector, a possibility suggested by the greater size and labor-intensity of the semi-finished sector relative to the primary sector. Further empirical analysis would be needed, however, to reach any firm conclusion on this point.

The remainder of this study is organized as follows. Section II provides an overview of the U.S. aluminum industry. Section III outlines our methodology and the REMI model we use to estimate the effects of aluminum tariffs on the U.S. economy. Section IV presents our primary findings. Section V presents a brief conclusion. Appendices provide information on the REMI model as well as detailed annual REMI modeling results.

II. The United States Aluminum Industry

Aluminum has certain characteristics and physical properties that have resulted in its widespread use in many industrial processes and consumer goods. It is light weight, highly resistant to corrosion and heat, malleable yet strong, well suited for surface finishes, reflective, and infinitely recyclable. This section provides a brief overview of the U.S. aluminum industry, including examples of products as well as some basic information on the various parts of the value chain.[4]

A. Overview of the Aluminum Value Chain

The aluminum value chain can be viewed as comprising three main segments[5]:

1. *Primary sector products*, including alumina refining and primary aluminum smelting using alumina, as well as secondary aluminum smelting using scrap aluminum;

2. *Semi-finished sector products*, including semi-fabricated aluminum products such as foil, bars and other shapes; and,

3. *End products*, including final products such as beverage cans and automotive parts that go into products sold to customers.

The following subsections provide brief descriptions of these three major value chain segments.

B. Primary Sector Products

The primary sector segment of the aluminum value chain includes various upstream products and processes.

- *Alumina refining*, which involves refining alumina from bauxite ores.

- *Aluminum production from alumina*, which involves smelting alumina into primary aluminum and casting it into ingots.

- *Aluminum production from scrap*, which involves collecting and re-melting aluminum scrap to produce secondary aluminum.

[4] See http://www.aluminum.org/ for information on the aluminum industry.

[5] Production of aluminum is sometimes separated into "primary aluminum" (i.e., aluminum from alumina) and "secondary aluminum" (i.e., aluminum from scrap). Because of the nature of the data we use, we group both sources of aluminum in the primary sector.

C. Semi-finished Products

Semi-finished producers purchase aluminum ingots and bars from primary sector producers and use them as inputs to produce semi-finished products. The following are the major subcategories of semi-finished products.

- *Extruded profiles*, which include a wide range of shapes and profiles used largely in the transport and construction sectors to manufacture automotive components, aircraft components, windows, doors, shelves, etc.
- *Rolled products*, which include plates, sheets, and foils that are used to manufacture vehicle bodies, airplane wings, rail segments, insulated packaging, etc.
- *Castings*, which include applications such as engine blocks, propellers, domestic appliances, and others.

D. End Products

The properties of aluminum make it an important component of a large number of end products. The following are some major examples of aluminum uses.[6]

- *Aerospace.* The airframe of a typical modern commercial aircraft is approximately 80% aluminum by weight. Fuselage, wing, and supporting structures of commercial airliners and military aircraft are also typically manufactured from aluminum alloys.
- *Aluminum Cans.* Aluminum canning is an important part of the beverage sector. Aluminum cans are recyclable and provide protection against oxygen, light, moisture, and other contaminants. Aluminum cans also are resistant to rust and corrosion and provide a longer shelf life than other types of packaging.
- *Automotive Parts.* The use of aluminum in automobiles, commercial vehicles, and engine-powered appliances is expanding as a cost-effective way to lower vehicle weight and improve fuel economy.
- *Building and Construction.* Aluminum is widely used in construction of buildings and other infrastructure. Aluminum alloys support the weight of heavy glass spans, allowing for use of natural light.
- *Electrical.* Aluminum-based electrical wiring is widely used in utility grid transmission and distribution networks. Aluminum has also been adapted for use as a rigid electrical conduit which does not spark and resists corrosion. Aluminum-based electrical materials are used widely in residential, commercial, and industrial buildings.

[6] See www.aluminum.org/product-markets for additional information on these and other end uses of aluminum.

- *Electronics and Appliances.* Aluminum's thermal characteristics make it an appropriate metal component of a large variety of home appliances, including washing machines, dryers, refrigerators, and laptops.
- *Foil and Packaging*. Aluminum foil is used in the manufacturing of billions of containers each year. Foil packaging is often used for packaging sensitive electronic components and pharmaceutical products.

E. United States Aluminum Industry Statistics

Table 4 summarizes 2015 U.S. Census Bureau data related to the size of the three broad aluminum industry segments, with end products represented by the ten largest users of aluminum. This table shows that the overall size—as measured by employment, total value of shipments, and value added—increases substantially at each subsequent stage in the aluminum production process. The table also provides information on imports and exports.

Table 4.U.S. Aluminum Industry Statistics for Primary Sector, Semi-finished Products and End Products

	Primary Sector	Semi-finished Products	End Products
Employment (Thousands of Jobs)[a]	14.0	43.5	564.4
Total Value of Domestic Shipments (Millions of Dollars)[a]	$12,000	$26,000	$230,000
Value Added (Millions of Dollars)[a]	$3,400	$7,700	$81,000
Import Value (Millions of Dollars)[b]	$7,900	$5,000	$81,000
Exports Value (Millions of Dollars)[b]	$2,000	$5,500	$45,000

Note: All dollar values in millions of 2015 dollars. Primary sector includes NAICS codes 331313 and 331314. Semi-finished products includes NAICS codes 331315 and 331318. End products values based upon ten largest end users of aluminum semi-finished products as indicated by USGS Crosswalk of Mineral Commodity End Uses. End products includes NAICS codes 332114, 332321, 332322, 332431, 336212, 33631, 33633, 33634, 33637, and 33639.

Source: (a) U.S. Census Bureau Annual Survey of Manufacturers, 2015.
(b) U.S. Census Bureau "USA Trade" Exports & Imports by NAICS Commodities, 2015.

Table 5 summarizes production, imports, exports, and consumption for the primary and semi-finished sectors in the U.S. in terms of metric tons of aluminum. Consistent with the financial and employment information in Table 4, the semi-finished sector is larger than the primary sector, but net imports make up a larger portion of domestic consumption for primary sector products than for semi-finished products.

Table 5. U.S. Aluminum Industry Information for Primary Sector and Semi-finished Products

	Primary Sector	Semi-finished Products
Domestic Production (Thousands of Metric Tons)	5,456	8,491
Imports (Thousands of Metric Tons)	3,397	1,599
Exports (Thousands of Metric Tons)	362	1,255
U.S. Consumption (Thousands of Metric Tons)	8,491	8,835

Note: All values provided in thousands of metric tons.
Source: Aluminum Association, 2015 Aluminum Statistical Review

III. Study Data and Methodology

This chapter describes the data and methodology we use to estimate the economic impacts of the import tariff scenarios on the U.S. economy. We first provide an overview of the REMI model and the modeling approach and then discuss specifics of the data and methodology.

A. REMI Model

We use the REMI Policy Insight Plus (PI+) model to develop estimates of the effects of the aluminum tariffs. REMI is a state-of-the-art regional economic tool that has been developed and refined by researchers over more than twenty-five years. It is widely used by federal, state, and local agencies, as well as analysts in the private sector and academia, to estimate the effects of regulations, investments, closures, and other policy scenarios. (Appendix A provides additional information on the REMI model.)

i. REMI PI+ Model

The core of the REMI model is a set of input-output ("I/O") relationships among different industries. These relationships show how industries are related to one another, in terms of both inputs and outputs. Thus, they allow one to estimate how changes in one industry will affect demand for other industries (those that provide inputs to the industry in question). In addition, I/O models can be used to trace the effects that result from changes in the income of workers in the affected industries.

The REMI model goes well beyond the standard I/O relationships to incorporate other important feedback effects. The model includes demographic components, because population over the long run depends in part on the available economic opportunities. Changes in population in turn have feedback effects on the economy, affecting the demand for housing and other goods. Other feedback effects include changes in wages as a result of changes in economic activity. If employment increases, for example, wages will tend to rise, affecting the competitive position of the U.S. relative to other countries.

The REMI model incorporates detailed and up-to-date macroeconomic data from the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and other public sources.

ii. REMI United States Model

Each version of the REMI model is custom-built for the region of interest, which can range from counties to the U.S. as a whole. The model built for this project was compiled in 2017 for the entire U.S., including all 50 states and Washington D.C., using version 2.1 of REMI's PI+ application.

B. Overview of REMI Modeling Approach

Figure 2 summarizes the steps we use to model the economic impacts on the U.S. economy of an aluminum import tariff. The following is an overview of our modeling process.[7]

- We begin by specifying two potential import tariff levels: (a) 7% tariff on the import shipment value; and, (b) 30% tariff on the import shipment value. We assume these import duties would apply to imports of both primary sector products and semi-finished products. As noted, this assumption is based upon the granularity of the REMI model, which precludes evaluation of the impacts of tariffs on the sectors individually. We assume that the potential import tariffs would take effect in 2020 and be in effect for the ten years from 2020-2029.

- We use the model of the U.S. economy provided by Regional Economic Models, Inc., REMI PI+.

- We translate the import tariff percentage into an increase in foreign import costs for the relevant REMI industry (which as noted is "Alumina Refining and Aluminum Production and Processing"). Increases in the foreign import costs in REMI lead to increases in domestic aluminum prices (although there is not a one-to-one correspondence).

- Using these inputs, we run simulations in REMI of the U.S. economy under each of the two potential import tariff scenarios considered in this study.

- We observe the simulated impact of the import tariff on the amount of imports associated with the "Alumina Refining and Aluminum Production and Processing" REMI industry and calculate revenues to the U.S. government using the value of imports and the tariff percentage.

- We assume that revenues to the U.S. government accrue to the government in the year they are received, and we translate these values into appropriate REMI inputs for transfer payments from the government to the public.

- We run final simulations in REMI of the U.S. economy for the two potential import tariff scenarios, with these scenarios accounting for the multiplier effects of the government tariff revenues.

[7] Although this methodology and the REMI model provide a sound basis for estimating the economic impacts of a tariff, certain other factors might influence the effects of an aluminum tariff. These complications include the detailed characteristics of international aluminum markets and possible "terms of trade" effects due to the tariff, the possibility of responses of other countries to a U.S. tariff, the potential lack of homogeneity of domestic and imported products not captured in the REMI model, the possibility of existing distortions in aluminum markets, and the cost structure of exporters of aluminum products to the United States. See, e.g., Feenstra and Taylor (2008) and Francois and Reinert, eds. (1997) for discussions of these and other complications in assessing the impacts of tariffs.

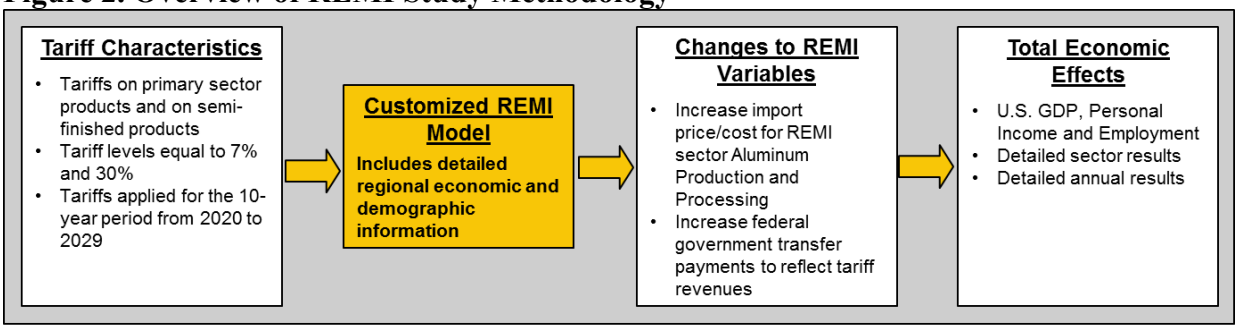
- Finally, we compare the results of the final tariff scenario model runs to REMI's "baseline" forecasts in order to estimate the economic impacts of the two potential import tariff scenarios on the U.S. economy, as measured by U.S. output, personal income and employment.

- The result of this modelling methodology is a set of estimates of the impacts of the two potential tariff scenarios on the U.S. economy.

- We use the REMI results to develop estimates of the average annual and cumulative impacts of the tariffs on the overall U.S. over the ten-year period from 2020-2029.

- We use detailed REMI results to develop estimates of impacts on detailed sectors as well as impacts on the U.S. economy over time.

Figure 2. Overview of REMI Study Methodology



Source: NERA methodology as explained in text.

C. Overview of Aluminum Import Tariffs

This section provides information on the potential aluminum import tariff scenarios. The two tariff levels are derived from a petition submitted by the United Steelworkers ("USW") to the U.S. government on April 18, 2016 (United Steelworkers 2016). Based upon the USW recommendations outlined in the petition, we evaluate the economic impacts of the following two tariff scenarios.

- *7% tariff.* This scenario is based upon the USW recommendation for an all-in price for aluminum on the London Metal Exchange ("LME") of $2,300/ton. This price translates to approximately a 7% increase from current LME prices. We presume that tariffs on semi-finished goods would be based on the same percentage.

- *30% tariff.* This scenario is based upon the USW recommendation for an LME all-in price of $2,800/ton for aluminum. This price translates to approximately a 30% increase from current LME prices. As with the 7% tariff, we presume that tariffs on semi-finished goods would be based on the same percentage.

As noted, we model the effect of these two tariffs on the assumption that they would be applied to import costs for products in the REMI sector labeled "aluminum production and processing."

Table 6 provides descriptions of the specific elements contained in this REMI category, which corresponds to the four-digit NAICS code 3313. This four-digit NAICS code includes four six-digit NAICS codes. As the descriptions of the six-digit codes indicate, this REMI sector corresponds to the combination of the primary (including secondary) and semi-finished elements of the aluminum value chain. As noted above, the REMI model does not allow us to disaggregate its aluminum sector into more detailed categories; thus, we cannot quantitatively model the effects of separate tariffs on primary sector products and semi-finished products using this tool.

Table 6. REMI Definition of Aluminum Production and Processing

NAICS Code				
4-Digit	**5-Digit**	**6-Digit**	**Industry Name**	**Industry Description**
3313	-	-	Alumina and Aluminum Production and Processing	See below
3313	33131	-	Alumina and Aluminum Production and Processing	This industry comprises establishments primarily engaged in one or more of the following: (1) refining alumina; (2) making (i.e., the primary production) aluminum from alumina; (3) recovering aluminum from scrap or dross; (4) alloying purchased aluminum; and (5) manufacturing aluminum primary forms (e.g., bar, foil, pipe, plate, rod, sheet, tube, wire).
3313	33131	331313	Alumina Refining and Primary Aluminum Production	This U.S. industry comprises establishments primarily engaged in one or more of the following: (1) refining alumina (i.e., aluminum oxide) generally from bauxite; (2) making aluminum from alumina; and/or (3) making aluminum from alumina and rolling, drawing, extruding, or casting the aluminum they make into primary forms. Establishments in this industry may make primary aluminum or aluminum-based alloys from alumina.
3313	33131	331314	Secondary Smelting and Alloying of Aluminum	This U.S. industry comprises establishments primarily engaged in (1) recovering aluminum and aluminum alloys from scrap and/or dross (i.e., secondary smelting) and making billet or ingot (except by rolling) and/or (2) manufacturing alloys, powder, paste, or flake from purchased aluminum.
3313	33131	331315	Aluminum Sheet, Plate and Foil Manufacturing	This U.S. industry comprises establishments primarily engaged in (1) flat rolling or continuous casting sheet, plate, foil and welded tube from purchased aluminum and/or (2) recovering aluminum from scrap and flat rolling or continuous casting sheet, plate, foil, and welded tube in integrated mills.
3313	33131	331318	Other Aluminum Rolling, Drawing, and Extruding	This U.S. industry comprises establishments primarily engaged in (1) rolling, drawing, or extruding shapes (except flat rolled sheet, plate, foil, and welded tube) from purchased aluminum and/or (2) recovering aluminum from scrap and rolling, drawing, or extruding shapes (except flat rolled sheet, plate, foil, and welded tube) in integrated mills.

Source: U.S. Census Bureau, North American Industry Classification System

IV. Impacts of Aluminum Tariffs on the U.S. Economy

This chapter provides empirical results of our REMI modeling, comparing the baseline REMI economic forecast with simulations of the economy under the two tariff alternatives. Following the methodology outlined in the previous chapter, we provide results for the entire U.S. economy of 7% and 30% tariff scenarios. We then provide results broken out by certain individual sectors and various groups of sectors.

The national impacts are based on gains and losses in the following REMI output variables:

- *National Output*, the total value added for goods and services;
- *National Personal Income*, aggregate personal income from all sources including wages, dividends and government transfer payments; and
- *National Employment*, total jobs (both full-time and part-time).

We run REMI over the ten-year period from 2020-2029. Results are reported both for the average annual impact over the period as well as the cumulative impact over the period. For values in dollars, the cumulative impacts are aggregated as a present value as of January 2020 using a real (inflation-adjusted) discount rate of 3%. The employment values are summed over the period without discounting and presented in job-years. As an example of the job-year calculation, if a policy leads to 100 fewer jobs in 2020 and 100 fewer jobs in 2021 (relative to the baseline level of jobs in those two years), the total loss would be 200 job-years over the two-year period.

A. Effects of Aluminum Tariffs on Overall Economic Performance

Table 7 provides the REMI national results for the 7% tariff and the 30% tariff. The national impacts—as measured by output, personal income, and employment—reflect: (a) the positive effects on domestic aluminum production and processing (which gain from higher costs for imports); (b) the positive effects of greater federal government revenues from the tariff; and, (c) the negative effects to the aluminum-using sectors that would be less competitive because of the higher domestic prices for primary and semi-finished aluminum due to the tariffs.

The impacts in terms of output, personal income, and employment on the U.S. economy are negative for both tariff scenarios and show a substantially greater impact for the higher tariff scenario. For a 7% tariff, national output decreases on average by $5 billion annually or by about $43.6 billion (present value) over the ten-year period. For the 30% tariff, national output decreases on average by $21.5 billion annually or by $188.6 billion (present value) over the ten-year period.

In terms of personal income, a 7% tariff on the aluminum industry is projected to reduce personal income on average by $2.5 billion annually or $22 billion (present value) over the ten-year period. For a 30% tariff, personal income is projected to decrease on average $10.9 billion annually or $96.3 billion over the ten-year period.

In terms of employment, the job losses due to an increase in import price range from approximately 23,000 per year for a 7% increase to almost 100,000 for a 30% increase. Over the ten-year period, the tariff scenarios would result in a loss of about 226,000 job-years for a 7% tariff and almost 1 million job-years for a 30% tariff.

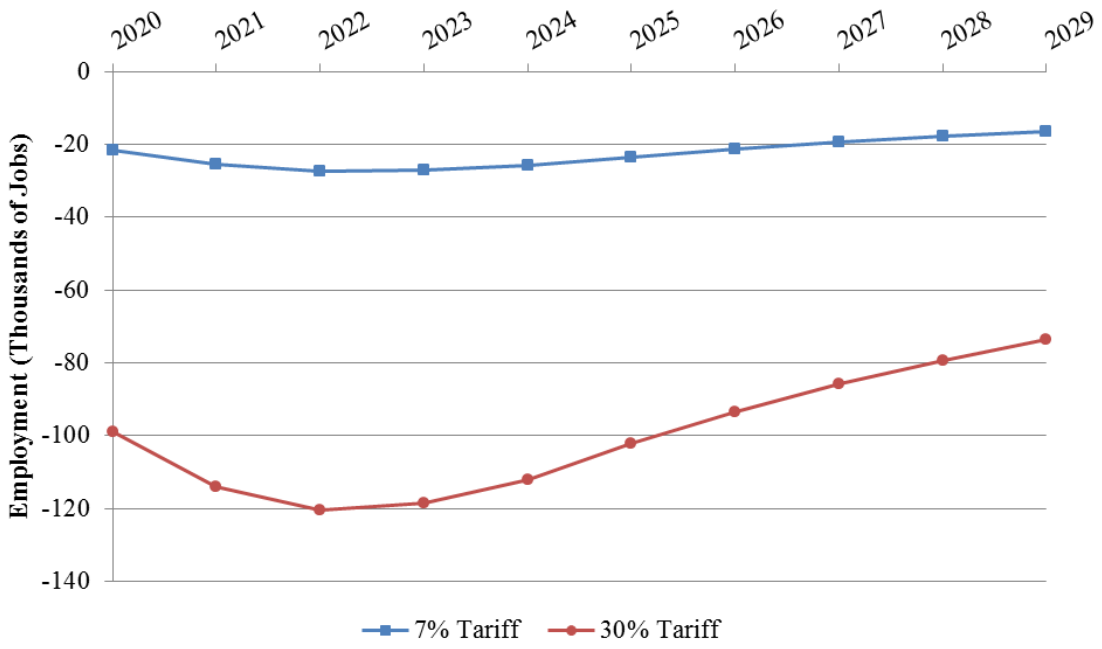
Table 7. Estimated U.S. Economic Impacts of Across-the-Board Tariffs on Imports of Primary and Semi-finished Aluminum Products

	7%	30%
National Output (Billions 2017$)		
Average Annual	-$5.0	-$21.5
Cumulative (3% DR)	-$43.6	-$188.6
Personal Income (Billions 2017$)		
Average Annual	-$2.5	-$10.9
Cumulative (3% DR)	-$22.0	-$96.3
Total Employment (Thousands)		
Average Annual (Jobs)	-22.6	-99.8
Cumulative (Job-years)	-225.9	-998.4

Note: Output and personal income values presented in 2017 dollars. Values are annual averages over the period from 2020-2029. Cumulative dollar values are present values over the same period calculated as of January 2020 at 3% (real) discount rate. Cumulative employment impacts are measured in job-years.
Source: NERA calculations as explained in text.

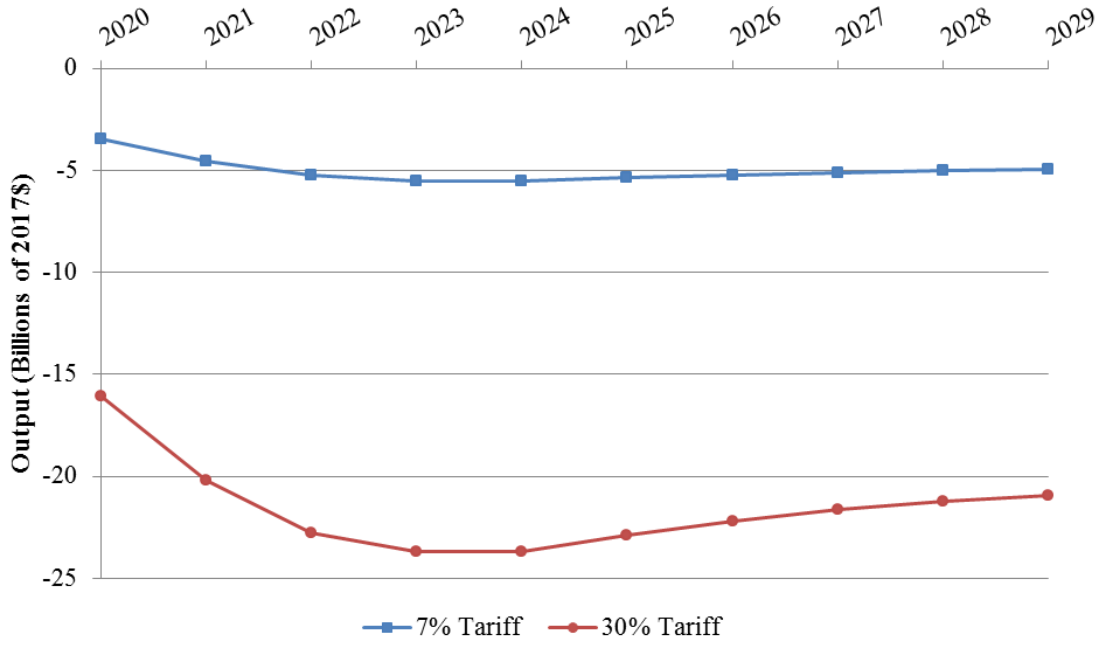
Figure 3 and Figure 4 show the effects of the two tariff scenarios over the period 2020 to 2029 on U.S. output and employment, respectively. For the 7% tariff, output and employment impacts remain relatively constant over the time period, with minor adjustments in the early years as downstream industries adjust to higher aluminum prices. For the 30% tariff scenario, however, the output and employment effects are substantially greater in the early years as the economy has to contend with the substantially greater aluminum prices, effects that tend to decrease over time as the economy adjusts to the changes.

Figure 3. Estimated U.S. Economic Impacts on Annual Output



Source: NERA methodology as explained in text.

Figure 4. Estimated U.S. Economic Impacts on Annual Employment



Source: NERA methodology as explained in text.

B. Sectoral Effects of Aluminum Tariffs

This section summarizes economic impacts on various sectors of U.S. economy of an import tariff on aluminum primary sector and semi-finished aluminum products. Table 8 provides results for the REMI sector (alumina and aluminum production and processing) that is subject to the tariff in our model as well as the other aggregated industries. (Our REMI model includes 160 sectors; the table aggregates these sectors.) For the aluminum industry specifically, the import tariff is projected to result in an average annual increase in output from $850 million for the 7% tariff scenario and $3.13 billion for the 30% tariff scenario. In terms of employment, the additional number of annual jobs on average in the aluminum industry ranges from about 1,000 per year for the 7% tariff scenario to about 3,700 per year for the 30% tariff scenario. For the 7% tariff, the average employment gain is equivalent to about 2% of the average baseline employment level for the alumina and aluminum production and processing sector. For the 30% tariff, the average employment gain is equivalent to about 7% of the average baseline employment level.

In contrast, other manufacturing industries are projected to lose production due to both tariff scenarios, with output reductions ranging from $2.25 billion for the 7% tariff scenario to $8.93 billion for the 30% tariff scenario. Other manufacturing jobs are projected to decrease on average by 4,040 per year in the 7% tariff scenario and 16,140 per year in the 30% tariff scenario. The losses in terms of output and employment for the other manufacturing industries exceed the gains generated by the aluminum industry in both tariff scenarios.

Table 8. Estimated U.S. Economic Impacts on REMI Sectors

	Average Annual Economic Impacts			
	7%		30%	
	Employment (Jobs)	Output (Millions)	Employment (Jobs)	Output (Millions)
Alumina and aluminum production and processing	**1,000**	**$850**	**3,720**	**$3,130**
Other Manufacturing	-4,040	-$2,250	-16,140	-$8,930
Construction	-3,730	-$550	-16,030	-$2,360
Retail trade	-3,490	-$400	-15,090	-$1,720
Professional, scientific, and technical services	-1,570	-$300	-6,780	-$1,290
Government	-1,230	-$170	-5,270	-$740
Administrative and waste management services	-1,210	-$100	-5,420	-$460
Other services, except public administration	-1,070	-$80	-5,230	-$400
Wholesale trade	-960	-$290	-4,180	-$1,260
Health Care and social assistance	-920	-$120	-5,100	-$660
Accommodation and food services	-870	-$80	-4,070	-$350
Finance and insurance	-850	-$250	-3,980	-$1,140
Transportation and warehousing	-790	-$160	-3,480	-$700
Real estate and rental and leasing	-780	-$420	-3,560	-$1,840
Mining	-460	-$150	-1,860	-$610
Arts, entertainment, and recreation	-440	-$40	-2,050	-$190
Management of companies and enterprises	-420	-$120	-1,770	-$510
Information	-400	-$300	-1,750	-$1,280
Educational services; private	-270	-$20	-1,380	-$110
Forestry, fishing, and related activities	-80	-$10	-340	-$50
Utilities	-10	-$10	-50	-$60
Total	-22,600	-$5,000	-99,800	-$21,500

Note: Rows may not sum to totals due to rounding.
Source: NERA calculations as explained in text.

Table 9 breaks out annual economic impacts within the manufacturing industry. Other than the aluminum sector, all other manufacturing sectors would see reduced output and employment under the tariffs. The fabricated metal manufacturing sector, which relies upon semi-finished aluminum products as inputs, is projected to experience employment losses that are more than half of the employment gains to the aluminum industry. Losses in employment and output in end use products more than outweigh the gains to the primary aluminum and semi-finished aluminum product industry. The manufacturing sector as a whole would lose an average of 3,040 jobs per year and $1.4 billion in annual output under the 7% tariff; the equivalent losses would be 12,430 jobs and $5.8 billion in output under the 30% tariff.

Table 9. Estimated U.S. Economic Impacts on REMI Manufacturing Sector

	Average Annual Economic Impacts			
	7%		30%	
	Employment (Jobs)	Output (Millions)	Employment (Jobs)	Output (Millions)
Alumina and Aluminum Production and Processing	**+1,000**	**+$850**	**+3,720**	**+$3,130**
Other Primary Metal Manufacturing	-120	-$90	-490	-$380
Beverage Manufacturing	-140	-$80	-530	-$300
Other Transportation Manufacturing	-160	-$110	-630	-$430
Electrical Equipment and Appliance Manufacturing	-230	-$100	-890	-$410
Motor Vehicles, Bodies, and Parts Manufacturing	-450	-$320	-1,760	-$1,280
Machinery Manufacturing	-490	-$220	-1,930	-$880
Fabricated Metal Product Manufacturing	-640	-$210	-2,580	-$840
All Other Manufacturing Industries	-1,820	-$1,110	-7,340	-$4,420
Total Manufacturing	-3,040	-$1,400	-12,430	-$5,800

Note: Rows may not sum to totals due to rounding.
Source: NERA calculations as explained in text.

C. Potential Effects of a Targeted Tariff on Semi-finished Products

In addition to the across-the-board tariffs analyzed above, we also examine the effects of a tariff targeted on semi-finished products only. Our interest in this policy option grows out of two sets of facts. First, some of the concerns that appear to be motivating policymakers—including the oversupply of semi-finished aluminum products as a result of state-driven output expansion in China—apply primarily to semi-finished aluminum production.[8] Raising tariffs on primary aluminum simply would not address these concerns. Second, the effect of raising the domestic price of primary aluminum would be to raise input costs for domestic producers of semi-finished aluminum, offsetting at least in part the increases in employment and output in the primary sector due to the tariff.

While the REMI model does not allow us to estimate the disaggregated effects of tariffs on the two sectors, our assessment of the available data, presented below, suggests that imposing tariffs on primary products would have an adverse effect on output and employment in the semi-finished sector, possibly exceeding any direct gains to the primary sector from the tariff. Specifically: [9]

- *Primary Aluminum (Alumina, Primary Aluminum and Secondary Aluminum)*. The direct effect of a tariff on primary aluminum would be to raise the price of imports, including alumina, primary aluminum and secondary aluminum. Domestic producers would respond by increasing output, and would hire additional workers as necessary to do so.

[8] See https://www.commerce.gov/page/section-232-investigation-effect-imports-aluminum-us-national-security for documents related to the Department of Commerce's investigation into the national security effects of U.S. aluminum imports.

[9] This summary of potential general effects of the tariff does not address complications that might influence the actual effects of an aluminum tariff, as noted in footnote 7.

- *Semi-Finished Aluminum.* The direct effect of a tariff on semi-finished aluminum would also be to raise the price of imports, leading domestic producers to increase output and employment. However, in the case of an across-the-board tariff, domestic producers of semi-finished aluminum would also face higher input costs, effectively shifting the supply curve for domestic semi-finished aluminum up and to the left. The magnitude of the offsetting effect would depend on a variety of factors.

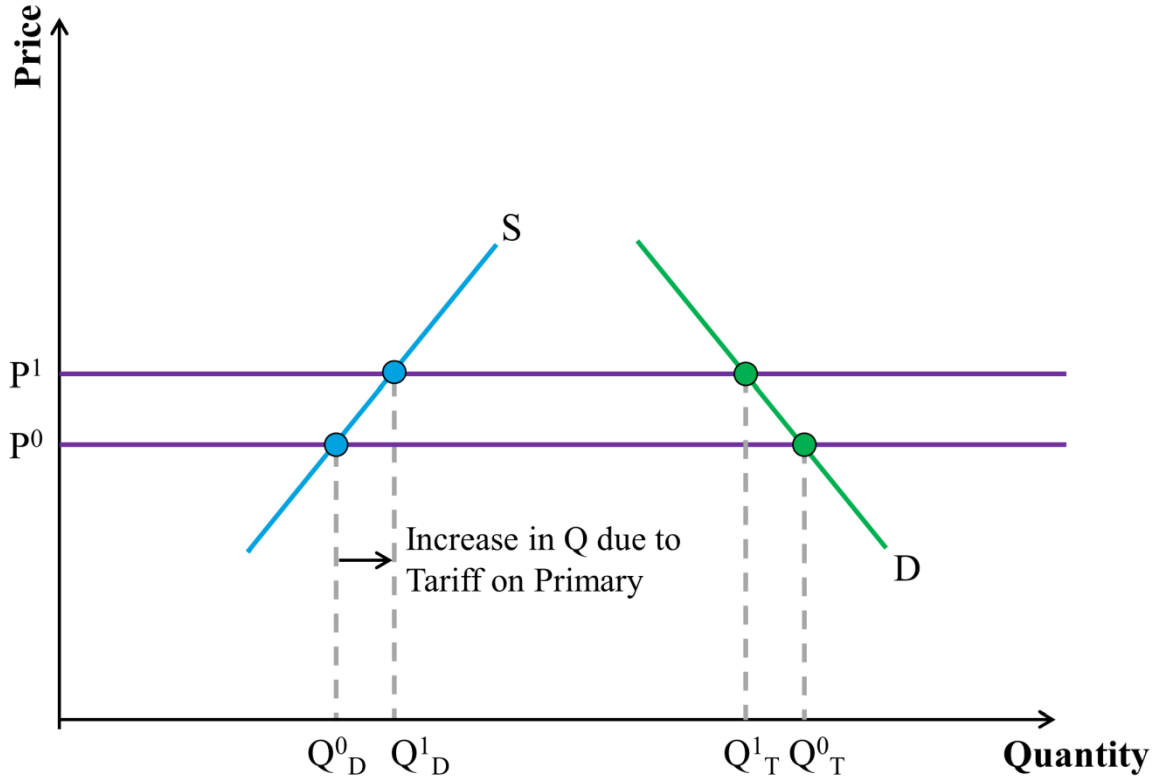
- *End Products.* Domestic producers of end products would face higher prices for semi-finished aluminum in the case of either an across-the-board or a targeted tariff. As our REMI model demonstrated, the downstream effects of an across-the-board tariff would be significantly larger than the effects on the aluminum sector, leading, to a net reduction in U.S. economic activity and employment.

The basic effects of a targeted tariff in comparison to those of an across-the-board tariff can be illustrated in the simple graphs shown in Figures 5, 6 and 7.

To begin, Figure 5 illustrates the effect of a stand-alone tariff on primary aluminum imports. (For simplicity, the figure focuses on U.S. price and output effects, although we describe the additional effects of the tariff on imports.) Prior to the tariff, the domestic U.S. price is determined by the world price, P^0. Domestic suppliers produce output equal to Q^0_D, which is the point at which marginal costs (represented by the supply curve) equal P^0. However, total demand at P^0 is Q^0_T, which exceeds the amount domestic producers are willing to produce given price P^0. The difference is accounted for by imports ($Q^0_I = Q^0_T - Q^0_D$).

As the figure shows, the effect of a tariff is to raise the domestic price of primary aluminum from P^0 (which is the world price) to P^1, which is equal to the world price plus the tariff. Domestic suppliers respond by increasing production until price again equals marginal costs, i.e., from Q^0_D to Q^1_D. The higher price also causes total quantity demanded to decline, to Q^1_T. Imports ($Q^1_I = Q^1_T - Q^0_D$) decline as a result of both increased domestic production and lower overall market demand. For our purposes, the main results of the tariff on primary sector aluminum products are to raise aluminum prices and to increase domestic production.

Figure 5. Effects on Domestic Prices and Production of an Import Tariff on Primary Aluminum Sector Products



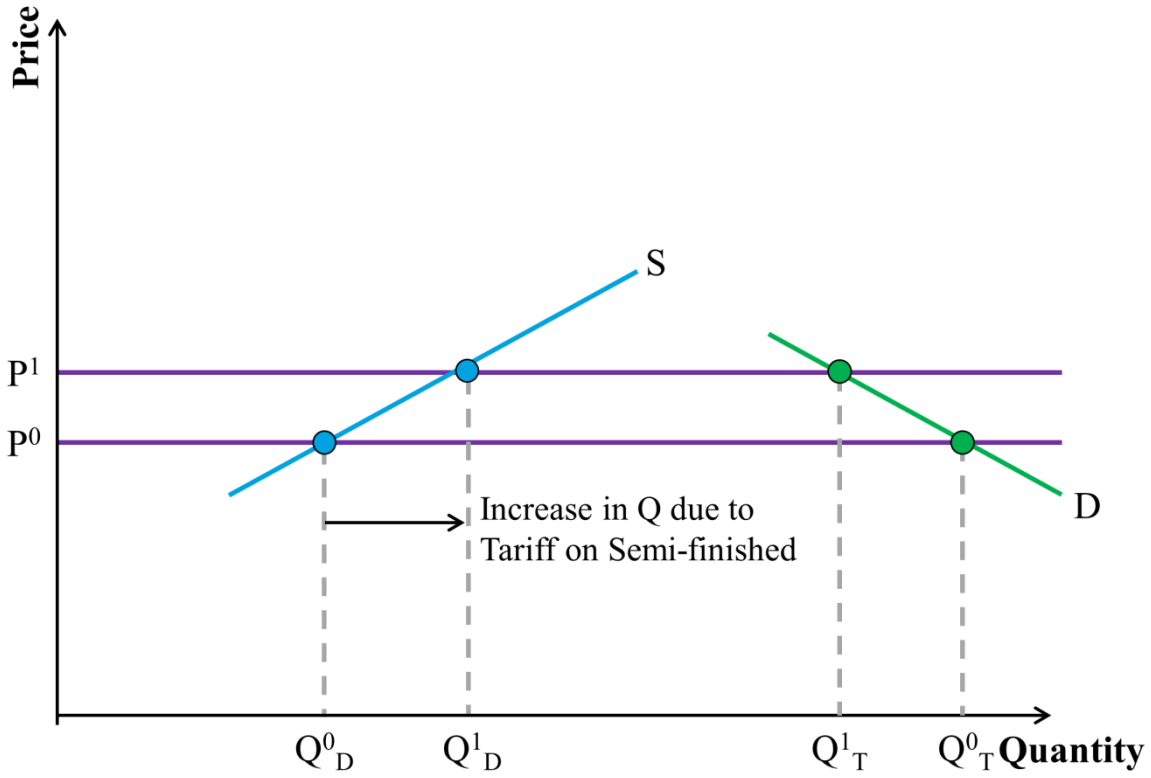
Source: NERA illustrative figure.

Figure 6 illustrates the same effects of a tariff that would be targeted on semi-finished aluminum only. (As with the prior graph, this graph shows changes in production and prices, although we describe changes in imports as well.) Prior to the tariff, the domestic U.S. price is determined by the world price, P^0. Domestic suppliers produce output equal to Q^0_D, which is the point at which marginal costs (represented by the supply curve) equal P^0. However, total demand at P^0 is Q^0_T, which exceeds the amount domestic producers are willing to produce given price P^0. The difference is accounted for by imports ($Q^0_I = Q^0_T - Q^0_D$).[10]

As the figure shows, the effect of a tariff on semi-finished aluminum is to raise the price of semi-finished aluminum in the domestic market by the amount of the tariff, i.e., from P^0 to P^1. Domestic suppliers respond by increasing production until price again equals marginal costs, i.e., from Q^0_D to Q^1_D. The higher price also causes total quantity demanded to decline, to Q^1_T. Imports ($Q^1_I = Q^1_T - Q^0_D$) decline as a result of both increased domestic production and lower overall market demand.

[10] These diagrams make various simplifying assumptions, notably that there are no exports of aluminum products and that imports are available at a constant (world market) price, i.e., the import supply curve is perfectly elastic.

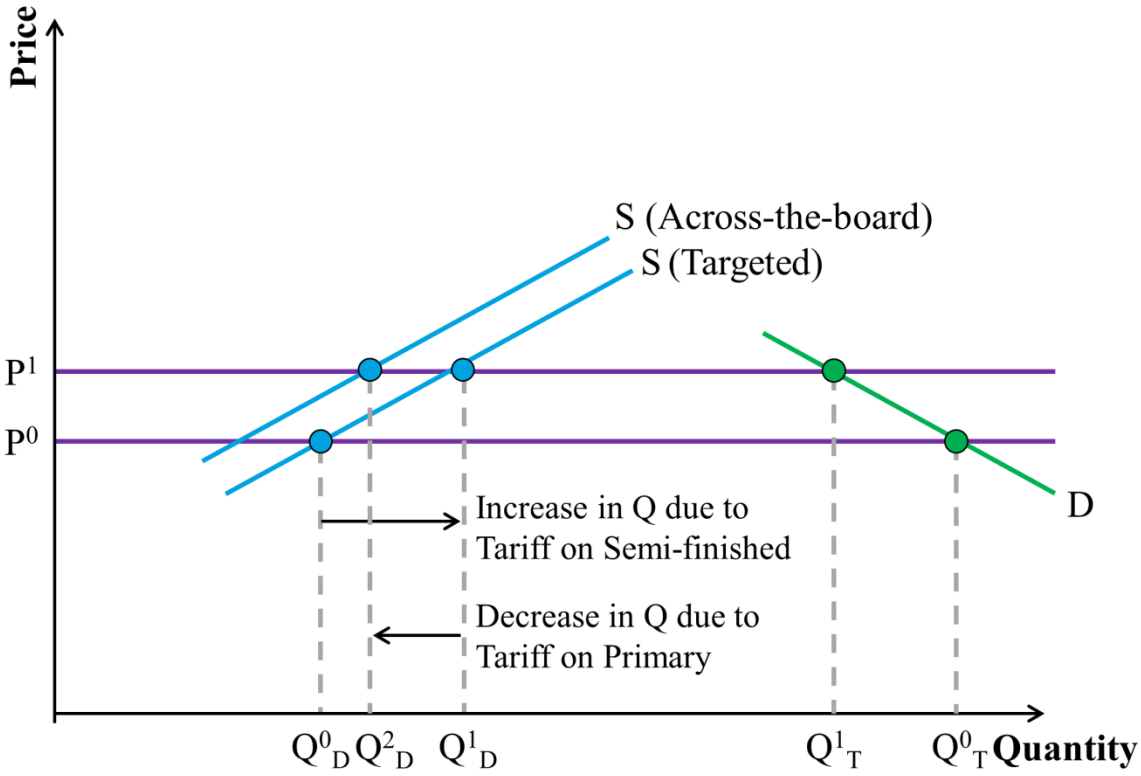
Figure 6. Effects on Domestic Prices and Production of an Import Tariff Targeted on Semi-finished Aluminum Products



Source: NERA illustrative figure.

Figure 7 is identical to Figure 6 except that it shows a second supply curve, above and to the left of the initial supply curve. The new supply curve reflects the effects of the higher input costs semi-finished producers would face if the tariff were extended to primary aluminum, i.e., an across-the-board tariff: At any given price, they would produce less output. As the figure shows, the effect is to reduce domestic production of semi-finished aluminum from Q^1_D to Q^2_D. In this simplified analysis, there is no effect on the price of semi-finished aluminum, which is still set by the world price plus the tariff (P^1), and thus no effect on total quantity demanded (which remains at Q^1_T). Imports, however, increase compared with the targeted tariff scenario to compensate for the decline in domestic production.

Figure 7. Effects on Domestic Prices and Production of an Across-the-Board Tariff Compared to Those of a Targeted Tariff on Semi-finished Products



Source: NERA illustrative figure.

These simple graphs illustrate the effects of moving from a targeted tariff on semi-finished aluminum to an across-the-board tariff that includes primary sector products—production and employment in the primary sector would increase, but production and employment in the semi-finished aluminum sector would decline relative to the targeted tariff scenario.

The sizes of these offsetting effects would depend on many factors including the following.[11]

- Supply elasticities for primary sector products, which influence how the tariff-induced increases in prices would translate into changes in U.S. production.
- Employment intensity for primary sector products. The larger the labor component, the greater the extent to which increases in output would translate into increases in employment.
- Significance of primary aluminum as an input in the manufacture of semi-finished products. The larger the role of primary aluminum, the greater will be the leftward shift

[11] This list is not intended to be exhaustive.

in the supply curve for domestic semi-finished products—and therefore the greater the increase in semi-finished production if the tariff on primary imports is removed.

- Supply elasticities for semi-finished products, which influence how the tariff-induced increases in costs for primary sector products would translate into changes in U.S. production of semi-finished products.

We have not analyzed the relevant supply elasticities or the cost shares of primary aluminum in the different semi-finished products (although those shares are certainly large). However, Table 10 provides information on some of factors that would affect whether overall employment in the aluminum sector might increase or decrease if the tariff were focused on semi-finished products. As the table shows, the semi-finished sector employs about three times as many workers as the primary sector and is more labor-intensive (as measured by jobs per million dollars of domestic shipments as well as jobs per million dollars of value added). These factors suggest that losses in semi-finished employment could exceed the gains in primary sector employment under a tariff on primary sector products.

Table 10. Sector Size and Employment Intensity for Aluminum Primary Sector and Semi-finished Products

	Primary Sector	Semi-finished Products
Employment (Thousands of Jobs)[a]	14.0	43.5
Total Value of Domestic Shipments (Millions of Dollars)[a]	$12,000	$26,000
Value Added (Millions of Dollars)[a]	$3,400	$7,700
Employment per Million Dollars of Domestic Shipments (Jobs)	1.2	1.7
Employment per Million Dollars of Value Added (Jobs)	4.1	5.6

Note: All dollar values in millions of 2015 dollars. End products values based upon ten largest end users of aluminum semi-finished products as indicated by USGS Crosswalk of Mineral Commodity End Uses.
Source: (a) U.S. Census Bureau Annual Survey of Manufacturers, 2015.

This analysis does not allow us to reach a firm conclusion with respect to the net employment and output effects of an across-the-board tariff relative to a targeted tariff limited to imports of semi-finished products. This information does, however, suggest that the question is one that policymakers should take into consideration in designing an effective trade policy for the U.S. aluminum sector if one of the key goals is to increase overall aluminum sector jobs.

V. Summary and Conclusions

The following are principal conclusions regarding the impacts of tariffs on imported aluminum products on the U.S. economy:

1. *Tariffs on primary sector and semi-finished aluminum products would lead to lower output, lower personal income and lower levels of employment for the U.S. economy*. Our estimates indicate that the negative impacts on end product sectors (like beverage cans and automobiles) far outweigh the gains in the domestic sectors covered by the tariff.

2. *Losses to the U.S. economy increase with the level of the tariff*. The estimated annual average job loss over the decade of the 2020s is about 23,000 jobs for the 7% tariff, compared to almost 100,000 jobs for the 30% tariff.

3. *Manufacturing employment as a whole would be reduced by imposition of tariffs on aluminum.* The tariff would reduce annual average employment for manufacturing as a whole, with our results indicating the losses would be about 3,000 jobs per year for the 7% tariff and about 12,000 jobs per year for the 30% tariff.

4. *More-focused tariffs may increase gains to overall aluminum sector employment.* Focusing the tariff on semi-finished products (and thus not including primary sector aluminum products in the tariff) could increase the *overall* employment gains to the domestic aluminum sector, a possibility suggested by the greater size and labor-intensity of the semi-finished sector. Empirical analyses would be needed, however, to reach any firm conclusion on this point.

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Appendix A. Overview of REMI PI+ Model

This overview is based on text prepared by Regional Economic Models, Inc. More detailed information is available from REMI PI+.

REMI PI+ is a structural economic forecasting and policy analysis model. It integrates input-output, computable general equilibrium, econometric, and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to compensation, price, and other economic factors.

The model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the specific model being used. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Compensation, Prices, and Costs, and, (5) Market Shares.

The Output and Demand block consists of output, demand, consumption, investment, government spending, exports, and imports, as well as feedback from output change due to the change in the productivity of intermediate inputs. The Labor and Capital Demand block includes labor intensity and productivity as well as demand for labor and capital. Labor force participation rate and migration equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the compensation equations. The proportion of local, inter-regional, and export markets captured by each region is included in the Market Shares block.

Models can be built as single region, multi-region, or multi-region national models. A region is defined broadly as a sub-national area, and could consist of a state, province, county, or city, or any combination of sub-national areas.

Single-region models consist of an individual region, called the home region. The rest of the nation is also represented in the model. However, since the home region is only a small part of the total nation, the changes in the region do not have an endogenous effect on the variables in the rest of the nation.

Multiregional national models also include a central bank monetary response that constrains labor markets. Models that only encompass a relatively small portion of a nation are not endogenously constrained by changes in exchange rates or monetary responses.

The following sub-sections describe the five blocks of the REMI PI+ model in more depth.

A. Block 1: Output and Demand

This block includes output, demand, consumption, investment, government spending, import, commodity access, and export concepts. Output for each industry in the home region is

determined by industry demand in all regions in the nation, the home region's share of each market, and international exports from the region.

For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities, and population. Input productivity depends on access to inputs because a larger choice set of inputs means it is more likely that the input with the specific characteristics required for the job will be found. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

B. Block 2: Labor and Capital Demand

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity, and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

C. Block 3: Population and Labor Supply

The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age, gender, and ethnic category, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after-tax compensation rate. Migration includes retirement, military, international, and economic migration. Economic migration is determined by the relative real after-tax compensation rate, relative employment opportunity, and consumer access to variety.

D. Block 4: Compensation, Prices, and Costs

This block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the compensation equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods, and services.

These prices measure the price of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs of distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of outputs in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by the cost of labor, capital, fuel, and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas, and residual fuels.

The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices. Housing prices change from their initial level depending on changes in income and population density.

Compensation changes are due to changes in labor demand and supply conditions and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

E. Block 5: Market Shares

The equations in the Market Shares block measure the proportion of local and export markets that are captured by each industry. These depend on relative production costs, the estimated price elasticity of demand, and the effective distance between the home region and each of the other regions. The change in share of a specific area in any region depends on changes in its delivered price and the quantity it produces compared with the same factors for competitors in that market. The share of local and external markets then drives the exports from and imports to the home economy.

Appendix B. Annual REMI Results

Table B-1 provides REMI results for the estimated annual effects of the two tariffs on U.S. output, personal income and employment over the ten years from 2020 to 2029.

Table B-1. Estimated Annual U.S. Output and Employment Impacts of Tariff Scenarios

	Annual Economic Impacts					
	Output (Billions)		Personal Income		Employment (Thousands)	
	7%	30%	7%	30%	7%	30%
Cumulative	-$43.61	-$188.58	-22.00	-96.27	-225.94	-998.35
2020	-$3.44	-$16.05	-2.73	-12.10	-21.53	-98.98
2021	-$4.54	-$20.21	-2.69	-11.69	-25.60	-114.13
2022	-$5.21	-$22.77	-2.73	-11.86	-27.32	-120.41
2023	-$5.50	-$23.71	-2.70	-11.68	-27.13	-118.58
2024	-$5.54	-$23.67	-2.61	-11.32	-25.71	-112.02
2025	-$5.37	-$22.88	-2.47	-10.75	-23.40	-102.13
2026	-$5.23	-$22.19	-2.37	-10.34	-21.36	-93.45
2027	-$5.10	-$21.62	-2.27	-9.98	-19.52	-85.77
2028	-$5.01	-$21.22	-2.19	-9.67	-17.89	-79.21
2029	-$4.93	-$20.96	-2.11	-9.40	-16.48	-73.66

Note: Output values in fixed 2017 dollars. Cumulative output values presented as present value as of January 2020 at a 3% annual real discount rate.

Source: NERA calculations as explained in text.

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