Trade Protection and the Rise of American Manufacturing

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Abstract

Did trade protection hinder or help the development of American manufacturing in the 19th century? Using newly digitized import price, tariff, and railway freight data, I develop a novel empirical design exploiting county variation in exposure to nationwide tariffs based on distance to international ports. The key insight is that trade protection is a composite of tariffs and transportation costs: when nationwide tariffs rise, the proportional increase in total protection is larger for coastal counties than for interior counties, which are already protected by high internal freight costs. I find that protection reduces output growth for products close to the technological frontier but increases growth for products far behind it. Near the frontier, protection enables firms to capture rents without innovating; away from it, protection makes catch-up feasible. These patterns are confirmed by the geographic distribution of patent activity after tariff increases: protection shifts patent activity toward laggard products, suggesting a reshaping of comparative advantage itself. These findings suggest that the effects of trade protection depend critically on how far behind the technological frontier an industry is.

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1 Introduction

> "We were at our richest from 1870 to 1913. That's when we were a tariff country"
>
> – Donald Trump (2025)

In 2025, the United States imposed its highest tariffs since the Great Depression – raising the average rate eightfold from 2% to 16% – marking a sharp reversal of decades of trade liberalization. A central argument for this shift is the American experience of the late 19th century, when the US had both high growth rates and high tariffs. As Oren Cass (2024) puts the argument: "Behind some of the world's highest tariff barriers, the United States transformed from colonial backwater to continent-spanning industrial colossus."

The economics and history literature is much more mixed on interpreting this aggregate correlation. Studies employing a wide range of methodologies — from qualitative historical studies to time series analysis to structural models to reduced form panel data methods — reach differing conclusions. Irwin (2001, 2004), O'Rourke (2000) and Klein and Meissner (2024) argue that protection has no significant effect or harms growth, while Allen (2014), Taussig (1931), Bairoch (1995) and Chang (2002) make the opposite case. I bring new data and a novel empirical design to study this age-old yet policy-relevant question.

The key insight of my empirical design is that protection at the county level is a composite of tariffs and transportation costs. When nationwide tariffs go up, areas near international ports, which are more reliant on tariffs for protection, see larger percentage changes in protection. By contrast, interior locations, already substantially protected by high freight costs, experience smaller proportional increases in protection.

Methodologically, this approach allows for an across-county, within-product comparison, which is infeasible in other canonical approaches used to study the impact of trade protection. For example, when nationwide steel tariffs rise, Philadelphia — a major international port — sees a larger proportional increase in protection than Chicago, an interior city already shielded by high freight costs. Comparing their growth rates isolates the ef-

fect of protection from any nationwide trends in the steel industry, such as technological developments.[1] By contrast, nationwide trade liberalization studies exploit cross-sector or cross-product variation in tariff cuts (e.g. Pavcnik 2002, Khandelwal and Topaleva 2011, De Loecker et al. 2016, Fajgelbaum et al. 2020). However, product level trends correlated with tariffs (whether coincidental or targeted by policymakers) would be a concern for this design – one that my within-product comparison addresses via product-time fixed effects. In addition, shift-share approaches (e.g. Autor, Dorn and Hanson 2013) are also subject to this concern, as Borusyak, Hull and Jaravel (2022) show.[2]

A second benefit of the within-product, across-space design is that I can estimate product-specific treatment effects, in contrast to both the shift-share and cross-product approach, which at best can only estimate a convex-weighted average of treatment effects across products.[3] This is important because the industrial policy literature stresses that the effects of trade protection vary across products or sectors (e.g. Lashkaripour and Wu 2025, Bartelme et al. 2025). Indeed, I find sharply heterogeneous effects depending on distance to the technological frontier.

Operationalizing this design requires combining several historical data sources, several of which I newly digitize. I digitize product-level import prices and tariffs from the Foreign Commerce and Navigation Tables of the United States for 1859 and 1869. To empirically discipline the functional form of transportation costs in this period, I digitize commodity-specific internal freight rates from the Aldrich Report (1893). I then use this information with Donaldson and Hornbeck's (2016) transportation network to construct county-level transportation costs to port. To control for changes in the cost of imported inputs, I construct

[1]For example, the Bessemer process, invented in 1856, revolutionized steel production in this period.

[2]This is true for designs based on the "exogenous shocks" view of Borusyak, Hull and Jaravel (2022). The "exogenous shares" view of Goldsmith-Pinkham, Sorkin and Swift (2020) requires that industrial composition is uncorrelated with future trends. This is unlikely to hold in my context, as locations specializing in different sectors are likely to be exposed to different shocks such as immigrant flows, technological changes and unionization drives. See discussion in Borusyak, Hull and Jaravel (2025).

[3]This is not taking into account econometric issues raised by de Chaisemartin and D'Haultefoeuille (2023) and Sun and Abraham (2021). They show that standard two way fixed effect estimators may fail to estimate a convex-weighted average treatment effect in the presence of heterogeneity.

an input-output table — unavailable for this period — using Atack, Bateman and Weiss' (2006) state-level census of manufactures. Finally, I harmonize British and American patent records in the 1850s to construct a product-level measure of distance to the technological frontier.

The 1860s provide a useful natural experiment: With tariffs accounting for 90% of Federal revenues (Irwin 2020), Civil War fiscal pressures drove rapid tariff increases, with Congress raising tariffs five times between 1861 and 1865. In addition, US trading partners did not retaliate, allowing me to isolate the import protection channel. Identification requires that nationwide tariff changes are uncorrelated with idiosyncratic county-product shocks. For policymakers to violate this, they would need to identify and target idiosyncratic county-product trends across roughly 1,500 counties and hundreds of tariff line items—an informational and cognitive burden far beyond what 19th-century wartime legislators could satisfy, let alone build Congressional consensus around. I validate this narrative by showing that county-product pairs receiving more protection are balanced on baseline observable characteristics relative to those receiving less. Finally, I employ a battery of robustness checks to control for wartime destruction, Emancipation, Reconstruction, military procurement, and input disruptions.

I find sharply heterogeneous effects of protection depending on a product's distance to the British technological frontier — Britain being the industrial leader of this period.[4] Using UK-US patent ratios as a measure of distance to frontier, protection reduces output growth for products close to the frontier but boosts growth for products far behind it. Turning to innovation, I find that protection shifts patent activity towards laggard products. This goes beyond the simple reallocation predicted by the static Ricardian model — it suggests that protection reshapes the patterns of comparative advantage itself.

I present a simple model with technological gaps and Bertrand competition that generates these comparative statics, building on Aghion et al. (2005). Close to the frontier, protection

[4] A position it occupied since at least the First Industrial Revolution in the 1760s.

substitutes for innovation, as domestic firms can capture rents without innovating. Away from the frontier, protection makes catch-up feasible: innovation now yields capturable rents.

Roadmap: Section 2 describes the historical context. Section 3 presents the model. Section 4 develops the empirical framework and identification strategy. Section 5 describes the data. Section 6 presents the results. Section 7 discusses aggregation of the local, partial equilibrium elasticity to a nationwide, general equilibrium elasticity.

1.1 Literature Review

Hanlon (2020) studies how protection from British competition affected the development of the shipbuilding industry in the US. He compares the Great Lakes region with the Atlantic Coast, as the Great Lakes' relative isolation provided natural protection from British competition. One way to think about my treatment can be viewed as smoothing his binary comparison into a continuous variable using freight costs. Another difference is that I study fourteen products, allowing me to estimate heterogeneous effects of protection and to include county-time fixed effects, which control for local growth rates in all products.

Juhasz (2018) uses variation in distance of French locations to the UK during the Napoleonic Wars as a measure of trade protection, with the idea being that Northern France had a larger change in their protection than Southern France. A key difference is that Juhasz focuses on a single product, cotton spinning. By contrast, my basket of products allows me to study heterogeneous impacts across products depending on distance to frontier. In addition, I aggregate my local partial equilibrium estimates into an aggregate general equilibrium estimate.

Klein and Meissner (2024) and Greenland and Lopresti (2024) also study the role of trade protection in the development of American manufacturing. The critical difference is between our identification strategies: I require that tariff shocks are uncorrelated with local idiosyncratic shocks whereas they require that the dependence of a sector on specific tariffs is uncorrelated with sector level trends. They make an across sector comparison, while I make

a within-product comparison (across counties). Their estimates directly deliver aggregate sector effects while I need to aggregate my local, cross-sectional estimates. Finally, I also estimate heterogeneous effect of trade protection based on distance to frontier.

den Besten and Känzig (2026) study the historical impact of tariff policy in the US using a narrative approach. Their identification requires national-level shocks to be uncorrelated with national-level trends, whereas mine requires those shocks to be uncorrelated with local-level trends, conditional on national-level fixed effects. In addition, they do not study heterogeneity across products.

A large empirical trade literature studies the impact of trade liberalization by comparing sectors that received larger tariff cuts to those that received smaller cuts (e.g. Pavcnik 2002, Khandelwal and Topaleva 2011, De Loecker et al. 2016, Fajgelbaum et al. 2020). Their identification requires tariff changes to be uncorrelated with product-level trends. My within-product design is robust to this concern via product-time fixed effects. In addition I estimate heterogeneous effects across products.

Shift-share approaches such as Autor, Dorn and Hanson (2013) rely on a similar identification assumption, as Borusyak, Hull and Jaravel (2022) show. My design avoids this requirement. Both shift-share and cross-product designs can at best estimate a convex-weighted average treatment effect, whereas my design recovers product-specific effects.

2 Historical Context

In the 1850s, the United States was an agrarian economy lagging behind Western Europe's industrial powers — the United Kingdom, France, Belgium, and the German states (which later unified to form Germany). The UK stood furthest ahead, having led the world technologically since the First Industrial Revolution in the 1760s. The US found itself in the position that many developing countries find themselves in today: a net exporter of agricultural and primary goods, while a net importer of manufacturing goods. For example, the

US imported 45% of iron bars and 95% of steel used domestically. By the 1890s, the US catches up, becomes a net exporter of manufactures, and GDP per capita increases by 50%.

This transformation was accompanied by high tariffs, ranging from 16%–45%, as Figure 1 shows. As discussed in the introduction, this aggregate correlation between tariffs and growth is often cited to justify current protectionist trade policy in the US. My period of analysis centers on the 1860s: as tariffs formed 90% of Federal revenues (Irwin 2020), fiscal pressures from the Civil War drove average tariffs to the highest level in US history since the Tariff of Abominations in 1828 (Figure 1; discussed further in Section 4.6).



Figure 1: Average US tariff rate on all imports, 1790–2023. Duties collected as a percentage of total imports for consumption. Data for 1790–2000 from Irwin (2006), Table Ee424-430. Data for 2001–2023 from U.S. International Trade Commission (2024). The dashed vertical line marks 1860.

On the international front, this period is often referred to as the First Globalization, a period of unprecedented economic and financial integration between nations. This was due to the rise of the steamship and telegraph, adoption of the gold standard and unilateral and bilateral reduction of protectionist measures. Within the US, exposure to the First Glob-

alization greatly varied depending on geographic distance and the transportation network.[5] As Commissioner David A. Wells (1869) states in a report to Congress,

> "If the duty on pig iron were entirely removed, the American producer in the interior would still enjoy a protection in the cost of transportation ... that intervene between the place of production and the port of entry ... which circumstances renders the transport of a single pound of foreign pig iron to any considerable distance into the interior a matter of ordinary commercial impossibility"

Indeed, this sentiment was also shared by trade economist Frank Taussig (1915), who stated "The cost of transportation from the sea-board to the interior is such that, even in the absence of the duty, steel rails would be imported only to supply railways near tide-water". Thus, high interior transportation costs were a form of protection for domestic producers against foreign imports. I will exploit this as part of my empirical design in Section 4.2.

One attractive feature of this period is the lack of a retaliatory response by trading partners. In Appendix A, I discuss the reasons why the European powers did not retaliate against the US for very high tariffs. This is useful because it helps isolate the import protection channel from retaliatory tariffs and loss of export markets.[6]

Another important dimension of this period is the wide variation in American technological capabilities across products. As Table 1 shows, in some industries, such as cotton textiles, American producers were near the technological frontier — the result of decades of transatlantic technology transfer dating back to the early republic (Jeremy 1981). In others, such as paints, the US lagged far behind: Sherwin-Williams was the first US paints company to hire a chemist in 1884, decades after European rivals like Perkin & Sons (est. 1857),

[5] In the modern day, other papers make a similar case. For example, Atkin and Donaldson (2015) show that the probability of finding foreign imports falls the further one goes into the interior. Bosker and Haasbroek (2025) and Cosar and Fajgelbaum (2016) find that access to ports mediates the impact of globalization. These predictions also hold theoretically for CES demand, the demand system adopted by the vast majority of the gravity, trade and spatial literature. See Appendix G for formal analysis under both CES and AIDS demand systems.

[6] Though this of course raises concerns about external validity: In the modern day, for example, protective tariffs are likely to be met with retaliatory tariffs.

Hoechst (1863) and BASF (1865) had built their firms around industrial chemistry.[7] As I show in the next section, this heterogeneity in technological proximity has sharp implications for how protection affects innovation incentives and output growth.

Table 1: Distance to Technological Frontier: British and US Patents, 1855-1859

Product	Distance to Frontier	British Patents	US Patents
Cotton Textiles	1.31	464	353
Worsted Goods	1.31	464	353
Boots	1.71	181	106
Hats	1.86	169	91
Iron Bar	2.53	374	148
Iron Pig	2.53	374	148
Steel	2.53	374	148
Paper	2.79	301	108
Beer	2.87	149	52
Whiskey	2.87	149	52
Glass	3.39	95	28
Gloves	3.64	222	61
Rope	3.88	128	33
Nails	4.98	214	43
Paints	7.82	297	38

Notes: Distance to frontier is the ratio of British to American patents in 1855–1859. A value of one indicates technological parity; higher values indicate the US lags further behind. Patent data from Hanlon (2016) and Shaw (undated, accessed 2025). See Section 5.1 for more details.

[7]See Appendix C for more examples and validation of my distance to frontier measure.

3 A Model of Protection and Distance to Frontier

I present a model, building on Aghion et al. (2005), in which the effect of trade protection on innovation and output growth is monotonically increasing in distance to the technological frontier. The mechanism operates through the differential effect of protection on pre- and post-innovation rents. Near the frontier, protection disproportionately raises pre-innovation rents, as the firm can compete without innovating. Far from the frontier, protection allows the firm to capture post-innovation rents, which it was unable to do before protection.

3.1 Setup

Two firms compete in Bertrand: a domestic (US) firm with unit cost c_{US} and a foreign (UK) firm with unit cost normalized to 1. The US firm is technologically behind: $c_{US} > 1$. A tariff $t \geq 0$ raises the UK firm's effective cost to $1 + t$. The US firm can innovate at fixed cost F, reducing its unit cost from c_{US} to c_{US}/γ, where $\gamma > 1$. Revenue is normalized to 1, the low-cost firm captures the market and prices at its rival's cost, and the high-cost firm earns zero.

3.2 Near the Frontier

Suppose the US firm is close to the frontier: $c_{US} > 1$ but $c_{US}/\gamma < 1$ and $c_{US} < 1 + t$. That is, the US firm is behind Britain, but can overtake it through either innovation or tariff protection.

Without a tariff, the US firm is uncompetitive unless it innovates. Innovation yields profit $\pi = 1 - c_{US}/\gamma$, so the gain from innovating is:

$$G_0 = \frac{\gamma - c_{US}}{\gamma}$$

With a tariff, the US firm is competitive even without innovating, earning $\pi = 1 -$

$c_{US}/(1+t)$. Innovation still raises profit, but the gain shrinks to:

$$G_t = \frac{c_{US}(\gamma - 1)}{\gamma(1+t)}$$

For $G_t < F < G_0$, the firm innovates without protection but not with it.

Mechanism: Without protection, the US firm must innovate to survive. Once protection is applied, the firm does not need to innovate to escape competition, thus in the close-to-frontier case, protection substitutes for innovation.

3.3 Far from the Frontier

Now suppose the US firm is far behind: $c_{US}/\gamma > 1$, so that even innovation does not bring costs below the UK's. However, with a tariff, the US firm can compete: $c_{US} < 1 + t$ and $c_{US}/\gamma < 1 + t$.

Without a tariff, the firm is uncompetitive whether or not it innovates. The gain from innovation is zero. With a tariff, the firm is now viable. Innovation reduces costs further, yielding a gain of:

$$G_t = \frac{c_{US}(\gamma - 1)}{\gamma(1+t)}$$

The firm innovates with protection iff $F < G_t$.

Mechanism: Domestic firm is far behind the technological frontier. Without protection, even with indigenous innovation, firm cannot catch up. However, with sufficiently large protection, the firm can now compete with the British. And because cost savings are high (as the firm is far behind the frontier), the firm innovates under protection.

3.4 Comparative Statics

Innovation: The tariff's effect on innovation incentives is monotonically increasing in distance to the frontier. Define $\Delta G \equiv G_t - G_0$ as the change in innovation gain due to protection.

In both the near- and far-from-frontier cases:

$$\frac{\partial \Delta G}{\partial c_{US}} > 0$$

This result implies $\frac{\partial \Delta I}{\partial c_{US}} \geq 0$, where ΔI is the change in binary decision to innovate. As we see, it is monotonic in distance to frontier.

Output: Under Bertrand with normalized revenue, output is $q = 1/p$ where p equals the rival's cost. Near-frontier firms that stop innovating under protection see output decline: without protection, the firm innovates and prices at $p = 1$, yielding $q = 1$; with protection, the firm does not innovate and prices at $p = 1 + t$, yielding $q = 1/(1 + t)$. Far-from-frontier firms that begin innovating under protection see output rise: without protection, the firm is uncompetitive and produces $q = 0$; with protection, the firm innovates and produces $q = 1/(1 + t)$.[8]

Therefore, the effect of protection on output is monotonic in distance to frontier:

$$\frac{\partial \Delta \log q}{\partial c_{US}} \geq 0$$

where $\Delta \log q$ is the logged change in output due to protection.

4 Empirical Framework

This section develops the empirical framework. I first derive a measure of protection that incorporates both tariffs and transportation costs (Section 4.1–4.2). I then present the econometric specification (Section 4.3) and instrument (Section 4.4), followed by the identification arguments (Section 4.5–4.7).

[8]Strictly speaking, this generates a discrete response of output to distance to frontier. To generate a smooth response of output, which matches my empirical specification in equation 3 more closely, we need to incorporate additional features. In Appendix H I introduce ex-ante uncertainty in R&D costs which generates this smooth response for near-frontier products.

4.1 Pricing Equation

To construct my measure of protection, I begin with the following equation for the local county i per-pound price of an imported product z:

$$p_{iz} = p_z + t_z p_z + \tau_{iz} \tag{1}$$

p_z is the price of European product z at the port, t_z is the ad valorem tariff applied to product z and τ_{iz} is the transportation cost from the nearest port to county i.

This pricing equation is quite general. First, as p_z is the pre-duty price, it incorporates complete or incomplete passthrough behavior. For example, the foreign exporter may cut their markup and price in response to a tariff increase, which will be incorporated into a lower p_z.

Second, I allow for a relatively general specification of transportation costs, which allows for markup pricing by the transportation sector. I let $\tau_{iz} = p_z^{\omega}\zeta_i$, where ζ_i is the freight cost from the nearest port to county i that is common to all products (i.e. a function of physical distance and transportation infrastructure). Note this specification nests the iceberg assumption ($\omega = 1$) , which is overwhelmingly the assumption used in the spatial and trade literatures. Rather than assuming iceberg, I digitize a dataset that has the requisite information to infer the nature of transportation costs and let the data "speak" in Section 5.2. My finding there is that $\omega = 0.139$, thus transportation costs are overwhelmingly additive (corresponding to $\omega = 0$) as opposed to iceberg. Thus for the rest of the paper, I set $\tau_{iz} = p_z^{0.139}\zeta_i$, though in Section 6.3 I examine robustness to setting $\tau_{iz} = p_z^0\zeta_i$.

Third, to economize on notation I only include ad valorem tariffs in the exposition. However, all empirics take into account whether tariffs are specific, ad valorem or composite. In Appendix F, I generalize the formula to include both ad valorem and specific tariffs. Virtually all the main intuitions carry through.

4.2 Treatment

If we take equation 1, subtract the port price from the local price and express it as a share of the port price, we yield the ad valorem equivalent of tariffs and transportation costs:

$$AVE_{iz} := \frac{p_{iz} - p_z}{p_z} = t_z + \frac{\tau_{iz}}{p_z} \tag{2}$$

Some features of this measure of protection are worth emphasizing. If $\tau_{iz} = 0$ (no transportation costs), then AVE_{iz} simply reduces to the tariff t_z, which is the notion of protection used in the vast majority of empirical trade papers (e.g. Pavcnik 2002, Khandelwal and Topaleva 2011, De Loecker et al. 2016).

For $\tau_{iz} > 0$, transportation costs are an additional form of protection as they serve to increase delivered import prices much like a tariff would, as in Juhasz (2018) and Pascali (2017). As discussed in Section 2, contemporary observers such as Wells (1869) and Taussig (1915) recognized that interior transportation costs rendered foreign imports commercially unviable beyond tidewater — effectively functioning as a tariff. See Figure 2 for a visual depiction of transportation costs across space for the product pig iron. Coastal counties near major ports such as New York and Philadelphia face low transportation costs relative to import prices. For interior Midwest counties, transportation costs alone exceed 45% of the import price — nearly twice the protection provided by the 24% pig iron tariff in place in 1860.

According to this perspective, transportation costs and tariffs are two sides of the same coin: They both serve to increase delivered prices for consumers and manufacturers needing inputs.[9]

Finally, the appearance of p_z is a result of the (mostly) additive transportation costs that I estimated in Section 5.2. Essentially, high transportation costs offer more protection for cheaper (low p_z) products rather than expensive ones, as the transportation cost will be a

[9]Of course, one crucial difference is that tariffs generate revenues for the Federal Government, which can be used to boost growth. I discuss this aspect in Section 7.2.

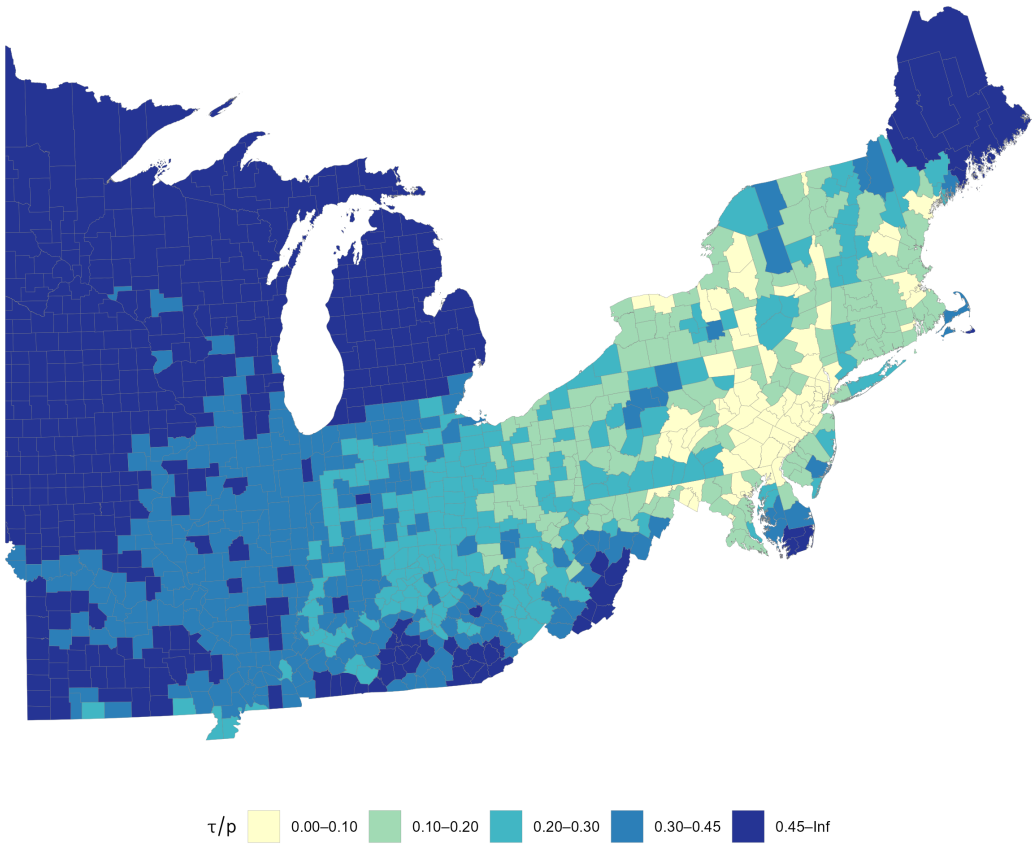


Figure 2: Transportation costs as a fraction of import price at port (τ_{iz}/p_z), for pig iron, 1860. Darker shading indicates higher transportation costs relative to port price, implying greater natural protection from foreign competition.

larger fraction of cost for cheaper goods. Therefore, in order to correctly specify protection levels, I will also need to collect port prices by product p_z.

Of course, protection, in addition to making competitor import products more expensive, may also make foreign inputs used by domestic firms more expensive. Thus, I also define an input protection measure in the following way:

$$\log(Input_AVE_{iz}) = \sum_{z'} \zeta_{z' \to z} \log(AVE_{iz'})$$

where $\zeta_{z' \to z}$ is the Leontief share of input z' used in the production of z, using the state-level census of manufactures digitized by Atack, Bateman and Weiss (2006). See Section 5.1

for details on the construction of $\zeta_{z' \to z}$. I include this variable in all specifications.

4.3 Econometric Specification

I estimate the following reduced form regression, expressed in growth rates:

$$\begin{aligned} \Delta \log y_{iz} = \beta[\Delta \log(AVE_{iz}) \times Dist_Front_z] + \theta \Delta \log(AVE_{iz}) + \\ \gamma \Delta \log(Input_AVE_{iz}) + \Delta\delta_i + \Delta\delta_z + \Delta e_{iz} \end{aligned} \tag{3}$$

where Δ is the difference operator (i.e. $\Delta \log y_{iz} = \log y_{iz,1870} - \log y_{iz,1860}$), i, z index county and product respectively. $\Delta\delta_i$ is a county-time fixed effect and $\Delta\delta_z$ is a product-time fixed effect. θ is the baseline effect of protection for a product with dist to frontier of zero, and β captures how the effect of protection varies with distance to the technological frontier. According to the model in Section 3, we expect $\beta > 0$.

First, note that taking the difference controls for any persistent-county product factors δ_{iz}. For example, this would control for Pittsburgh being better at producing steel than Boston. Second, the county-time fixed effect $\Delta\delta_i$ controls for local equilibrium effects such as agglomeration, factor supplies and local price indices.[10] This would, for example, control for Chicago growing rapidly in all product categories. Third, unlike other designs, we are also able to include product-time fixed effects $\Delta\delta_z$, capturing any nationwide trends in products such as technological developments. Thus, this design isolates within-product, across-county changes in trade protection.

In words, this design is comparing the growth rate of Philadelphia steel to Chicago steel when the change in protection is higher for Philadelphia steel than Chicago steel (while

[10]This fixed effect makes identification credible, but then we must interpret the parameter β as the effect of protection on output, **holding** real incomes fixed. When protection increases, real incomes can increase due to increased demand, or can decrease due to higher import goods costs. In other words, this is a partial equilibrium elasticity rather than a general equilibrium elasticity. In Section 7, I discuss this issue in depth and try to recover the general equilibrium elasticity. See discussion in Chodorow-Reich (2019, 2020) and Guren et al. (2021).

controlling for county-time fixed effects). If Philadelphia steel grows faster than Chicago steel, then we infer that output protection benefits growth. One notable feature of this design is that identification operates entirely within-product — comparing counties producing the same product — rather than across products, as is common in the empirical trade literature.

However, the error term Δe_{iz} may still be correlated with $\Delta \log(AVE_{iz})$. For example, railroads may target high growing areas. Or railroads being built facilitate access to markets (domestic or foreign) and inputs. In both cases, this would lead to an inconsistent estimate for β. Thus we turn to an instrument to deal with this concern.

4.4 Instrument

Because transportation costs may be endogenous – for example, railroads may facilitate access to inputs or markets – I instrument for $\Delta \log(AVE_{iz})$ using only the tariff-driven component of protection changes. To do so, I use a first order approximation (see Appendix B for derivation):

$$\Delta \log(AVE_{iz}) \approx \underbrace{STS^t_{iz} \Delta \log t_z}_{IV} + STS^\tau_{iz} \Delta \log \tau_i - STS^\tau_{iz} \Delta \log p_z$$

where $STS^t_{iz} = \frac{t_z p_z}{t_z p_z + \tau_{iz}}$ and $STS^\tau_{iz} = \frac{\tau_{iz}}{t_z p_z + \tau_{iz}}$.

STS^t_{iz} captures the tariff's share in total protection for a given county-product iz pair. This expression has a "shift-exposure" structure to it as in Borusyak and Hull (2023), where there are cross-sectional exposures to aggregate shifters.[11]

I use the first component $STS^t_{iz} \Delta \log t_z$ as an instrument. Intuitively, counties where the tariff forms a larger fraction of local protection (i.e. those with high STS^t_{iz}) are more sensitive to tariffs. In other words, high STS^t_{iz} areas will see larger increases in protection for any

[11] This is technically not a shift-share according to the definition in Borusyak, Hull and Jaravel (2025), though it in spirit resembles the same structure of a local exposure to an aggregate shifter. Borusyak and Hull (2023) show that shift-shares are a specific case of the "shift-exposure" framework.

tariff increase (i.e. for any $\Delta \log t_z > 0$), making the intuitions in Section 2 mathematically precise.

Thus, as coastal areas will generally have larger values of STS_{iz}^t than interior regions, they will also be more exposed to aggregate tariff shocks. One way to think about this is to note that interior regions have two forms of protection – tariffs and internal transportation costs – thus their level of protection is less sensitive to tariff fluctuations than coastal areas, which can only rely on the tariff as its protection. See Figure 3 for a visual depiction of the tariff-driven component of protection changes across space for pig iron. Coastal counties near major ports such as New York and Philadelphia see the largest increases in protection, while interior counties — already shielded by high freight costs — see much smaller changes despite facing the same nationwide tariff increase.

The goal in this section was to isolate the change in protection arising **only** from the change in tariffs.[12] The next three sections will then argue that this component is exogenous to county-product shocks.

4.5 Identification

Formally, we need the following IV orthogonality condition to hold for consistent estimation:

$$\mathbb{E}(STS_{iz}^t \Delta \log t_z \cdot \Delta e_{iz} | \Delta\delta_i, \Delta\delta_z) = 0 \tag{4}$$

A sufficient condition for Equation 4 is (Appendix D for proof):

$$\mathbb{E}(\Delta \log t_z \cdot \Delta e_{iz} | \Delta\delta_i, \Delta\delta_z, STS_{iz}^t) = 0 \tag{5}$$

Condition 5 requires **nationwide** tariff changes to be uncorrelated with **local** product shocks, *conditional* on product-time and county-time fixed effects.

This is, in many contexts, a weaker condition than other canonical designs. For example,

[12] Another way to think about this is that this is the change in protection if the US had no new railways built in the decade 1860-1870 and port prices did not change.

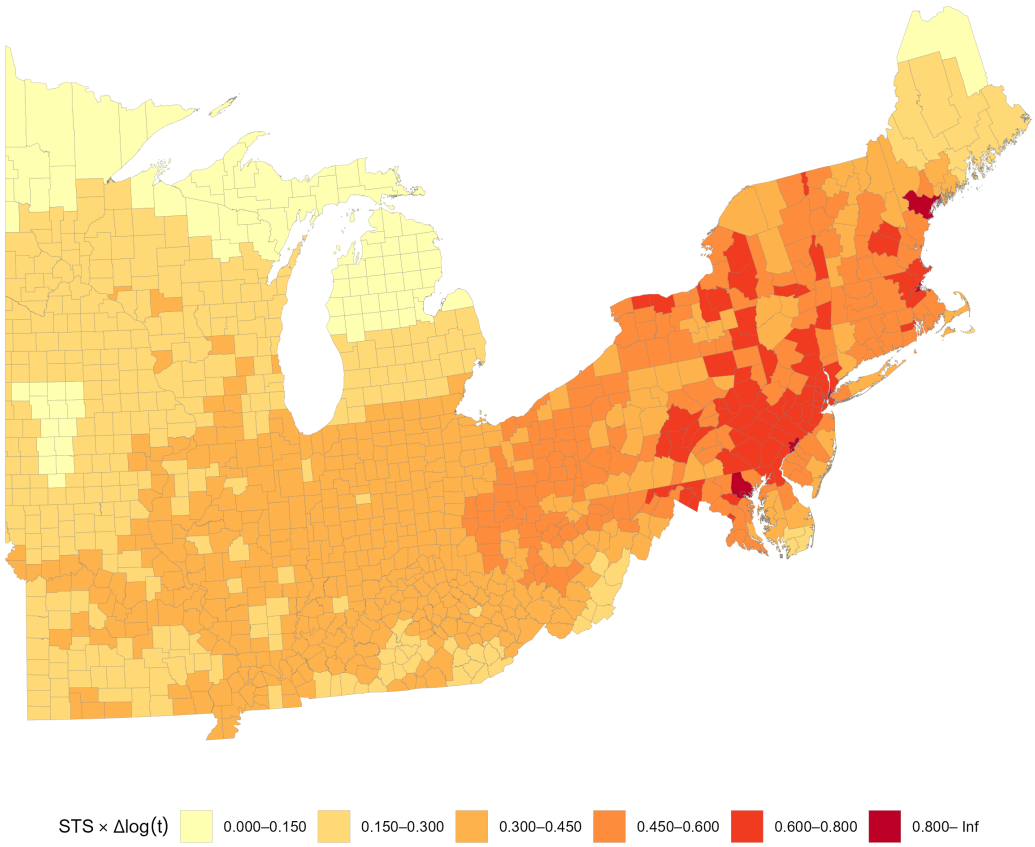


Figure 3: Instrumental variable ($STS_{iz}^{t} \times \Delta \log t_z$) for pig iron, 1860–1870. Darker shading indicates greater exposure to the nationwide tariff shock, with coastal counties near major ports receiving the largest percentage increases in protection.

one canonical approach is to take a nationwide trade liberalization episode – such as Pavcnik (2002), Khandelwal and Topaleva (2011), and De Loecker et al. (2016) – and compare the change in outcomes for sectors that received larger tariff cuts to sectors that received smaller cuts. For these cross-product comparisons, the equivalent condition would be: $\mathbb{E}(\Delta \log t_z \cdot \Delta e_{zt} | \Delta\delta) = 0$, which in words, is **nationwide** tariff shocks need to be uncorrelated with **nationwide** – as opposed to local – product shocks. Thus, if policymakers are targeting nationwide product trends, this would invalidate a nationwide cross-product empirical design, but would not invalidate my design due to the presence of the product-time fixed effect $\Delta\delta_z$.

In addition, as Borusyak, Hull and Jaravel (2022) show, shift-share designs based on

exogenous shocks – such as the China Shock paper of Autor, Dorn and Hanson (2013) – rely on a similar identification argument as nationwide cross-product studies. Thus shift-shares based on the exogenous shocks view are invalidated if products receiving different tariffs are on differential trends, while my approach is robust to this concern.[13]

There are two major threats to condition 5 holding: 1) endogenous tariff setting by policymakers, and 2) other shocks that are coincidentally correlated with tariffs. The rest of the section will discuss the trade policy environment, provide a narrative for why neither endogeneity concern is likely to hold in my context, and present a balance test showing that location-product pairs receiving more protection are balanced on observable characteristics with those receiving less.

4.6 Policy Environment and Narrative

In this period, 90% of Federal revenues came from tariffs (Irwin 2020), and federal budgets and surpluses played a pivotal role in tariff policy. In November 1860, Abraham Lincoln is elected President. Out of fears that Lincoln would restrict slavery, Southern states begin seceding from the Union and the Civil War begins two months after Lincoln's inauguration. While many assumed the War would be over by Christmas 1861, it drags on and turns out to be an unprecedented fiscal burden. Figure 4 shows the dramatic spike in federal expenditures and deficits during the war years.

To finance the war effort, Congress passes five major tariff increases (and many more minor revisions) in 1861-1865. For comparison, Congress only passed one major tariff bill in the 1850s. Tariffs went from 16% in 1860 to 45% by 1870.

While it seems clear that revenue generation was policymakers' first order concern, other goals – such as industrial development or protecting a lobby – could have been pursued in tandem. A key advantage of my study is that it is robust to policymakers targeting nation-

[13]The other path to identification for shift-shares, based on the exogeneity of shares (Goldsmith-Pinkham et al. 2020), is likely to not hold in my context. Locations specializing in different sectors are likely to be exposed to a variety of different shocks such as immigrant flows, technological changes and unionization drives.

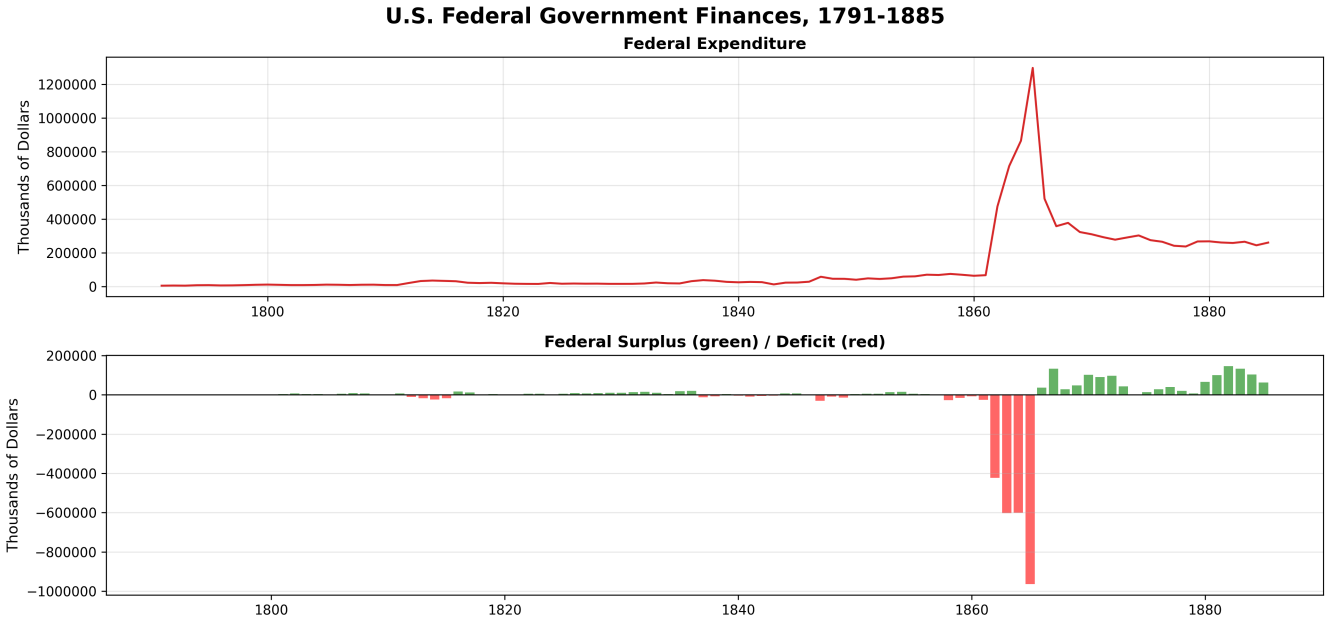


Figure 4: U.S. Federal Government Finances, 1791-1885 (Carter et al. 2006)

wide product trends, unlike other canonical approaches based on cross-product approaches, such as shift-shares or nationwide trade policy studies.

In order for condition 5 to be violated, policymakers would need to be reacting to idiosyncratic county product shocks in a way that systematically deviates from the county-time, county-product and product-time average. First, policymakers would need to identify county-product trends that deviate from the product-time, county-time and county-product averages – across roughly 1,500 counties and hundreds of tariff line items. Then they would need to set tariff levels to systematically exploit these residual trends. Finally, they would need to build majority consensus on this targeting in both the House and Senate. In peacetime, this is already a very high cognitive and informational burden on 19th-century policymakers – one only exacerbated by the wartime fiscal pressures. In contrast, targeting national product-level trends is more tractable and easier to build Congressional consensus around.

This assuages concerns about endogenous tariff setting but other Civil War shocks – such as military procurement, Emancipation and the effect of battles – loom large. I address these

concerns in Section 6.3.

4.7 Balance Tests

While condition 5 cannot be directly tested, balance tests provide suggestive evidence. If county-product pairs receiving more protection differ systematically on observable characteristics from those receiving less, it would suggest the threat of endogenous tariff setting or confounding shocks loom large—either of which would violate condition 5. For example, systematic imbalance might indicate that policymakers were able to overcome the informational constraints discussed above and selectively target county-product pairs with certain characteristics. This would then raise concerns they could also identify and target idiosyncratic county-product trends, violating condition 5.

I regress a number of initial period variables on the change in input and output protection, with product-year and county-year fixed effects.[14] These characteristics include total labor (county-product pairs with larger labor forces may have more electoral and lobbying power), firm size (county-product pairs with larger firms may be able to overcome collective action problems and lobby (Olson (1965)) and output (implying more resources for lobbying).

Table 2 presents the results. The change in output and input protection is not systematically correlated with baseline observable characteristics. County-product pairs that saw increases in protection are roughly balanced on initial period observable characteristics with those that saw less, thereby assuaging concerns of selective targeting by policymakers.

The value of the within-product comparison becomes clear when we omit the product-time fixed effect $\Delta\delta_z$. Without it, we go from 0/16 to 6/16 significant correlations (at the 10% level), raising concerns that condition 5 does not hold when we also exploit cross-product variation. Isolating the within-product comparison is thus crucial for the exogeneity narra-

[14] Mathematically:

$$\log Y_{iz,1860} = \phi \Delta \log(AVE_{iz}) + \psi \Delta \log(Input_AVE_{iz}) + \Delta\delta_z + \Delta\delta_i + \Delta\epsilon_{iz}$$

Table 2: Balance Test

	IV Output		IV Input	
Dependent Variable	Coef.	SE	Coef.	SE
Log Total Labor (first)	−1.921	(2.854)	−3.299	(2.051)
Log Establishments (first)	−2.015	(1.498)	−0.739	(1.098)
Log Capital (first)	−0.286	(2.369)	−2.545	(2.418)
Log Labor Productivity (first)	−0.694	(1.489)	0.539	(0.540)
Log Output (first)	−2.194	(1.908)	−3.190	(1.832)
Log Output per Estab (first)	−0.183	(1.929)	−2.405	(1.496)
Log Average Wage (first)	−0.635	(0.443)	0.242	(0.357)
Log Capital-Labor Ratio (first)	1.635	(2.696)	0.754	(1.094)

Notes: Each row reports coefficients from a separate IV regression of the baseline (1860) characteristic on changes in output and input protection, with county-year and product-year fixed effects. Standard errors clustered at the county and product level in parentheses. None of the 16 coefficients are statistically significant at conventional levels. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

tive — and is infeasible in canonical approaches, including both shift-share and nationwide liberalization designs.

Table 3: Imbalance Test: Without Product-Year Fixed Effects

	IV Output		IV Input	
Dependent Variable	Coef.	SE	Coef.	SE
Log Total Labor (first)	−0.143	(0.151)	−0.885*	(0.444)
Log Establishments (first)	0.018	(0.056)	−0.232	(0.170)
Log Capital (first)	0.032	(0.128)	−0.877*	(0.437)
Log Labor Productivity (first)	0.264***	(0.089)	0.331	(0.197)
Log Output (first)	0.208*	(0.107)	−0.430	(0.355)
Log Output per Estab (first)	0.189	(0.131)	−0.192	(0.397)
Log Average Wage (first)	0.062**	(0.024)	0.192**	(0.081)
Log Capital-Labor Ratio (first)	0.175	(0.124)	0.008	(0.272)

Notes: Each row reports coefficients from a separate IV regression of the baseline (1860) characteristic on changes in output and input protection, with county-year fixed effects only (no product-year fixed effects). Standard errors clustered at the county and product level in parentheses. 6 of 16 coefficients are statistically significant at the 10% level, in contrast to 0 of 16 when product-year fixed effects are included (Table 2). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

5 Data

5.1 Data

I digitize foreign import prices entering US ports as well as US tariffs from the Foreign Commerce and Navigation Tables of the United States for 1859 and 1869. These tables record, for each product, the total quantity imported and total customs value, from which I infer per-unit import prices (see Figure 5 for an example). They also list the applicable tariff — whether ad valorem, specific, or composite — for each tariff line item.

As there is no input-output table available in this period, I construct one using Atack, Bateman and Weiss' (2006) digitized state-level census of manufacture samples, which records input-specific usage by product.[15]

[15]I limit the sample to single product establishments, as, like in the vast majority of manufacturing censuses even today, input usage is not recorded by product. See Orr (2022) and De Loecker et al. (2016) for further discussion on inferring input allocations in multi-product establishments. I first compute the firm-specific Leontief share. Then I aggregate from the firm Leontief share to a product Leontief share by taking a weighted average across firms, where the weights are the Domar weight (share of firm revenue in total revenue). Mathematically: Let $\zeta_{z' \to z}$ be the Leontief share of input z' used for z. $\zeta_{z' \to z, f} = \frac{\text{expenditure on input } z' \text{ by } f}{\text{total input expenditure of } f}$, and $\zeta_{z' \to z} = \sum_{f \in z} w_f \zeta_{z' \to z, f}$, where $w_f = \frac{y_f}{\sum_{f' \in z} y_{f'}}$ and y_f is the revenue of

No 9.—*General statement of foreign imports*—Continued.

	WHENCE IMPORTED.	MERCHANDISE PAYING SPECIFIC DUTIES.									
		IRON, AND MANUFACTURES OF IRON.									
		Bar iron, rolled or hammered.		Railroad iron, not above six inches high.		Boiler plate.		Band iron.		Hoop iron.	
		$15 per ton.		$12 per ton.		$20 per ton.		$20 per ton.		$20 per ton.	
		Cwt.	Dollars.	Cwt.	Dollars.	Cwt.	Dollars.	Cwt.	Dollars.	Cwt.	Dollars.
1	Sweden and Norway	8,105	30,686								
2	Swedish West Indies										
3	Denmark										
4	Danish West Indies										
5	Hamburg										
6	Bremen	5,505	14,069								
7	Holland										
8	Dutch West Indies										
9	Dutch Guiana										
10	Dutch East Indies										
11	Belgium										
12	England	33,174	63,243	48,744	62,226	1,284	2,973	1,915	3,751	5,770	12,942
13	Scotland	30	36								
14	Ireland										
15	Gibraltar										
16	Malta										
17	Canada	4	12			2	8				
18	Other British North American Possessions	5	12								
19	British West Indies										
20	British Honduras										
21	British Guiana										
22	British Possessions in Africa										
23	British East Indies										
24	France on the Atlantic										
25	France on the Mediterranean										
26	French West Indies										
27	French Guiana										
28	Spain on the Atlantic										

Figure 5: Excerpt from the 1859 Foreign Commerce and Navigation Tables. Below each product name, the tariff is listed (e.g. $15 per ton for bar iron, rolled or hammered). Prices are inferred by dividing the 'Dollars' column by the 'Cwt.' column (hundredweight = 100 pounds).

I deflate all nominal values to 1870 dollars using the Historical Statistics of the United States (2006). Data on county-product output, labor employment, total materials usage and capital are taken from the recently digitized Census of Manufactures for the years 1860 and 1870 (Hornbeck and Rotemberg 2024).

British patent data comes from Hanlon (2016). Table 4 lists the basket of products in my sample alongside British patent counts. As expected, products associated with the two Industrial Revolutions saw more patenting activity, with textiles — the quintessential First Industrial Revolution sector — at the top. Iron and steel, already the second most patented category, foreshadow their dominant role in the coming Second Industrial Revolution. US patent data comes from Shaw (undated, accessed 2025).

establishment f.

Table 4: British Patents by Product Class

Product	British Patents	Category
Cotton Textiles	464	First IR
Worsted Goods	464	First IR
Iron Bar	374	First/Second IR
Iron Pig	374	First/Second IR
Steel	374	Second IR
Paper	301	First IR
Paints	297	Second IR
Glove	222	Neither
Nails	214	First/Second IR
Boots	181	Neither
Hats	169	Neither
Beer	149	Neither
Whiskey	149	Neither
Rope	128	Neither
Glass	95	Neither

Notes: IR = Industrial Revolution. Classification based on whether the product had crucial innovations during the First Industrial Revolution (c. 1760–1840), the Second Industrial Revolution (c. 1870–1914), or neither. Patent data from Hanlon (2016).

$$Dist_Front_z = \frac{\text{\# British Patents}_{1855-1859,z}}{\text{\# US Patents}_{1855-1859,z}}$$

To construct a measure of technological gaps, I harmonize product categories across the two countries' patent data and create a distance to frontier variable, which takes the ratio of British to American patents in the pre-treatment period (1855-1859). This patent-based measure of technological gaps is similar in spirit to the one used by Akcigit, Ates and Impullitti (2024). A value of one means the US has as many patents as the UK (thus it's "at the frontier"), while a large value signifies the US significantly lags behind the UK in that product category. Table 1 displays the rankings of the products by distance to frontier, and Appendix C presents historical context and validation for these rankings as a measure of technological gaps. For example, cotton textiles' near-frontier status reflects decades of transatlantic technology transfer dating to Samuel Slater and Francis Cabot Lowell (Jeremy

1981), while paints' position as the most distant product is consistent with the US's late adoption of industrial chemistry relative to European pioneers such as Perkin & Sons and BASF.

Finally, I extract transportation cost data from Donaldson and Hornbeck (2016).(DH hereafter)[16] This map contains information on whether travel is possible by waterway (fastest), railway (close to fastest) and by wagon (very slow). Assigning values to the speed of travel per mile-ton (and assigning a cost to transitioning between different modes of transportation), DH compute the shortest path between any two counties in the US and assign this value as the transportation cost.

I build on DH's network by 1) adding in access to international ports and 2) empirically disciplining the functional form of transportation costs rather than assuming iceberg. I assume that trade operates according to a "hub-and-spoke" system: US port $\rightarrow$ US internal counties. I first compute the distance from the US county to one of nine US ports[17] using DH's map. Then I set the "transportation cost" to be the minimum of these nine distances, i.e. the transportation cost of any US county and the nearest major port. See Figure 6 for a graphical depiction of the transport network in the East Coast and Midwest. In the next subsection, I empirically discipline the functional form of transportation costs.

5.2 Nature of Transportation Costs

To form my measure of protection in section 4.2, I need to measure transportation costs as accurately as possible. To empirically discipline the functional form of transportation costs, I use information in the Aldrich Report (Aldrich 1893) which I digitize specifically for this purpose. Let $\tau_{odzs} = p_{ozs}^{\omega}\zeta_{ods}$, where o is an origin, d is the destination, z is a product, s is year, τ_{odzs} is transportation cost for product z, p_{ozs} is the origin price of product z and ζ_{ods} is the freight rate common to all products.

[16]This was built using Atack's shapefiles (2015, 2016, 2017).

[17]These are ports that had more than \$250,000 worth of imports from the United Kingdom in 1870: Boston, New York City, Philadelphia, Baltimore, Charleston, Savannah, New Orleans, Mobile and Texas City.

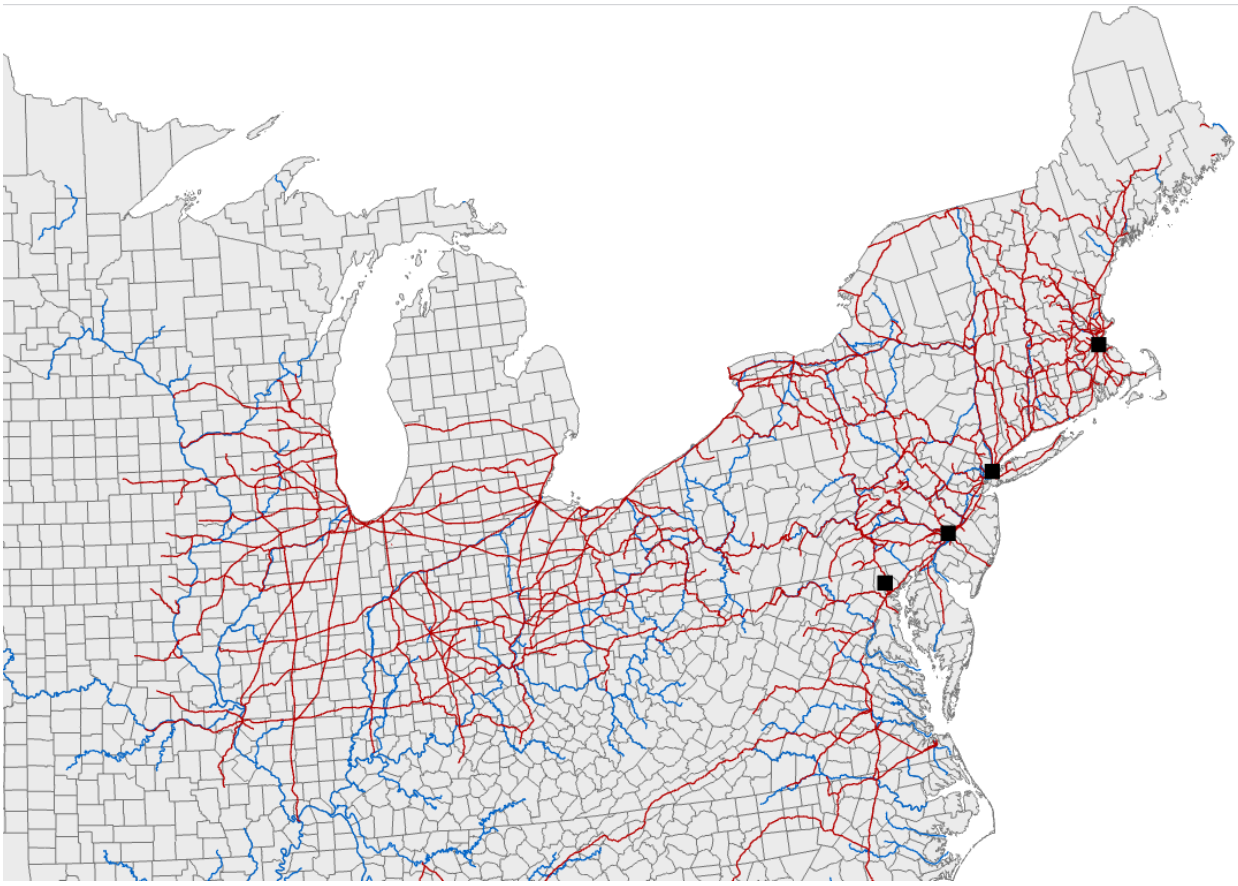


Figure 6: U.S. East Coast and Midwest transportation network, 1860. Railways (red), waterways (blue). Source: Atack (2015, 2016, 2017). Black squares with black center represent major international ports. See footnote 17 for how major international ports were selected.

Note this specification nests the iceberg formulation when $\omega = 1$, which is widely assumed in trade and spatial. In this case, transportation costs scale proportionally with the price of the product in the origin. This may be due to more expensive goods having more expensive handling requirements or due to markup pricing.[18]

At the other extreme, when $\omega = 0$, transportation costs are fully additive, and are the same for all products regardless of the product's origin price. Thus, only bilateral features between o and d matter, such as physical distance between the two locations and transportation infrastructure. Of course, ω can also be between 0 and 1. Taking logs yields:

[18]Hummels and Skiba (2004) show that a monopolist in the transportation sector's markup is increasing in the origin's good price.

$$\log \tau_{odzs} = \omega \log p_{ozs} + \delta_{ods}$$

Critically – and unusually – the Aldrich Report contains information on transportation costs for a given route, but for different products. This information allows me to infer the nature of transportation costs. Thus τ_{odzs} is not assumed but rather directly taken from the data (though only for a subset of routes and products). As for p_{ozs}, I set it to the price of imported products (inclusive of the tariff) if o is a port city.

Table 5: Transportation Cost Regression

	Log Transport Cost
	(1)
Log Import Price ($\hat{\omega}$)	0.139***
	(0.022)
Observations	124
Route-Year FE	Yes

Notes: Regression of log product-specific transportation costs on log import prices with route-year fixed effects. Transport cost data digitized from the Aldrich Report (1893); port price data from Foreign Commerce and Navigation Tables (1859, 1869, 1879). Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

As Table 5 shows, I find that $\hat{\omega} = 0.139$ with a 95% confidence interval of $[0.0959, 0.182]$, thus transportation costs are much closer to being additive than iceberg. I therefore set $\omega = 0.139$ in the baseline specification, but I examine robustness to $\omega = 0$ (fully additive case), $\omega = 0.0959$ (lower bound of 95% confidence interval), and $\omega = 0.182$ (upper bound of 95% CI) in Section 6.3.

6 Cross-Sectional Results

6.1 Output Growth Results

We now run our specification in equation (3), reproduced here:

$$\Delta \log y_{iz} = \beta[\Delta \log(AVE_{iz}) \times Dist_Front_z] + \theta \Delta \log(AVE_{iz}) +$$
$$\gamma \Delta \log(Input_AVE_{iz}) + \Delta\delta_i + \Delta\delta_z + \Delta e_{iz}$$

where i is county, z is product and Δ represents a difference. AVE_{iz} is our measure of output protection, and $Input_AVE_{iz}$ our measure of input protection as discussed in Section 4.2. $\Delta\delta_i$ is a county-time fixed effect and $\Delta\delta_z$ is a product-time fixed effect. $STS^t_{iz}\Delta \log t_z$ is the IV for $\Delta \log(AVE_{iz})$, where $STS^t_{iz} = \frac{t_z p_z}{t_z p_z + \tau_{iz}}$ is the county-exposure to the nationwide tariff shock, as discussed in Section 4.4.

Table 6: IV Estimates: Distance to Frontier and Protection Effects on Output Growth

	Δ Log Output
	(1)
Δlog(AVE) × Distance to Frontier	1.496***
	(0.399)
Δlog(AVE)	-4.434**
	(2.002)
Observations	833
Input AVE Control	Yes
County-Year FE	Yes
Product-Year FE	Yes
First-stage F-statistic (Kleibergen-Paap)	15.6

Notes: Each column reports IV estimates of specification 3 of the change in log protection on log output. The instrument is $STS^t_{iz} \times \Delta \log t_z$, the interaction of the tariff share in total protection with the nationwide tariff change. All specifications include controls for the change in input protection, county-year fixed effects and product-year fixed effects. Standard errors clustered at the county and product level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

We look at the impact of protection on output growth in Table 6. At baseline (i.e. product with distance to frontier of 0 or US technological dominance), a 1% increase in protection leads to a 4.4% fall in output growth. Each unit increase in the distance-to-frontier ratio increases the effect of protection on growth by 1.5 percentage points, implying that the effect of protection flips from negative to positive at a British-to-US patent ratio of roughly 2.96. To put this in context, protection harms growth for near-frontier products such as cotton textiles (1.31) and iron and steel (2.53), but boosts growth for laggard products such as glass

(3.39) and paints (7.82).

6.2 Mechanisms and Alternative Interpretations

I first rule out an alternative interpretation based on trade elasticities. Standard trade theory predicts that more substitutable products see a larger output response to a given increase in protection. If products far from the frontier also happen to have higher elasticities of substitution, this could rationalize the positive interaction coefficient without any innovation channel as predicted by my model in Section 3.

I test this by correlating $Dist_Front_z$ with trade elasticities from three sources: Caliendo and Parro (2015), Shapiro (2016), and Giri, Yi, and Yilmazkuday (2021).

Table 7: Correlation between Distance to Frontier and Trade Elasticities

Elasticity Source	Correlation with $Dist_Front_z$
Caliendo & Parro (2015)	−0.229
Shapiro (2016)	−0.555
Giri, Yi & Yilmazkuday (2021)	−0.170
Median	−0.533

Notes: Each row reports the correlation between the distance-to-frontier measure ($Dist_Front_z$) and the trade elasticty ($\sigma_z - 1$) from the indicated source. All correlations are negative, indicating that products further from the British technological frontier are less substitutable — the opposite of what would be required for trade elasticities to explain the positive interaction coefficient in Table 6.

As Table 7 shows, the correlations are uniformly negative: products far from the frontier have *lower*, not higher, elasticities of substitution, ruling out this alternative interpretation. Results are also robust to directly controlling for $(\sigma_z - 1) \times \Delta \log(AVE_{iz})$ in the main specification (Appendix Table I13).

A more substantive alternative interpretation comes from the static Ricardian model, which is also consistent with the results in Table 6. If we interpret $Dist_Front_z$ as a proxy for US comparative advantage, then protection would reallocate resources from comparative advantage to comparative disadvantage products, generating a similar pattern in output growth.

To distinguish between these mechanisms, I examine whether innovation activity responds to protection with the same frontier gradient. A static Ricardian reallocation shifts output toward protected sectors but does not generate differential innovation responses along the technological frontier. Using patent-level data from Shaw (undated, accessed 2025), geocoded to the county-level using Berkes, Karger and Nencka (2023), I run specification 3 with patent issuances as the dependent variable.

Table 8: IV Estimates: Distance to Frontier and Protection Effects on Patent Growth

	Δ Log Patents
	(1)
Δlog(AVE) $\times$ Distance to Frontier	1.312**
	(0.572)
Δlog(AVE)	-7.138*
	(3.537)
Observations	281
Input AVE Control	Yes
County-Year FE	Yes
Product-Year FE	Yes
First-stage F-statistic (Kleibergen-Paap)	45.2

Notes: Each column reports IV estimates of specification 3 of the change in log protection on log output. The instrument is $STS_{iz}^{t} \times \Delta \log t_z$. All specifications include controls for the change in input protection, county-year fixed effects and product-year fixed effects. Standard errors clustered at the county and product level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

As we see in Table 8, at baseline (i.e. distance to frontier of 0), a 1% increase in protection results in a 7.1% fall in patent issuances. Each unit increase in distance-to-frontier increases the effect of protection on patent issuances by 1.3 percentage points, just as the model in Section 3 predicts. Thus, protection shifts patent activity towards laggard products. This differential effect suggests that the pattern of comparative advantage itself is changing, rather than just a reallocation due to static comparative advantage.

6.3 Civil War Confounds and Robustness

The Civil War was not merely a fiscal shock — it had wide-ranging impacts across a variety of social and economic domains, making War-related omitted variables loom large. I address this with a battery of robustness checks. My baseline specification excludes the Confederate

South due to the potential effects of battles, Confederate governance, Emancipation, and Reconstruction. However, results are robust to including the Confederate South in the sample (Column 1 of Table 9). I also examine sensitivity to excluding the four slave states that fought on the side of the Union — Kentucky, Maryland, Missouri, and Delaware; results are robust to their exclusion (Column 2 of Table 9). Finally, I restrict the sample to counties – whether North or South – without a documented Civil War battle from the Civil War Sites Advisory Commission (CWSAC, 1993), thereby removing any county that may have experienced direct physical destruction of productive capacity. Results are once again robust (Column 3 of Table 9).

Table 9: Robustness: Civil War Geographic Sample Restrictions

	Δ Log Output		
	Including South	Excl. Border States	Excl. Battle Counties
	(1)	(2)	(3)
Δlog(AVE) × Distance to Frontier	1.508***	1.203***	1.568***
	(0.406)	(0.267)	(0.406)
Δlog(AVE)	-4.159*	-3.634*	-4.691**
	(2.109)	(1.995)	(2.037)
Observations	883	771	853
Input AVE Control	Yes	Yes	Yes
County-Year FE	Yes	Yes	Yes
Product-Year FE	Yes	Yes	Yes
First-stage F-statistic (Kleibergen-Paap)	16.6	19.2	16.2

Notes: Each column reports IV estimates of specification 3 of the change in log protection on log output under alternative geographic sample restrictions. Column 1 includes the Confederate South. Column 2 excludes the four Union slave states (Kentucky, Maryland, Missouri, Delaware). Column 3 excludes all counties with a documented Civil War battle (CWSAC, 1993). Standard errors clustered at the county and product level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Beyond direct conflict, The War also generated economic shocks, as military procurement created geographically concentrated demand boosts. I digitize the report of the Quartermaster General documenting Civil War purchases by county; Table 10 shows that results are robust to dropping counties with any military purchases.[19]

[19]Results are also robust to dropping the neighbors of these counties. See Appendix Table XXX.

Table 10: Robustness: Excluding Counties with Military Purchases

	Δ Log Output
	(1)
Δlog(AVE) × Distance to Frontier	1.695***
	(0.549)
Δlog(AVE)	-5.073**
	(2.339)
Observations	800
Input AVE Control	Yes
County-Year FE	Yes
Product-Year FE	Yes
First-stage F-statistic (Kleibergen-Paap)	13.6

Notes: Each column reports IV estimates of specification 3 of the change in log protection on log output, excluding counties with documented military purchases from the Quartermaster General's report. Standard errors clustered at the county and product level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

The War also severely disrupted the supply and transportation of cotton, the vast majority of which was produced in the South. If this disruption differentially affected cotton textile producers on the coast relative to interior producers, it could confound the identifying variation. Table 11 shows that results are robust to dropping cotton textiles.

Table 11: Robustness: Excluding Cotton Textiles

	Δ Log Output
	(1)
Δlog(AVE) × Distance to Frontier	1.663***
	(0.469)
Δlog(AVE)	-4.833**
	(2.146)
Observations	743
Input AVE Control	Yes
County-Year FE	Yes
Product-Year FE	Yes
First-stage F-statistic (Kleibergen-Paap)	15.9

Notes: Each column reports IV estimates of specification 3 of the change in log protection on log output, excluding cotton textiles from the sample. Standard errors clustered at the county and product level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Beyond Civil War-related concerns, I also examine robustness to alternative specifications of transportation costs. In Section 5.2, I estimated $\hat{\omega} = 0.139$ and used the following specification for transport costs: $\tau_{iz} = p_z^{0.139}\zeta_i$. In Table 12, results are robust to setting $\omega = 0$ (corresponding to fully additive transport costs), $\omega = 0.0959$ (lower bound of the 95%

confidence interval for $\hat{\omega}$ estimated in Section 5.2) and $\omega = 0.182$ (upper bound).

Table 12: Robustness to Transportation Cost Specification (ω)

	Δ Log Output		
	$\omega = 0$	$\omega = 0.096$	$\omega = 0.182$
	(1)	(2)	(3)
Δlog(AVE) $\times$ Distance to Frontier	1.066***	1.340***	1.666***
	(0.288)	(0.354)	(0.452)
Δlog(AVE)	-3.289*	-4.017**	-4.885**
	(1.557)	(1.820)	(2.225)
Observations	833	833	833
Input AVE Control	Yes	Yes	Yes
County-Year FE	Yes	Yes	Yes
Product-Year FE	Yes	Yes	Yes
First-stage F-statistic (Kleibergen-Paap)	10.6	14.0	16.9

Notes: Each column reports IV estimates of specification 3 of the change in log protection on log output under alternative values of ω, the elasticity of transportation costs with respect to product price (estimated in Section 5.2). Column 1: fully additive ($\omega = 0$). Column 2: lower bound of 95% confidence interval ($\omega = 0.096$). Column 3: upper bound ($\omega = 0.182$). Standard errors clustered at the county and product level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

7 Aggregation and General Equilibrium

The coefficients estimated in Section 6.1 are local, partial equilibrium elasticities, which are distinct from nationwide, general equilibrium elasticities.[20]

Mathematically, there are three interesting economic objects:

$$\frac{\partial \log y_{iz}}{\partial \log AVE_{iz}}|_{\Delta \log y_i} \tag{6}$$

$$\frac{d \log y_{iz}}{d \log AVE_{iz}} \tag{7}$$

$$\frac{d \log Y_z}{d \log AVE_z} \tag{8}$$

Object 6 corresponds to the parameters estimated in Section 6.1. In words, it answers the question of what happens to county-product output when we increase county-product protection by 1%, holding local real incomes fixed. I refer to this parameter as the local, partial equilibrium elasticity. It is local because it refers to county-level rather than nationwide outcomes. It is partial equilibrium because it holds real incomes fixed. For example, real incomes may go up because protection increases local demand which boosts local wages. On the other hand, real incomes can decline as protection increases the prices of consumer goods that are imported, increasing the local price index. The county-time fixed effect controls for the real income effects arising from protection.

Object 7 is the local, general equilibrium elasticity. In words, it answers the question of what happens to county-product output when we increase county-product protection by 1% (inclusive of local real income adjustment, i.e. the general equilibrium effect). The reason why Equation 3 does not estimate this parameter is due to the presence of the county-time fixed effect $\Delta\delta_i$. In theory, one can omit the $\Delta\delta_i$ fixed effect, but then identification is not

[20] See discussion in Chodorow-Reich (2019, 2020) and Guren et al. (2021).

credible as one does not control for local trends common to all products. For example, the Midwest was rapidly growing and being populated in this period, thus this would confound the effect of protection with other trends.

Object 8 is the aggregate, general equilibrium elasticity. This is aggregate as we look at the change in nationwide output when protection increases. This can differ from the local, general equilibrium elasticity for a number of reasons, as discussed in the "missing intercept" literature (Muendler 2017, Chodorow-Reich 2019). Suppose for simplicity there was a positive impact of output protection on growth in the cross section. This is consistent with a null aggregate (or even negative) effect, as locations with more protection crowd out areas with less protection by "stealing" the latter's labor force or capital. This results in a positive local coefficient yet a null aggregate effect. In theory, if I exclude the product-nationwide fixed effect $\Delta\delta_z$ from Equation 3, I can recover the "missing intercept", i.e. estimate the third parameter. However, once again, identification is likely not credible as products are likely to be on differential trends.[21]

Theoretically, the aggregate elasticity may be larger, smaller or equal to the local elasticity. Two of the reasons for this divergence are factor crowd out and revenue effects.[22] I take two approaches: In Section 7.1, I use data from the population census to look at the impact of trade protection on labor reallocation across county-product pairs, thereby giving us a sense of whether there is crowd out or not. Tariffs also potentially generate revenues which can be used by the Federal government to boost growth. In Section 7.2, I look at the revenue effects using a variety of estimates from the literature.

However, while the approaches in Section 7.1 and Section 7.2 rely on fewer assumptions, there are still other factors driving a wedge between the local, partial equilibrium elasticity and the nationwide, general equilibrium elasticity – such as demand spillovers and local income effects. In addition, a model can give us a sense of the quantitative importance of

[21] And as the balance table suggests when we omit $\Delta\delta_z$, protection is correlated with baseline observables, suggesting endogeneity concerns.

[22] Factor crowd out tends to reduce the aggregate effect relative to the local effect, whereas we cannot sign whether the revenue effect makes the aggregate effect larger or smaller than the local effect.

the various channels. I thus turn to a model in Section 7.3.

7.1 Factor Crowd Out and Labor Market Analysis

To be completed

7.2 Revenue Effects

In the earlier sections, I treated tariffs and transportation costs as two sides of the same coin: They both serve to increase the local delivered price of imports. However, there is one critical difference: Tariffs generate revenues, which can be used by the Federal government to boost growth.

In this period, the vast majority of spending was done for military purposes. However, military spending often stimulated industrial activity, most notably textiles, chemicals and firearms (Rosenbloom 2025).

It is ambiguous whether the revenue effects of tariffs make the local effect a lower or upper bound for this nationwide effect. The first thing to determine is how much revenue the tariff increase generates. Due to Laffer Curve effects, tariff increases may actually decrease revenue if imports fall sufficiently. The elasticity of revenue to the tariff can be expressed as (see Appendix E for derivation)

$$\epsilon_t^R = \frac{1+t}{t} + \rho(\epsilon_t^D + 1) - 1 \tag{9}$$

where $\rho = \frac{\partial \log p(1+t)}{\partial \log(1+t)}$ is the passthrough of tariff to the tariff-inclusive price, ϵ_t^D is the price elasticity of import demand, t is the tariff as before and R is revenue. Intuitively,[23] the more elastic import demand is, the less revenue is generated from tariffs, as imports shrink by more and thus the volume of imports fall, reducing the tariff base. On the other hand, lower passthroughs ρ can counteract some of this effect, as foreign exporters absorb some of

[23]This holds for elastic import demands, which are the empirically relevant ones

the tariff increase and thus demand by domestic agents does not fall by as much, dampening the reduction in the tariff base.

Irwin (1998) reports $\epsilon_t^D = -2.6$ for the late 19th century, while I set $t = 24\%$ as this was the average tariff for the manufactured goods in the first period of my sample. Unfortunately, to the best of my knowledge there are no estimates of the passthrough ρ available, thus I use 0.7 and 1. Under complete passthrough, $\epsilon_t^R = 2.6$ and under $\rho = 0.7$, $\epsilon_t^R = 3$, thus we have a relatively elastic response of revenue to the tariff.[24]

The second component is to determine the effects of spending. I turn to estimates of fiscal multipliers provided by the literature. Ramey (2011) reports a range of 0.8-1.5, while Chodorow-Reich's (2019) preferred estimate is 1.7. These are deficit-financed multipliers estimated without monetary policy responses. The absence of monetary policy is appropriate for my setting, as the Federal Reserve was not founded until 1913, more than forty years after the end of my sample. However, the deficit-financing assumption is not, since tariff revenue is tax-financed.

To my knowledge, no estimates of tariff multipliers exist, and estimates of the closest analog — consumption or value-added taxes[25] — are also scarce. I therefore use estimates of income and corporate tax multipliers as proxies, drawing on four estimates that range from -0.5 to -3.1: Romer and Romer (2010), Zidar (2019), Giavazzi and Favero (2012) and Barro and Redlick (2011). For comparability, I convert both the tax and government spending multipliers to elasticities, using $G/Y = 1.6\%$ and $T/Y = 1.2\%$, which are figures from 1859 taken from the Historical Statistics of the United States (2006).

However, two additional adjustments are needed to translate these estimates into a tariff multiplier proxy. The first is that unlike consumption, income or corporate taxes, tariffs are only levied on a fraction of items. Thus we must first multiply the tax multiplier by the share of manufactured imports, which is 23% as reported by Irwin (2001). Second, I multiply by the passthrough parameter. The reason is, under incomplete passthrough, the foreign exporter

[24]Under the income elasticity of -2.6, the revenue maximizing tariff rate (or Laffer rate) is roughly 62.5%.
[25]Tariffs are essentially consumption taxes applied only to goods produced abroad.

partially absorbs the tariff shock, which softens the blow for domestic consumers (echoing the analysis in Weyl and Fabinger 2013), thereby dampening the contractionary effect of the tariff increase.

Therefore, my proxy for the tariff multiplier is:

$$\underbrace{Tax_Mult}_{0.006-0.0357} \times \underbrace{Import_Share}_{0.23} \times \underbrace{Passthrough}_{0.7 \ \& \ 1}$$

Thus, with these two components, we yield the total effect arising from revenues generated from the tariff:

$$Total_Effect = \underbrace{Spending_Mult}_{0.015-0.031} \times \underbrace{Revenue_Elast}_{3 \ \& \ 2.6} -$$

$$\underbrace{Tax_Mult}_{0.006-0.0357} \times \underbrace{Import_Share}_{0.23} \times \underbrace{Passthrough}_{0.7 \ \& \ 1}$$

This yields a range of +0.031 to +0.092. These are elasticities, so they should be interpreted as the percent increase in GDP due to a percent increase in tariffs. From these numbers, the revenue effects from tariffs mildly increase the aggregate effect relative to the cross-sectional effect, but not dramatically so.

7.3 Model

To be completed.

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Appendix A Why Didn't Major Trade Partners Retaliate?

The three major European powers – the United Kingdom, France, and Germany – did not retaliate against the US for their high tariffs.

The United Kingdom, the industrial leader in this period, had committed to free trade in the mid 19th century, and begun eliminating tariffs on all goods except for sin goods such as alcohol and sugar. This had occurred after a bitter political battle over The Corn Laws[26], a set of protectionist measures designed to protect domestic British agrarian producers, which lead to food riots and arguably contributed to the Irish famine. In 1846, the British Prime Minister, Robert Peel, was able to overcome opposition and repealed the Corn Laws. This set into motion a process that ended up reducing tariffs on all goods other than sin goods by 1880. Furthermore, retaliatory measures to high American tariffs, though vigorously debated by British politicians especially during the Civil War period, did not end up passing.

In the mid 19th century, France and Germany begun a process of bilateral trade reductions with partner countries. There is no documented active bilateral treaty between either of these European nations and the US in 1860-1880 (Pahre 2008). Furthermore, there is no evidence that the US was a major consideration of the general trade policy for either of these European countries (i.e. tariffs applied to countries not subject to a specific bilateral treaty). Generally, it appears both these continental countries, unlike the UK, were concerned with trade with other European nations and their colonial empires, not the US.

Appendix B First Order Approximation of $\Delta \log(AVE_{izt})$

$$\Delta \log(AVE_{izt}) \approx d\log(AVE_{izt}) = \frac{1}{AVE_{izt}} d(AVE_{izt}) = \frac{1}{AVE_{izt}} d(t_{zt} + \frac{\tau_{izt}}{p_{zt}})$$

Focusing on the last term:

$$d(\frac{\tau_{izt}}{p_{zt}}) = \frac{1}{p_{zt}^2}(p_{zt} d\tau_{izt} - \tau_{izt} dp_{zt}) = \frac{1}{p_{zt}^2}(p_{zt}\tau_{izt} d\log\tau_{izt} - \tau_{izt} p_{zt} d\log p_{zt}) =$$

$$\frac{\tau_{izt}}{p_{zt}}(d\log\tau_{izt} - d\log p_{zt})$$

Plugging this back to the equation above:

$$d\log(AVE_{izt}) = \frac{1}{AVE_{izt}} d(t_{zt} + \frac{\tau_{izt}}{p_{zt}}(d\log\tau_{izt} - d\log p_{zt}))$$

Note:

$$\frac{1}{AVE_{izt}} d(t_{zt}) = \frac{t_{zt}}{t_{zt} + \frac{\tau_{izt}}{p_{zt}}} d\log t_{zt} = \underbrace{\frac{p_{zt} t_{zt}}{p_{zt} t_{zt} + \tau_{izt}}}_{STS^t_{izt}} d\log t_{zt}$$

[26] The Economist magazine was founded as an anti-Corn Law journal.

Note that $\frac{p_{zt}t_{zt}}{t_{zt}p_{zt}+\tau_{izt}} = STS^t_{izt}$ as in the main text.
Also note:

$$\frac{1}{AVE_{izt}}(\frac{\tau_{izt}}{p_{zt}}(d\log\tau_{izt} - d\log p_{zt})) = \underbrace{\frac{\tau_{izt}}{t_{zt}p_{zt}+\tau_{izt}}}_{STS^\tau_{izt}}(d\log\tau_{izt} - d\log p_{zt})$$

Putting these two together:

$$d\log(AVE_{izt}) = STS^t_{izt}d\log t_{zt} + STS^\tau_{izt}(d\log\tau_{izt} - d\log p_{zt})$$

Appendix C Validation of Distance to Frontier Measure

This appendix provides historical evidence that the patent-based distance to frontier measure captures meaningful technological differences across products.

Cotton textiles (1.31). Despite restrictions on technology transfers, British emigrants such as Samuel Slater — referred to as the "father of American manufactures" (White 1863) — alongside Americans like Francis Cabot Lowell, who memorized British power loom designs during a visit to England, established the New England textile sector. By the early 19th century, technology flowed in both directions across the Atlantic (Jeremy 1981), consistent with near-frontier status.

Iron and steel (2.53). Allen (1979): "In the middle of the nineteenth century Britain was the major supplier of iron and steel to the world market, while Germany and the United States were substantial importers... I shall demonstrate that Britain's mid-century export success was due to its superior technical efficiency." Temin (1964) adds that before the Civil War, American manufacturers produced only small quantities of steel, as they were "unable to master the demanding requirements to create steel through puddling," with imports from Sheffield dominating the domestic market.

Beer (2.87). Pattinson (2014): "While at the beginning of the century, British breweries had led the world in technology and scale of operation, by the end of it the Americans were the ones at the bleeding edge of innovation" — consistent with mid-range distance to frontier in the 1850s.

Glass (3.39). Scoville (1944): "The first glassmen in the United States naturally patterned their methods after those current in European countries, and they continued to do so throughout most of the nineteenth century. Few innovations were of American origin. Technological development lagged appreciably behind that in Belgium, England, France, and Germany."

Paints (7.82). Britain's William Henry Perkin synthesized the first synthetic dye in 1856. Sherwin-Williams did not hire its first chemist until 1884, decades after European firms such as Perkin & Sons (est. 1857), Hoechst (1863), and BASF (1865) had built their operations around industrial chemistry.

Appendix D Proof of Sufficiency of Identification Condition

The IV orthogonality condition is:

$$\mathbb{E}(STS_{iz}^{t}\Delta \log t_z \cdot \Delta e_{iz} | \Delta\delta_i, \Delta\delta_z) = 0$$

I show the following orthogonality condition implies the above:

$$\mathbb{E}(\Delta \log t_z \cdot \Delta e_{iz} | \Delta\delta_i, \Delta\delta_z, STS_{iz}^{t}) = 0$$

Proof (Borusyak and Hull 2023):

By Law of Iterated Expectations,

$$\mathbb{E}(STS_{iz}^{t}\Delta \log t_z \cdot \Delta e_{iz} | \Delta\delta_i, \Delta\delta_z) = \mathbb{E}(\mathbb{E}(STS_{iz}^{t} \cdot \Delta \log t_z \cdot \Delta e_{iz} | STS_{iz}^{t}, \Delta\delta_i, \Delta\delta_z))$$

$$= \mathbb{E}(STS_{iz}^{t} \cdot \mathbb{E}(\Delta \log t_z \cdot \Delta e_{iz} | STS_{iz}^{t}, \Delta\delta_i, \Delta\delta_z))$$

If $\mathbb{E}(\Delta \log t_z \cdot \Delta e_{iz} | STS_{iz}^{t}, \Delta\delta_i, \Delta\delta_z) = 0$, we yield the desired result

Appendix E Elasticity of Revenue to the Tariff

Revenue $R = ptM$, where p is price of imports, t is tariff and M is quantity of imports.

$$\frac{\partial R}{\partial 1+t} = \underbrace{\frac{\partial t}{\partial 1+t}}_{1} pM + \frac{\partial M}{\partial 1+t} tp + tM \frac{\partial p}{\partial 1+t}$$

Elasticity of revenue to tariff is equal to:

$$\epsilon_t^R := \frac{\partial R}{\partial 1+t}\frac{1+t}{ptM} = \frac{pM(1+t)}{ptM} + \frac{\partial M}{\partial 1+t}\frac{tp(1+t)}{ptM} + \frac{\partial p}{\partial 1+t}\frac{tM(1+t)}{ptM}$$

Focusing on the middle term:

$$\frac{\partial M}{\partial 1+t}\frac{tp(1+t)}{ptM} = \frac{\partial M}{\partial 1+t}\frac{1+t}{M} = \frac{\partial \log M}{\partial \log 1+t} = \frac{\partial \log M}{\partial \log p(1+t)}\frac{\partial \log p(1+t)}{\partial \log(1+t)} = \epsilon_t^D \rho$$

where ϵ_d^M is the import elasticity of demand and ρ is the passthrough of tariffs to the (tariff-inclusive) price.

Focusing on the last term:

$$\frac{\partial p}{\partial 1+t}\frac{tM(1+t)}{ptM} = \frac{\partial p}{\partial 1+t}\frac{(1+t)}{p} = \frac{\partial \log p(1+t)}{\partial \log 1+t} - 1$$

where in the second equality we used the result that $\frac{\partial p}{\partial 1+t} = (\frac{\partial p(1+t)}{\partial 1+t} - p)\frac{1}{1+t}$ (Below is derivation of this)

$$\frac{\partial p(1+t)}{\partial(1+t)} = p + (1+t)\frac{\partial p}{\partial(1+t)} \iff \frac{\partial p}{\partial(1+t)} = \frac{1}{1+t}(\frac{\partial p(1+t)}{\partial(1+t)} - p)$$

Putting everything together, we yield Equation 9:

$$\epsilon_t^R = \frac{1+t}{t} + \rho(\epsilon_t^D + 1) - 1$$

Appendix F Formulas Including Specific Tariffs

In the main text, for brevity and ease of exposition I present tariffs as if they are all ad valorem. In the empirics, I take into account whether tariffs are ad valorem or specific. Here, I present the formulas taking into acccount specific tariffs.

The pricing equation with specific tariffs now is:

$$p_{iz} = p_z + t_z^{AV} p_z + t_z^{SP} + \tau_{iz}$$

where t_z^{AV} denotes ad-valorem tariff, and t_z^{SP} denotes specific tariffs.

The ad valorem equivalent of tariffs and tranpsortation cost is:

$$AVE_{iz} := \frac{p_{iz} - p_z}{p_z} = t_z^{AV} + \frac{t_z^{SP}}{p_z} + \frac{\tau_{iz}}{p_z}$$

Finally, the first-order approximation in this case will be:

$$d\log(AVE_{iz}) = STS_{iz}^{t^{AV}} d\log t_z^{AV} + STS_{iz}^{\tau}(d\log\tau_{iz} - d\log p_z) + STS_{iz}^{t^{SP}}(d\log t_z^{SP} - d\log p_z)$$

where $STS_{iz}^{t^{SP}} = \frac{t_z^{SP}}{t_z^{AV} p_z + t_z^{SP} + \tau_{iz}}$

Appendix G Spatial Impact of Tariffs

This appendix seeks to show that the impact of a tariff is larger in coastal areas than interior areas that using two widely used demand systems in trade and spatial.

Appendix G.1 CES Demand

We now examine the impact of trade protection on domestic demand for domestic manufacturing. Consider demand for domestic products in county i for industry z at time s, given by the CES demand system:

$$X_{iizs}^d = p_{iizs}^{1-\sigma} P_{izs}^{\sigma-1} E_{izs} \tag{10}$$

where X_{iizs} is demand for domestic products, p_{iizs} is the domestic price, P_{izs} is the local price index, E_{izs} is total expenditure in county i, and $\sigma > 1$ is the elasticity of substitution.

The local price index aggregates domestic and foreign (imported) varieties:

$$P_{izs} = (p_{iizs}^{1-\sigma} + p_{ifzs}^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{11}$$

where p_{ifzs} is the delivered price of foreign goods to county i.

Taking logs of equation (1):

$$d\log X_{iizs} = (1-\sigma)d\log p_{iizs} + (\sigma-1)d\log P_{izs} + d\log E_{izs} \tag{12}$$

Focus on the price index, the total differential yields:

$$d\log X_{iizs} = (\sigma-1)d\log P_{izs} + ... \tag{13}$$

To compute the change in the price index, differentiate equation (2):

$$(1-\sigma)P_{izs}^{-\sigma}dP_{izs} = (1-\sigma)p_{iizs}^{-\sigma}dp_{iizs} + (1-\sigma)p_{ifzs}^{-\sigma}dp_{ifzs} \tag{14}$$

Dividing by $(1-\sigma)P_{izs}^{-\sigma}$:

$$d\log P_{izs} = \frac{p_{iizs}^{1-\sigma}}{P_{izs}^{1-\sigma}}d\log p_{iizs} + \frac{p_{ifzs}^{1-\sigma}}{P_{izs}^{1-\sigma}}d\log p_{ifzs} \tag{15}$$

Define the import penetration rate as the share of foreign goods in total local consumption:

$$\lambda_{ifzs} = \frac{X_{ifzs}}{X_{ifzs} + X_{iizs}} = \frac{X_{ifzs}}{E_{izs}} \tag{16}$$

In the CES framework, this expenditure share equals:

$$\lambda_{ifzs} = \frac{p_{ifzs}^{1-\sigma}P_{izs}^{\sigma-1}E_{izs}}{E_{izs}} = p_{ifzs}^{1-\sigma}P_{izs}^{\sigma-1} = \frac{p_{ifzs}^{1-\sigma}}{P_{izs}^{1-\sigma}} \tag{17}$$

Similarly, the domestic share is:

$$1 - \lambda_{ifzs} = \frac{p_{iizs}^{1-\sigma}}{P_{izs}^{1-\sigma}} \tag{18}$$

Substituting equations (8) and (9) into equation (6), and using $d\log p_{iizs} = 0$:

$$d\log P_{izs} = \lambda_{ifzs} \cdot d\log p_{ifzs} \tag{19}$$

Combining equations (4) and (10):

$$d\log X_{iizs} = (\sigma-1)\lambda_{ifzs} \cdot d\log p_{ifzs} \tag{20}$$

The delivered price of foreign goods incorporates both the factory-gate price, tariffs, and

transport costs:

$$p_{ifzs} = p_{fzs}(1 + t_{zs}) + \tau_{iz} \tag{21}$$

Taking the differential with $d \log p_{fzs} = 0$ and $d\tau_{iz} = 0$:

$$d \log p_{ifzs} = \frac{p_{fzs}(1 + t_{zs})}{p_{fzs}(1 + t_{zs}) + \tau_{iz}} \cdot d \log(1 + t_{zs}) \tag{22}$$

Therefore:

$$d \log X^d_{iizs} = (\sigma - 1)\lambda_{ifzs} \cdot STS^t_{izs} \cdot d \log(1 + t_{zs}) \tag{23}$$

STS^t_{izs} is higher for low τ_{izs} locations. In addition, s_{izs} tends to be higher for coastal areas. Thus, $\frac{\partial \ln x_{iizs}}{\partial \ln(1+t_{zs})}$ will be a larger number for coastal i than for interior i.

According to appendix C.1 of Borusyak and Hull (2021), the base specification estimates a convex weighted average, where weights are proportional to λ_{ofzs} (locations with higher λ_{ofzs} (higher import shares) are weighed more heavily in these calculations).

Appendix G.2 AIDS System

Here I turn to the AIDS specification adopted by Fajgelbaum and Khandelwal (2016), which allows for non-homotheticities unlike the CES demand case.

The expenditure share on domestic goods in county i, product z, time s is:

$$s^d_{izs} = \alpha_z + \gamma_z \ln\left(\frac{p^f_{izs}}{p^d_{izs}}\right) + \beta_z \ln\left(\frac{E_{izs}}{a(p)}\right) \tag{24}$$

where p^d_{izs} is the domestic price, p^f_{izs} is the delivered foreign price, E_{izs} is total expenditure, $a(p)$ is a price aggregator, γ_z governs substitution, and β_z is the semi-elasticity of the expenditure share with respect to log income.

Demand is given by $x^d_{izs} = s^d_{izs} E_{izs}/p^d_{izs}$, so $\ln x^d_{izs} = \ln s^d_{izs} + \ln E_{izs} - \ln p^d_{izs}$.

Marshallian cross-price elasticity: Differentiate w.r.t. $\ln p^f_{izs}$:

$$\eta^M_{izs} = \frac{1}{s^d_{izs}} \frac{\partial s^d_{izs}}{\partial \ln p^f_{izs}} = \frac{\gamma_z - \beta_z s^f_{izs}}{s^d_{izs}}$$

using the approximation $\frac{\partial \ln a(p)}{\partial \ln p^f_{izs}} \approx s^f_{izs}$ (Stone index).

Following the same logic as the CES case:

$$d \log X^d_{izs} = \eta^M_{izs} \cdot STS^t_{izs} \cdot d \log(1 + t_{zs}) \tag{25}$$

The condition for tariffs to increase domestic demand is $\eta^M_{izs} > 0$, or equivalently $\gamma_z > s^f_{izs} \cdot \beta_z$.

Fajgelbaum and Khandelwal (2016) estimate $\gamma = 0.066$ (Table III) for manufacturing, implying $\gamma_z = \gamma/2 = 0.033$ for the two-good case. They find $\beta_z < 0$ for manufactured goods: $\beta = -0.0031$ for basic metals, $\beta = -0.0028$ for machinery, $\beta = -0.0063$ for textiles (Table

II). Since $\gamma_z > 0$ and $\beta_z < 0$, the condition is always satisfied:

$$\underbrace{\gamma_z}_{>0} > \underbrace{s^f_{izs}}_{\in(0,1)} \cdot \underbrace{\beta_z}_{<0} \tag{26}$$

Thus, with a positive η^M_{izs}, and STS^t_{izs} being higher for coastal counties than interior counties, coastal areas receive a larger demand shock. With these particular parameter values, nonhomotheticities amplify the effect relative to the CES case.

Appendix H Smooth Output Comparative Statics with Ex-Ante R&D Uncertainty

The baseline model in Section 3 generates a smooth innovation response but discrete output predictions: near-frontier firms see output decline under protection, while far-from-frontier firms see output rise. Here I introduce ex-ante uncertainty in R&D costs to generate smooth conditional expectations of output as a function of distance to the frontier.

Setup. The model is identical to Section 3, except the fixed cost of innovation F is not known ex ante. Instead, F is drawn from a uniform distribution $F \sim U[0, \bar{F}]$, where $\bar{F}$ is sufficiently large. The firm observes the realization of F and then decides whether to innovate.

Innovation decision. The firm innovates iff $F < \Delta G(c_{US}, t)$, where ΔG is the change in the gain from innovation due to protection, as defined in Section 3. The probability of innovation is:

$$\Pr(\text{innovate} \mid c_{US}, t) = \frac{\max\{\Delta G(c_{US}, t), 0\}}{\bar{F}}$$

Since ΔG is monotonically increasing in c_{US} (as shown in Section 3), so is the probability of innovation.

Expected output. For a product with cost c_{US}, expected output under protection is:

$$\mathbb{E}[q \mid c_{US}, t] = \Pr(\text{innovate}) \cdot q^{\text{innovate}} + (1 - \Pr(\text{innovate})) \cdot q^{\text{no innovate}}$$

In the near-frontier case ($c_{US} < \gamma$):

$$q^{\text{innovate}} = \frac{1}{1+t}$$
$$q^{\text{no innovate}} = \frac{1}{1+t}$$

Both are the same since the firm is competitive either way under protection. The effect of protection on output operates through the *change* in innovation behavior relative to the no-protection benchmark. Without protection, the firm innovates with probability $\Pr(F < G_0) = G_0/\bar{F}$ and produces $q = 1$ (pricing at the UK's cost of 1). Without innovation, the

firm is uncompetitive and produces $q = 0$. Thus expected output without protection is:

$$\mathbb{E}[q \mid c_{US}, \text{no protection}] = \frac{G_0}{\bar{F}} \cdot 1 = \frac{G_0}{\bar{F}}$$

With protection, the firm always competes (whether or not it innovates), producing $q = 1/(1+t)$:

$$\mathbb{E}[q \mid c_{US}, \text{protection}] = \frac{1}{1+t}$$

The expected change in output due to protection is:

$$\Delta\mathbb{E}[q] = \frac{1}{1+t} - \frac{G_0}{\bar{F}}$$

Since $G_0 = (\gamma - c_{US})/\gamma$ is decreasing in c_{US}, $\Delta\mathbb{E}[q]$ is increasing in c_{US}: firms closer to the frontier have higher G_0 (they were more likely to innovate and produce without protection), so the gain from protection is smaller — or negative.

In the far-from-frontier case ($c_{US} > \gamma$), expected output without protection is zero (the firm cannot compete even with innovation). With protection:

$$\mathbb{E}[q \mid c_{US}, \text{protection}] = \frac{1}{1+t}$$

so $\Delta\mathbb{E}[q] = 1/(1+t) > 0$ for all far-from-frontier firms.

Summary. The expected change in output due to protection is weakly increasing in c_{US}: protection is least beneficial (or most harmful) for near-frontier products and most beneficial for far-from-frontier products.

Appendix I Robustness to Trade Elasticity

Table I13: Robustness: Controlling for Trade Elasticity

	Δ Log Output			
	(1)	(2)	(3)	(4)
	Median	CP (2015)	Shapiro (2016)	GYY (2018)
$\Delta\log(\text{AVE}) \times$ Distance to Frontier	2.650**	1.585***	3.586**	1.995***
	(1.027)	(0.433)	(1.370)	(0.695)
$(\sigma_z - 1) \times \Delta\log(\text{AVE})$	0.851	1.426	0.993*	0.395
	(0.602)	(2.030)	(0.539)	(0.491)
$\Delta\log(\text{AVE})$	−15.009*	−9.242	−23.539*	−9.253
	(7.914)	(6.883)	(11.410)	(6.052)
Observations	833	833	833	833
Input AVE Control	Yes	Yes	Yes	Yes
County-Year FE	Yes	Yes	Yes	Yes
Product-Year FE	Yes	Yes	Yes	Yes
First-stage F-statistic (Kleibergen-Paap)	7.59	3.55	25.62	7.71

Notes: Each column reports IV estimates of specification 3 of the change in log protection on log output, augmented with an interaction between the trade elasticity of substitution $(\sigma_z - 1)$ and the change in log protection. Each column uses a different source for σ_z: Column 1 uses the median across sources, Column 2 uses Caliendo and Parro (2015), Column 3 uses Shapiro (2016), Column 4 uses Giri, Yi, and Yilmazkuday (2021). The distance-to-frontier interaction remains significant across all specifications. Standard errors clustered at the county and product level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.