*How Geography Unified Germany: Endogenous Trade Costs and the Formation of a Customs Union**

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Abstract

We analyze the foundation of the German Zollverein as an example how geography can shape institutional change. We show how the redrawing of the European map at the Congress of Vienna 1815—notably Prussia's control over the Rhineland and Westphalia—affected the incentives for policymakers to cooperate. Our argument comes in three steps. First, we show that the new borders were not endogenous to trade. They were at odds with the strategy of Prussia in 1815, but followed from Britain's intervention at Vienna regarding the Polish-Saxon question. Second, we develop a theoretical framework, where state planners set tariffs on imports and transits to maximize revenue. We show that in a world with transit tariffs a revenue-maximizing state planner faces a trade-off between benefits from cooperation and the cost of loosing geographical advantage. In a third step we calibrate the model combining historical data on tariffs, freight rates, market sizes with GIS data on lowest costs routes under endogenous tariffs. We then run counterfactuals to show how borders affected incentives: if Prussia would have succeeded with her strategy to gain the entire Kingdom of Saxony instead of the western provinces, the Zollverein would not have formed. We conclude that geography can shape institutional change. To put it differently, as a collateral damage to her intervention at Vienna "Britain unified Germany".

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"Man and not nature initiates, but nature in large measure controls"
Halford J. Mackinder, 1904

How does geography matter for long-run development? A common perspective is that geographical features affect economic development indirectly, as they might shape institutions Acemoglu (2008). Notable examples include Easterly and Levine (2003), Dell (2010), or Nunn and Puga (2012), considering features like climate, natural resources or ruggedness of terrain, respectively. Another branch of the literature highlighted the role of geography for trade (Frankel and Romer, 1999; Feyrer, 2009; Pascali, 2017), as more trade could cause growth due to specialization or better access to markets (Redding and Venables, 2004; Redding and Sturm, 2008). But what about geographic

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location as such? Intuitively, a country's relative location to others should matter, as long as the costs of trade and factors flows depend on their routes. The more countries my imports have to pass, the more my trade will depend on the trade policy of my neighbors. Many armed conflicts were related to disputes about trade routes and access to the sea, such as the Atamaca border conflict between Chile and Bolivia, the Suez Crisis in 1956, or the various conflicts between Eritrea and Ethiopia to name a few. In this paper, we show that geographic location can play a major role for development. This is because location can determine a country's bargaining position and its ability to implement institutional change.

In particular, we ask how location and physical trade costs affect political trade costs, such as tariffs and the formation of tariff agreements. We develop a theoretical framework to guide our empirical work. To keep things as simple as possible, we extend a partial equilibrium framework following Irwin (1998) with an arbitrary number revenue maximizing states. In our framework states are not only constrained by domestic demand but also by their location and physical trade costs. For example, some states have direct access to the sea, while others are landlocked. If tariffs can be levied not only on imports but also on transit flows, as it was generally the case until the Barcelona Statute of 1921 (Uprety, 2006, p. 48ff) this can give rise to multiple marginalization, known from the literature on supply chains (Greenhut and Ohta, 1979) and spatial competition (Mathewson and Winter, 1983). We show theoretically, how the location of a state will now affect its ability to raise tariffs, where some states can increase their tariff revenue at the expense of their hinterland. In turn, we show that a customs union can be beneficial for a group of states, because it can solve the problem of multiple marginalization.

A major empirical challenge is that a state's political boundaries (and hence location) do not change very often, and if they do, the change is unlikely to be exogenous to trade or factor flows. In our paper we use the change of the Prussian border after the congress of Vienna in 1815 as a quasi-experient. We use archival evidence to argue that this border change was imposed by Britain against the intention of Prussia. Next, we show that this crucially changed Prussia's location relative to that of other German states and allowed Prussia to force the smaller German states into a customs union, against stiff political resistance. With counterfactual borders after 1815 the Zollverein would have been less likely to emerge. In this way, Britain, unintentionally, helped to unify Germany.

Our historical case study, the formation of the Zollverein, is relevant in its own right, because it was often considered as a step towards the economic and political unification of Germany during the 19^{th} century, which in turn fundamentally changed the European balance of power (Simms, 2013). It is remarkable that several small sovereign states such as Bavaria or Saxony, which had just escaped their elimination during the Napoleonic wars, started to give up parts of their sovereignty little more than a decade later to cooperate under Prussian leadership. We argue that our theory helps to explain the rise of Prussia to become the dominating power within Germany. With the change of borders after 1815 Prussia held sway over both large continental transport systems before the age of the railway - most of the rivers Elbe in the East of Germany and the Rhine in the West feeding into the North Sea. After Prussia formed a preliminary union with Hesse-Darmstadt in 1828, and again after the Belgian revolution in 1830, this pressure increased further and by 1835 all German states placed between the two Prussian territories or to the South of them had joined into the Zollverein. Note that we do not claim here that the formation of the German Empire in 1871 was a foregone conclusion after 1834, only that it made the formation of such an Empire under Prussian leadership more likely. There is a growing body of evidence that the Zollverein helped to deepen economic, administrative and political integration between the German states Hahn and Kreutzmann (2012), Keller and Shiue (2014).

Our theoretical model provides a mechanism for how location can shape institutions. Specifically, it can explain the formation of the Zollverein and the sequence of decisions that led to it. But in the model with many states, the selected equilibrium is not pinned down by fundamentals. Instead, the equilibrium will depend on the sequence of decisions. Therefore, our empirical strategy comes in two parts. First, we provide reduced form estimations showing that a state joined the Zollverein earlier if its imports had to cross Prussian territory as transit. We capture transit flows using GIS data on historical infrastructure and calculate (physical) least cost paths from the Atlantic economy (London) to any German state in our sample. This is motivated by the fact that more than 50% of tariff

revenues around the time of the formation of the Zollverein stemmed from tariffs on colonial goods such as sugar and tobacco (Onishi, 1973). These goods would arrive in Germany typically from London via one of the major continental ports (Hamburg, Rotterdam or else) and further crossing the territories of other states. Variation in transits flows via Prussia alone account for 60% of the variation in access dates to the Zollverein, which is robust to the inclusion of many other variables such as distance to the sea, cultural distance to Prussia, or status as constitutional monarchy. In a second step we use our model to simulate the chain of events that led to the formation of the Zollverein. The reduced form evidence neglected the fact that according to our model, the decision of a state to join a customs union is not independent from the decision of others. Related to this, the least cost paths, and hence transits depend not only on physical transport costs but also on tariffs, which in turn are endogenous. To deal with this, we use historical and GIS data on territories, infrastructure, population and estimated demand elasticities from the literature and to simulate our model. This gives us endogenous tariffs, least cost paths and revenues for given state boundaries and customs unions. We use this to analyze how tariff revenues change in response to a change in state boundaries and customs union membership. We show that the chain of events in terms of border change, and changes in customs union membership are well captured by our simulation. We also provide a thought experiment with counterfactual borders. We compare the factual borders of Prussia after 1815 (with two separate territories in the East and West of Germany and small gains from the northern part of Saxony) to a counterfactual with historical validity: a Prussian state in alternative borders according to the original plan of count Hardenberg, Prussia's negotiator at the congress of Vienna. According to this plan, a new Prussian state would have consisted of Prussia's eastern territories and the entire former Kingdom of Saxony, while the latter would have formed a new sovereign state on the territory of Westphalia and the Rhineland. We show that with the factual borders of 1815, several German states had an incentive to join a customs union with Prussia, and increasingly so the more had joined. The Belgian revolution in 1830 increased these incentives again, because it led to a reduction of dutch tariffs on the Rhine. Instead, with a counterfactual Rhineland state, the situation would have been very different. The same states would have had little incentive to form a customs union with Prussia, while in turn a counterfactual Rhineland state would have fared best independently. A customs union that would have encompassed both the eastern and western parts of Germany would not have formed. As recently shown by Keller and Shiue (2014), the formation of the Zollverein had very large effects on the integration of markets. It prepared the monetary unification of German states within the boundaries of the Zollverein Holtfrerich (1993) and helped to pave the way to Germany's political unification in 1871 under the leadership of Prussia, if only by fostering market integration and the growth of Prussia's industry (Wehler, 1989, pp. 125ff).

Our paper is related to several strands in the literature, notably on trade costs and trade agreements, economic geography, nation building, persistence in economic development and not at least the historical literature on the formation of the Zollverein. To start with, a recent literature has improved our understanding of trade costs (Anderson and van Wincoop, 2003, 2004). Important new contributions have considered physical trade costs, notably Allen and Arkolakis (2014) and Fajgelbaum and Schaal (2017). Both show in a general equilibrium framework how geography gives rise to a topography of physical trade costs. However, both abstract from political trade costs, because they assume a single central planner. Our paper explores how physical trade costs can shape political trade costs. Related to this is the large literature on trade agreements, including Ossa (2011, 2012) and Antràs and Staiger (2012). These papers argue that trade agreements can reduce negative externalities from tariffs due to profit-shifting, firm-relocation or trade-volume externalities, beyond the older arguments based on terms of trade effects. For example, Antràs and Staiger (2012) discuss the implications of offshoring and resulting lock-in effects for buyers and sellers for trade policy. In their case, the fragmentation of production and trade into upstream and downstream firms gives rise to a hold-up problem that can be remedied by trade agreements. Instead, we abstract from fragmented production but focus on the relative geographical position of states and show how this affects incentives to coordinate tariff policy. Our setting also pioneers a more complex understanding of geography than what is typically considered. While the role of geographical distance and market access have been fairly well understood since the theoretical advances on the gravity model (Eaton and Kortum, 2002; Anderson and van Wincoop, 2003; Redding and Venables, 2004), the routing of trade has been typically ignored in the recent literature. In contrast, routing plays an increasing role in the literature on operational research and logistics in the

face of increasingly fragmented production processes (e.g. the survey by Nagy and Salhi (2007) on the so called location-routing-problem). In our framework, trade routes are crucial for trade policy.

The literature on economic geography in the wake of Krugman (1991) has analyzed how 'first nature geography' such as access to the sea or climate can affect 'second nature geography' such as the emergence of economic agglomerations and patterns of core and periphery. But these models remained highly stylized and were of limited use for empirical research. The more recent application of quantitative models of international trade (notably Eaton and Kortum (2002)) to the study of economic geography allowed to derive new hypotheses on the spatial distribution of economic activity and directly test for them (e.g. Donaldson (2016), Ahlfeldt et al. (2015); see the survey by Redding and Rossi-Hansberg (2016). In a recent study Michaels and Rauch (2013) show how network effects mattered for city dynamics in the very long-run. German history after 1815 provides us with a quasi-experiment on a similar type of network effects for sovereign states rather than individual cities. To show to this, we derive a theoretical model that can be calibrated to historical data and simulated to assess its explanatory power. Moreover, trade costs are typically treated as exogenous in the recent literature on economic geography. In our framework, exogenous physical trade costs lead to much larger endogenous political trade costs.

Next, our paper is related to the recent literature on nation building and endogenous political borders in the wake of Alesina and Spolaore (1997) and Bolton and Roland (1997). Both papers argue that there is a basic trade-off between the benefits of larger jurisdictions and the costs of that size. Alesina and Spolaore (1997) show that the benefits from economies of scale and scope of larger jurisdictions have to be balanced against the political costs of heterogeneity. Bolton and Roland (1997) also consider the benefits from economies of scale and weigh them against the loss of control on political decisions at the local level. An emerging literature analyzes the factors that changed these trade-offs in the long-run, notably military rivalry (Aghion et al., 2012) and war-related institutional change Acemoglu et al. (2011). We add to this literature by showing how geographical constraints can affect the cooperation between sovereign states and induce long-run institutional change.

Another set of studies on which we draw and to which we contribute is on the role of history for economic development. In his survey on the topic Nunn (2009) stresses the prominent role of geography for economic outcomes via its impact on past events. As argued by Engerman and Sokoloff (1997s, 2002), differences in soil quality and climate may have shaped the incentives of elites to foster education systems. Related to this is the argument that variation in the suitability of land for growing potatoes affected the growth of population and cities, with persistent effects until today Nunn and Qian (2011). We extend a long-standing argument that access to waterways and relative geographic position affected the incentives to cooperate between states and their ability to impose certain policies on each other (Mahan (1890); Mackinder (1919) and more recently Simms (2013) and Kaplan (2012)). Our paper is therefore related to Redding et al. (2011) and Bleakley and Lin (2012) on geographical lock-in and again Michaels and Rauch (2013) on the long-run effects of geographical fundamentals for the dynamics of urban networks.

Finally, several authors have tried to explain the emergence of customs unions and in particular that of the Prussian Zollverein. In his work on the economics of customs unions Viner (1950) already considered the Zollverein to be the "pioneer and by far the most important customs union". There is a small but prominent historical literature on the formation of the Zollverein. In his seminal work on the Zollverein, Dumke (1976) considered several possible motives for joining the Zollverein. He argued that by joining the Zollverein German states could hope to benefit from economies of scale in the collection of tariff revenues, benefit from a larger market for industrial products (i.e. Smithian growth), while simultaneously staying in control over these revenues. Dumke (1976) provides several pieces of descriptive evidence to support his argument but he cannot directly test it. Voth (2001) surveyed the existing literature to challenge the common view that the Zollverein was important for the economic or political development of Germany, asking for more and better evidence. More recently Keller and Shiue (2014) have estimated the effect of the Zollverein on market integration, taking into account that the incentives to join were endogenous to ex ante trade, similar to Baier and Bergstrand (2007). They use a state's average distance to the coast relative to average distance to the coast of non-member states as an instrument to control for the endogeneity of

Zollverein membership and find that joining the Zollverein had a substantial causal effect on the integration of markets. In an insightful study Ploeckl (2010) explored the negotiations over Zollverein membership and argued that Prussia could act as an agenda setter in a bargaining game. In particular he provided descriptive evidence for the hypothesis that Prussia negotiated sequentially with German states over their membership in order to maximize coalition externalizes on states still outside the union. Our contribution to this literature is twofold. First, we provide a new theoretical framework that can be seen as a synthesis of earlier ideas and matters beyond the specific historical context of the Zollverein. Second, we are the first to trace the specific formation of the Zollverein back to the exogenous change in political borders at the congress of Vienna in 1815.

We proceed in this paper as follows. In section a we introduce our historical example of the formation of the German Zollverein. In section b we present our theoretical framework. We start with a very basic framework on the role of geography for a revenue maximizing state that is step by step generalized. In section **??** we provide reduced form evidence in support of our theory. In section **??** we show how we used historical and GIS data to calibrate and simulate the model. Section e. contains our main results on the fit and explanatory power of the model. We show how the model can capture the sequence of events that led to the formation of the Zollverein. We also show that under counterfactual borders - absent the British intervention - the Zollverein would not have formed. In section f we summarize the paper and conclude.

A. From the Congress of Vienna to the Zollverein

Our historical case study on the role of location for institutional change is the formation of the Zollverein in 19th century Germany. First, we will outline why we consider the decision on Prussia's borders at the Congress of Vienna to be exogenous to economic rationale, notably to trade. Second, we will explain why trade costs should be treated as endogenous for the period under consideration. This includes a discussion on the role of tariffs and transit trade for government revenues. Third, we will discuss the role of the Rhine. Forth, we will discuss some of the dynamics that led up to the formation of the Zollverein, including failed attempts to form alternative customs unions. We will later use our theoretical framework to replicate some of these dynamics.

1. Great Power Politics at the Congress of Vienna

At the end of the Napoleonic wars 1792–1815 only Russia and Great Britain had emerged as major military powers. Habsburg, Prussia and the defeated France attempted to consolidate their position at the expense of the many smaller states that had survived the recent wars, notably the former allies of Napoleon such as Saxony or Poland. A central object of the negotiations at Vienna was the redrawing of the European map, especially the so-called Polish-Saxon question. Overall, the negotiations were dominated by military-strategic considerations between the two great powers. By hindsight, we know from the correspondence between the major negotiators at Vienna that economic aspects and the position of Prussia were both of minor importance to the outcome of the congress. Alexander I. of Russia aimed for a double-monarchy of Russia and Poland. This expansion of Russia to the West met stiff opposition from Britain and Habsburg. Britain's ambassador Castlereagh warned his Prime Minister that this "would have the colour of an attempt to revive the system we all united to destroy, namely one colossal military Power holding two powerful States in a species of dependence and subjection, and through them making her influence in the remotest parts of Europe" (Müller, 1986).

Prussia's chancellor Hardenberg, who led the Prussian delegation at Vienna, pursued predominantly military-strategic aims[1]: In order to ease the defense of its territory and capital, he intended to annex the entire Kingdom of Saxony (Clark, 2007, p. 389). Castlereagh consented under the condition that Prussia would support the British

[1]This military-strategic argument was already developed by Friedrich II (1712–1786), probably during the Seven Years War (1756–1763). In his notes "par droit de bienséance", he outlines the territory of Saxony as key for the defense of Berlin (cited after (Mittenzwei, 1985, p. 209).

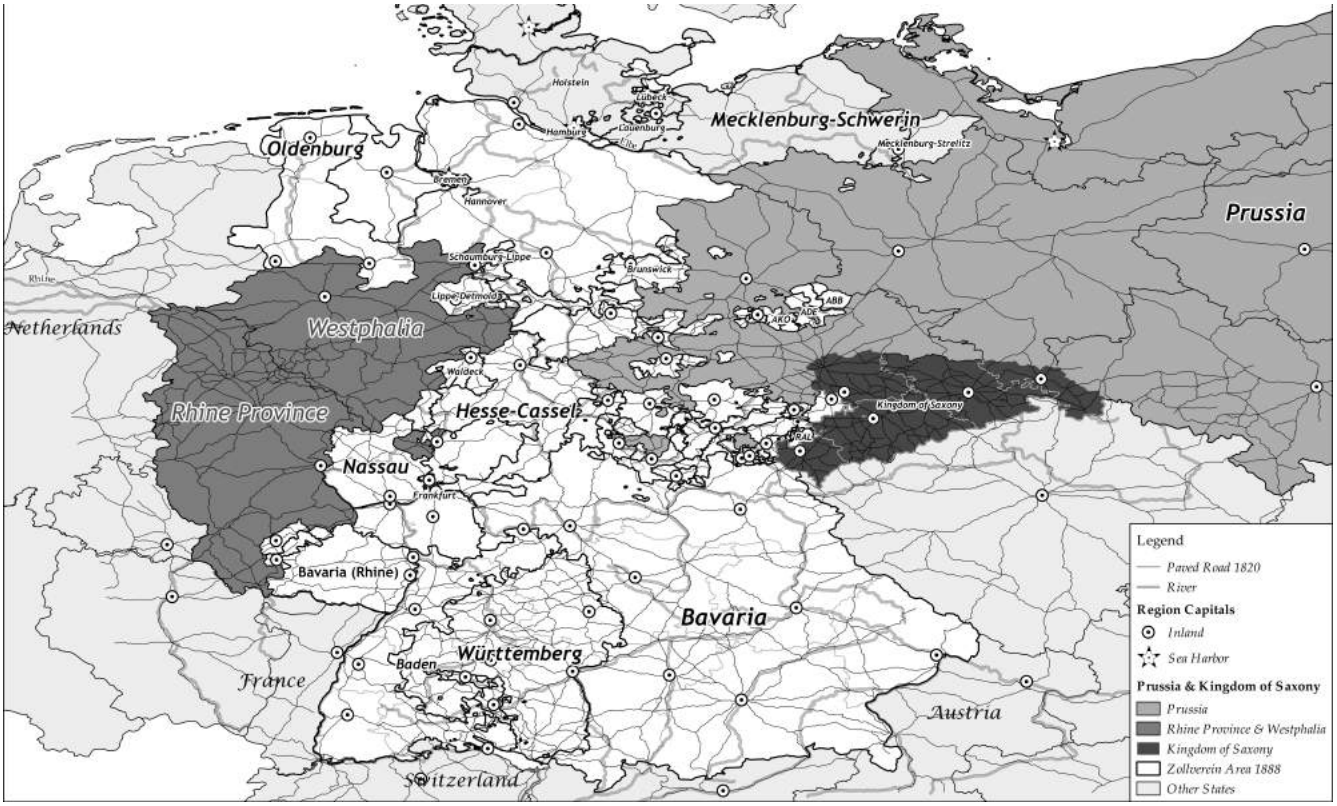

Figure 1: *Map of the German lands after the Congress of Vienna including the rivers and the 1820 road network. Hesse-Darmstadt is the state just South of Hesse-Cassel.*[4]

position in the Polish Question[2], so does Metternich[3]. Under the leadership of Castlereagh, the three formed an informal coalition against Russia. However, Prussia left this alliance under pressure of Alexander, because Russian troops had occupied Saxony (Burg, 1993, p. 12ff.). In a desperate move to secure the Saxon territory for Prussia, Hardenberg offered in late 1814 to relocate the entire court of Saxony to the Rhine including "a city pleasantly situated at the Rhine, suitable for a residence" for the Saxon king (Müller, 1986, p. 262). As this offer was rejected, Hardenberg, seeing the Prussian position decaying between the Tsar's plans and 'British interest', threatened with war. The response was a defense alliance between Great Britain, Austria and France against Prussia and Russia with put Europe at the brink of a new war in late 1814 (Burg, 1993, p. 27).

Ultimately, the Congress ended as a big compromise, shaped very much by the attempt of Great Britain to contain Russia's westward expansion. Poland was divided (again) between Russia ('Congress Poland'), Prussia and Austria. Also, Saxony was divided in two parts. The Kingdom of Saxony was shrunk to its southern part, while the northern part formed the new Prussian province of Saxony. As compensation, Prussia was also given the Rhineland and Westphalia in the West, to become the "warden of the German gate against France"(Clapham, 1921, p. 98). Figure 1 shows the map of Germany after 1815.

As Clark (2007, p. 389) concludes, "Berlin failed to get what it wanted and got what it did not want.[...] The creation of a large Western wedge along the river Rhine was a British, not a Prussian, idea.". The German Bund was established as a loose federation of German countries under the joint leadership of Habsburg and Prussia (Hahn, 1982, p. 127).

[2]Note from Castlereagh to Hardenberg, October 11th 1814 (Müller, 1986, p. 211).

[3]In his note, Metternich consents as long as Habsburg would keep its influence within Germany. Note to Hardenberg, October, 22nd (Müller, 1986, p. 214 f.).

2. Transit Tariff, and Structure of Trade

While the Congress of Vienna settled the large geopolitical issues, most German states still faced existential threats after 1815. To start with, after years of war and territorial changes back and forth and indeed after financial difficulties inherited from the pre-Napoleonic era, state finances were out of control Borchard (1968). What was needed was fundamental administrative reform and new sources for revenue. Prussia, pressed very hard after the defeat in 1806, had started a series of reforms, including a fundamental reorganization of the administration, agrarian reforms, changes in the educational system and some first attempts to reform taxation. But still in 1821, six years after the war, the ratio of Prussia's government debt to total state income stayed above 400 percent (Mieck, 1992, p. 124). A major step towards a new financial system was Prussia's tariff law of 1818, which abolished all internal tariffs and established one common tariff along the external border following the examples of France and Britain Onishi (1973). This and the introduction of a class-wise income tax system helped to consolidate Prussia's state finances in the following decades and put other states in Germany under pressure to react. The revenue from tariffs and taxes on foreign goods increased between 1819 and 1831 from around 6 mio. Reichsthaler (rtl) to above 16 mio rtl, their share in overall revenue from indirect taxes increased from 35 percent in 1819 to 69 percent in 1831 Onishi (1973). However, the main challenge from a Prussian perspective was to connect the two separate territories in East and West for both administrative and strategic reasons. Here Prussia faced resistance from smaller states who feared to loose their independence. It turned out that the main asset of Prussia in this was her geographic position for trade policy.

Trade policy was at center stage for government revenue at the time, not only due to tariff income but also due to the indirect effect of market access on industrial growth and tax revenue. In Central Europe, trade flows had to pass often a dozen of tariff borders even on relatively short distances. This was considered by many contemporaries to be a main disadvantage compared to politically unified territories such as France or the United Kingdom. As shown in the theoretical section the fact that tariffs were usually also levied on transit trade until the Barcelona Statute of 1921 (Uprety, 2006, p. 48ff) had far reaching implications for tariff policy at large. Prussia's tariff law of 1818 forced traders to detour the large territory, or accept the tollage. As Clapham puts it, "The analogy between the King of Prussia and some robber baron of the middle ages could not but occur to the least learned pamphleeter." (Clapham, 1921, p. 99). In turn, for states located on the few avaialble detour routes, such as the state of Hesse-Cassel, this was a large source of income.

Traders were often willing to incur transit tariffs, because they lacked alternatives. In the early 19^{th} century, these alternatives were mostly determined by geography. Transport on water was much cheaper than transport over land. According to Sombart (1902), the average freight cost per tonkilometer during early 19th century Germany on river was between 0.6 and 1.5 percent of the average freight cost on country roads. The main instrument to improve the transport infrastructure apart from building canals was to construct paved roads with a fully developed drainage system ("Chausseen") that made them usable even during bad weather conditions. This could bring down average freight cost per tonkilometer to 25 percent of that on standard roads. But road construction was expensive and time-consuming, hence no option in the short-run. Railroad construction started in Germany only after 1835, most lines were built in the two decades after 1848.

The multitude of tariff barriers also had consequences for the type of goods that could be traded over longer distances. In 1829, almost 80 percent of the value in exports from Amsterdam upriver originated from only two goods: coffee, and sugar (Kutz, 1974, p. 341). Wine was another important item. These three goods, sugar, coffee, and wine could be traded in spite of the high trade costs, because their import demand was highly inelastic. First, they faced only limited competition from local substitutes. Sugar beet production on a significant scale started only in the late 1830s in Germany, and required initially government support. Around 1840, domestic production of wine and spirits accounted only for a seventh of demand in the Zollverein (Dieterici, 1846). Coffee, unlike tobacco, which accounted for half of domestic demand (Dieterici, 1846), could not be grown in Germany. Second, all these goods are 'drug-alike', which suggests that demand should respond relatively little to variation in prices. What Ferguson noted for the British Empire was similarly true for the German Zollverein: "the empire, it might be said,

was built on a huge sugar, caffeine and nicotine rush – a rush nearly everyone could experience." (Ferguson, 2002). According to Onishi (1973) these three goods alone accounted for more than half of Prussia's revenues from tariffs in the 1820s, which increased to around 80 percent in 1831.

3. The Role of the Rhine

Navigable rivers attracted the bulk of all trade flows due to their much lower physical transport cost per ton-kilometer. However, river banks were historically fragmented. Adam Smith noted that "the navigation of the Danube is of very little use to the different states [...], in comparison of what it would be if any of them possessed the whole of its course till it falls into the Black Sea" (Smith, 1776, p. 19). This is especially true when states maximize revenues. One single state can harm all others' revenues, and credible commitment makes everyone better off—a classical prisoner's dilemma[5]. Wilson (2016, p. 469) views the inability to coordinate Rhine states as a major failure of the Holy Roman Empire. Running through over 30 toll stations, much of the Rhine trade was eventually rerouted overland, notably through the Hessian hills.

Napoleon's unification of several Rhine states into Westphalia and the Rhineland was a first step to address the problem of fragmentation. Soon after 1815 Prussia had gained control over much of the Rhine, it was realized that the Rhine would be a substantial source of revenue, if the tariff levels could be lowered and unified. Hans Count of Bülow, minister of finance, noted in 1817 that "The long coast, the location of the Rhenish and Westphalian provinces between France, the Netherlands and Germany, make this country very suitable for transito. The greater the freedom, the more trade one will be able to seize."[6]. This outlines a central motive of Prussia—exploiting the geographic position to raise tariff revenues *induced by, and not in spite of* trade liberalization. Central to this is an understanding that multiple taxation reduces overall revenue, because of multiple marginalization. However, still after 1815 trade on the Rhine was subject to a multitude of political trade costs such as tariffs and duties payable at Rotterdam or staple rights and the requirement to use specific shipping companies for parts of the voyage (Spaulding, 2011). One event that contributed to a further reduction in tariff fragmentation along the Rhine was the Belgian revolution in 1830/31. The (prospective) independence of Belgium from the Netherlands and the rise of Antwerp as a competitor to Rotterdam limited the bargaining power of the Netherlands and helped the negotiations between the various riparian states to reduce tariffs along the Rhine. As a consequence, after 1831 more traders used the Rhine and less trade was routed over land through the Hessian states, notably through Hesse-Cassel (Hahn, 1984, p. 60).

4. Failed Unions and Agreements

The high levels of debt of small German states called for immediate action after the Napoleonic Wars. The main source of new revenue had to be taxation, given that the revenue from state monopolies and state-owned farms or factories could not be easily increased at the time (Ullmann, 2005, p. 34). However, smaller states must have feared that by joining the Prussian Customs Union, they gain revenue at the risk of giving up sovereignty towards Prussia. The option to form a free trade area rather than a customs union, which would have allowed states to set their external tariff independently, was not viable at the time, due to difficulties to implement a rule of origin in the fragmented German state system (Ploeckl, 2010). The perceived solution of this problem seemed to be a customs union without Prussia. And indeed, the 1820s witnessed several attempts to form such customs unions. Bavaria, Württemberg, Baden, and two Hessian states signed already in 1820 a preliminary agreement to take up negotiations on a customs union excluding Prussia and Austria alike. However, the negotiations did not succeed, mostly because it was unlikely to pay: the interests of Baden and Hesse-Darmstadt diverged too far from those of Bavaria and

[5]See also Bagwell and Staiger (1999). An interesting note is that their theoretical debate on optimal tariffs is dependent on the assumption of either a small or a large country setting tariffs, in terms of whether the tariffs will shift world prices. In our framework, even the smallest state can affect prices in other states, depending of it's geographical position.

[6]cited after (Dieterici, 1846, p. 64); own translation.

Württemberg. Calls upon Austria in the early 1820's to lead a tariff union, prominently put forward by Friedrich List, were turned down, as Austrian trade was mostly directed in the flowing direction of the Danube (Hahn, 1984, p. 31). The only tangible result was the formation of a customs union between Bavaria and Württemberg in January 1828.

In the meantime, the small state of Hesse-Darmstadt had started to turn to Prussia, which should change the situation fundamentally. A look at the maps suggests why. The two Prussian territories in the East and in the West were separated by the two states of Hesse-Darmstadt and Hesse-Cassel. The financial situation of Hesse-Darmstadt was considered to be the worst among all German states after 1815. The small state itself was divided into two territories and economically more dependent than others on the neighboring Rhineland, now under Prussian control. A first attempt of Hesse-Darmstadt in 1825 was rejected by Prussia on the grounds that only a simultaneous agreement with both Hessian states would be attractive for the Prussian side. But Hesse-Cassel was much less pressed and actually benefited from trade diverted away from the Rhine. In 1827 Prussian negotiators started to realize that the desperation of Hesse-Darmstadt was a strategic opportunity. In the negotiations during that year, Prussia was eager to be as benevolent as possible towards Hesse-Darmstadt. In February 1828 the two states formed a customs union between two equal sovereign partners, where in exchange to Hesse-Darmstadt's agreement to adopt the Prussia customs law of 1818, Prussia treated the small state as its equal such that all changes in tariff policy would have to be agreed unanimously (Hahn, 1984, p. 46). This helped increasing the tariff revenue of Hesse-Darmstadt, but it hardly contributed to higher revenues for Prussia. However, the strategic value of this can be seen in the externalities of this Prusso-Hessian customs union on other states (Ploeckl, 2010). As this was rightly considered as a first step of Prussia to connect its two territories, the reactions across German states as well as in Vienna, London and Paris were quick and harsh. In September 1828, Hanover (still in personal union with the United Kingdom), Saxony, Hesse-Cassel, Nassau, the free city of Frankfurt, and the Thuringian States signed a contract—on not signing contracts with anybody else (Hahn, 1984, p. 50). Also, the governments of Bavaria and Württemberg tried to contain a further expansion of Prussian influence, because they realized their growing dependency on Prussian tariff policy. However, already in late 1828 they gave up. The Bavarian government started to negotiate an agreement and eventual merger between the customs unions of Bavaria-Württemberg and Prussia-Hesse-Darmstadt. The reduction of tariffs on the Rhine in the wake of the Belgian revolution helped to convince the government of Hesse-Cassel to join the union of Prussia and Hesse-Darmstadt, which completed the territorial link between the two parts of Prussia in August 1831. This move put the Southern states under further pressure to join the Prussian customs union. As this was a breach of the treaty of September 1828, Habsburg in an Alliance with England attempted to sue Hesse-Cassel over this on the courts of the German Bund in a last attempt to stop the Prussian victory. But economic incentives proved to be stronger. In autumn 1833 the Southern Customs Union was merged with the Prusso-Hessian customs union and enlarged by others, including Saxony and the Thuringian states. Baden followed in 1835, Brunswick in 1841 and even Hanover joined in 1851, Oldenburg a year later. Only states with direct access to the sea stayed out before the formation of the German Empire in 1871.

Habsburg's chancellor Metternich always considered the Zollverein as a tool to establish Prussia's dominance in Germany and tried to prevent its formation (Mieck, 1992, p. 163). By hindsight, he was right. While we do not claim that the Zollverein determined Prussia's way to become hegemon within Germany, it was clearly instrumental in this process. The Zollverein helped Prussia to consolidate its new territory and to use the benefits from the industrializing regions in the West for its rise as a political and military power. In the next sections we show theoretically and empirically how geographic position and transits can explain sshape institutional change. Specifically, we can explain many of these historical facts: how the customs union between Bavaria and Württemberg mattered for Prussia, why the customs union between Prussia and Hesse-Darmstadt increased pressure on the remaining states in Central and Southern Germany, why this pressure was more limited for states closer to the coast. Crucially, the model also highlights that a different outcome of the Congress of Vienna, one without British intervention, would have likely prevented the formation of the Zollverein altogether.

[6] Abbreviations: ABB: Anhalt-Bernburg, ADE: Anhalt-Dessau, AKO: Anhalt-Köthen, HHE: Hohenzollern-Hechingen, HHO: Hess-Homburg, HSI: Hohenzollern-Sigmaringen, REB: Reuß-Ebersdorf, RGA: Reuß-Gera, RLS: Reuß-Lobenstein, RSC: Reuß-Schleiz, SGA: Saxony-Gotha-

B. THEORETICAL FRAMEWORK

The theoretical framework explains the role of geography for revenue-maximizing countries, and their benefits from cooperation. We start off with the framework by Irwin (1998) on tariffs and revenues. Free on board (f.o.b.) prices are exogenous, such that tariffs[7] are paid for by consumers, demand is linear and reacts to the tariff as part of the price.

Irwin (1998), as most common literature, limits his analysis on two countries where one country is the producer and the second the consumer. We extend this and assume that all countries face a given world supply, where one country's imports are its neighbour's transits. This induces room for cooperation in customs unions. In our model, all transit countries face multiple trade-offs in their attempt to maximize their tariff revenues, and their decisions depend on geography. We introduce the concept of multiple marginalization known from industrial organization (see Church and Ware (2000)) to the optimal tariff literature and the foundation of customs unions. Multiple marginalization occurs when a product is manufactured by a revenue-maximizing producer using raw-material (called upstream) from a revenue-maximizing supplier (called downstream). In our context, if a state has good access to the sea and hence to colonial goods, it will behave like an upstream monopolist, while a state that has access to these goods only via third states will behave like a downstream monopolist. Decisions to join a customs union can be analyzed in analogy to decisions about mergers & acquisitions. Note that for this reason, upstream and downstream are not used here according to their geographical meaning.

We treat physical trade costs as exogenous, and concentrate on the effect of political trade costs, tariffs [8]. Migration occurred mostly towards Prussia and Northern German states, which would only strengthen our argument. Hence, we assume population to be constant. Moreover, we simplify the analysis assuming that states cannot discriminate between imports and transits and hence set only one tariff rate for both. If states could discriminate tariffs, this would further improve the position of upstream states and only strengthen our argument.

1. One Country

Consider a world of many small countries facing given world supply. With respect to the small geographic scope of our analysis, assume similar preferences, uniform income distribution, and equal price elasticity of demand across countries. Consider a representative good that does not have any domestic substitute (historical examples would be coffee or sugar). Demand for this imported good $M_i \geq 0$ in any country i is linear and given by

$$M_i = D_i - ap_i \tag{1}$$

$D_i > 0$ stands for the size of the market in i, and $a > 0$ stands for the elasticity of demand w.r.t. price at location i, $p_i > 0$. Markets are perfectly competitive. Transport of the good from w to i comes with positive per-unit cost $cost_{wi}$.

Altenburg, SHH: Saxony-Hildburghausen, SCS: Saxony-Coburgurg–Saalfeld, SRU: Schwarzburg-Rudolstadt, SSO: Schwarzburg-Sondershausen, SWE: Saxony-Weimar-Eisenach.

[7] Think of any costs that a country can set and adds to the price of the good. The framework captures not only costs de jure codified as tariffs. Transit trade was subject to all kinds of taxes, tolls, and fees, which countries gained revenue from. Larger countries, such as Prussia (Onishi, 1973) or Bavaria (Schlögl, 2002, p. 139), aimed at simplifying this structures. Traders will account for non-monetary political costs of transport, such as staple rights, and include them into the price of the good. An example here is Hamburg. While de jure tariffs are absent Dumke (1976), harbor fees and a variety rights induce costs to traders, and therefore have a monetary equivalent.

[8] First, before the emergence of the railway, due to the vast technological advantage of sea and river transport, sea harbors and river access were the most important geographic advantage. This implies that strategic building of infrastructure before the 1840s as described in Thimme (1931), had only have minor effects. Recent research, for example Fajgelbaum and Schaal (2017), has proposed general equilibrium frameworks with endogenous physical transport costs, which could be an interesting extension for future work. Second, the existence of transit tariffs and therefore manyfold taxation of goods within 19th century Germany was evidently more important than even the high physical transport costs of that time Onishi (1973)

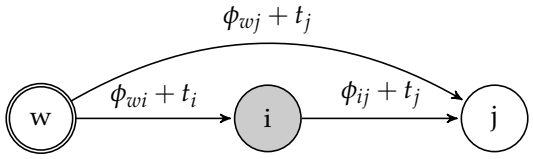

Figure 2: *Two countries and the world. If the direct edge from w to j is more costly than via i, i gains potential revenue. If wj would be infinitely expensive, j would be an enclave of i.*

These costs are specific (non-iceberg). Traders are fully informed and cost-minimizing. Assume there exists a route r which bears the minimum costs out of all routes W_{wi} connecting w and i, which traders would use exclusively. This yields

$$p_i = p_w + \min_{r \in W_{wi}} (cost_r). \tag{2}$$

There are two types of transport costs between w and any i: Physical transport costs and political costs (tariffs). Physical costs $\phi > 0$, the costs of actually moving one unit of good, are exogenous and always positive. They need not to be symmetric, so that $\phi_{wi} \not\equiv \phi_{iw}$. Political transport costs t_i, which are costs associated with the crossing of any border of country i are endogenous to the framework, and will be in focus later. To this point, just assume they are also specific, per-unit. The list of countries on a route is given by $r = (r_1, .., r_{|r|})$. Assume that countries are just points in space (with no area), and that these points are connected via different routes. For any two countries i and j, the costs of any route r in W_{ij} is the sum of all physical and political costs,

$$r \in W_{ij} \Rightarrow r_1 = i \text{ and } r_{|r|} = j \qquad cost_r = \sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} + t_{r_n} \right). \tag{3}$$

while $r_1 = i$ and $r_{|r|}$ is always j. There cannot be any route around the border of the destination country (that is there is no smuggling).

Following Irwin (1998), countries choose the tariff rate that maximizes their tariff revenues. This case represents a country with direct access to the source of production, without any other countries possibly interfering with its trade with world markets, and also without any other countries downstream of it. Such an "island" country i can gain revenue by charging a tariff t^I_{ig} to maximize revenue

$$R^I_i = \max_{t^I_i} \left(t^I_i M_i \left(t^I_i \right) \right). \tag{4}$$

.

This revenue-maximizing tariff t^I_{ig}, which we will call "'island tariff"' is retrieved by inserting equations 1 – 3 into equation 4, and taking the first derivative w.r.t the tariff rate,

$$\frac{\partial \left[t^I_i \left(D_i - a \left(p_w + \phi_{wi} + t^I_i \right) \right) \right]}{\partial t^I_i} = 0 \Leftrightarrow t^I_i = \frac{D_i - a \left(p_w + \phi_{wi} \right)}{2a}. \tag{5}$$

2. Two Countries

Add a second country as in figure 2. Now it depends on the geographical parameters how the two countries will set their tariffs, whether there will be transit trade or no transit trade, and how much revenue countries

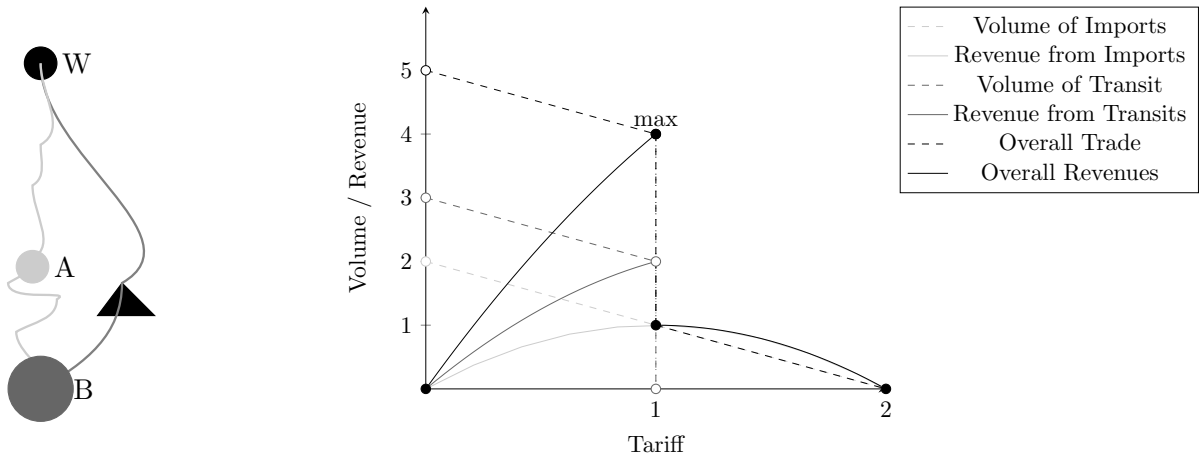

Figure 3: *The left sketch shows the stylized geography of two countries A and B, in which there is demand for products from the world W. The left line indicates a river that allows transporting one unit cheaper than via the land road (indicated in gray). The optimization of country A is depicted in the graph on the right. A has initial domestic demand (imports, dashed line starting at 2), indexed to one. Country B's demand satisfied via A is depicted in dashed starting at 3. With any one unit increase in tariffs, consumers react by demanding one units less. A can get revenues from imports (parabel starting at origin), and transits to B (curve in center). Overall trade, the sum of imports and transits, is depicted in solid black. From our assumptions on geography, it follows that at any tariff above one, transit trade will start detouring A. Therefore, the overall revenue (solid black) is retrieved at a tariff marginally below one. Note that the revenue function is not differentiable.*

gain from tariffs. In the most simple case, both countries' have direct access to world markets at the same costs ($\phi_{wi} + t_i + \phi_{ij} + t_j = \phi_{wj} + t_j$). There is no upstream-downstream relationship, and hence no transit trade—countries' tariff revenue is only restricted by their own import demand.

(i) Revenue-Maximizing Tariff With Two Countries

Now assume that ϕ_{wj} would be very high. For example, imagine i being located at the sea, and j is landlocked and only connected to world markets via i. With this geography the optimization problem translates to a standard problem from the industrial organization literature, multiple marginalization (see Church and Ware (2000)). Country j knows that its consumers will have to bear the price of the tariff, and sets the optimal tariff solving for (analogously to equation 5), anticipating j's reaction tariff (see sec. 1 of math appendix for details) to

$$\left[t_i^j \mid \phi_{wj} \to \infty\right] = \frac{\frac{2}{3}D_i + \frac{1}{3}D_j - a\left(p_w + \phi_{wi} + \frac{1}{3}\phi_{ij}\right)}{2a}. \tag{6}$$

Compare this tariff with the island tariff from equation 5. The resulting tariff can be higher, or lower than the island tariff, depending on the relative size of the countries, and the transport costs ϕ_{ij}. The larger D_j is relative to D_i, the higher the tariff t_i^j compared to the island tariff. Neglecting relative size (e.g. $D_i = D_j$), the larger transport costs from w to j relative to w to i (since $\phi_{ij} > 0$), the lower is t_i^j.

(ii) The Trade-Off of an Upstream Country

If a detour around i would be costless, there would be no transit trade, and if it would be infinitely expensive there would be either transit trade or no demand for imports in j at all. Hence, detour costs are a central variable in the

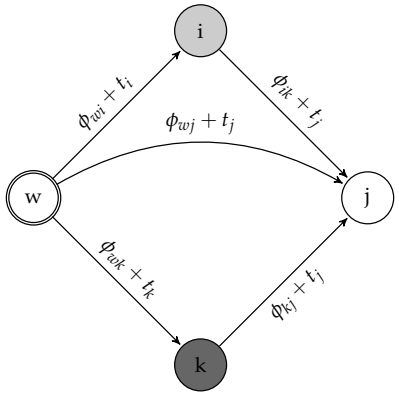

Figure 4: *Given that the direct route from w to j is very expensive, i and k compete over transits. If i and k could agree on a single tariff rate (e.g. by sharing the revenue), this competition can be avoided.*

optimization problem. Let's define the difference between the least-cost-path including a set of countries, and the least-cost-path that detours the same set of countries, $\{i\}$ in our case, as

$$h^j_{\{i\}} = \min_{r \in W_{wj}, \{i\} \not\subset r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) - \min_{r \in W_{wj}, \{i\} \cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) > 0 \tag{7}$$

This yields

$$h^j_{\{i\}} = \phi_{wj} - \left(\phi_{wi} + \phi_{ij} \right) > 0.$$

As in figure 3, the revenue of i is discontinuous at $h^j_{\{i\}}$. Any higher tariff implies the loss of transit trade to j. Country i is confronted with a binary decision problem $d_{ijg} \in \{0, 1\}$ and compares the revenue from setting $t_{ig} \leq h^j_{\{i\}}$, which would allow imports from j to transit i ($d_{ijg} = 1$), or setting t_{ig} above $h^j_{\{i\}}$ and force traders to detour i ($d_{ijg} = 0$). The problem of i is therefore given by

$$R_i = \max_{t_i, d_{ij} \in \{0,1\}} \left(t_i (M_i(t_i) + d_{ij} M_j(t_i)) \right) \qquad \text{s.t. } d_{ij} t_i \leq h^j_{\{i\}}. \tag{8}$$

Proposition 1. *Countries may have to give up revenue from transit trade when setting the island-tariff*

Proof. See appendix. □

(iii) Competition Between two Upstream Countries

This trade-off, which a potential transit country faces, is changed once we introduce a third country k that can allow access to world markets to j.

Consider k as our third country, as in figure 4. There are three routes to j, $W_{wj} = \{(w, j), (w, i, j), (w, k, j)\}$. Let the cheapest route go via i, the second cheapest route goes via k, and the most expensive route is the direct one. The cheapest route to j therefore depends on parameters,

$$min(cost_{wk}) = \begin{cases} \phi_{wi} + \phi_{ij} + t_i + t_j & \text{(cheapest route via i)} \\ \phi_{wi} + \phi_{ij} + h^j_{\{i\}} + t_k + t_j & \text{(second cheapest, detour i, via k)} \\ \phi_{wi} + \phi_{ij} + h^j_{\{i,k\}} + t_j & \text{(detour both i and j)} \end{cases}. \tag{9}$$

Proposition 2. *Two countries can engage in Bertrand competition over the least cost routes between world market and a third country. The decision whether any country will find it beneficial to engage in competition depends on their relative size and position.*

Proof. See appendix. □

3. Customs Unions

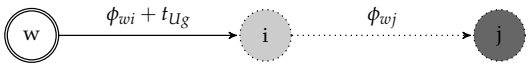

Figure 5: *A potential customs union between i and j would eliminate tariffs between i and j*

Consider now a situation with many countries, and that countries are allowed to form customs unions. Following Viner (1950), a customs union is a set of countries U that agree on a single tariff rate (for imports and transits) t_U, distribute the tariff revenues according to a distribution mechanism so that any member i would receive a share π_i^u of R_U, and abolish internal borders. The rules of this unions are given and non-negotiable, and defined as followed.

Country i from figure 5 faces a binary decision γ_i^u between its independent revenue and its share in union revenue Π_{iU}

$$\max_{\gamma_i^u \in \{0,1\}} \left((1 - \gamma_i^u) R_i + \gamma_i^u \pi_i^U R_u \right) \tag{10}$$

(i) Benefits of a Customs Union

Conditional on geography, the foundation of a customs union can create revenues otherwise wasted due to multiple marginalization.

Proposition 3. *The decision of any country to join a customs union depends on the absolute and relative geographic position of the country, compared with the absolute and relative geographic position of the customs union.*

Proof. See appendix. □

(ii) Negative Effects of a Customs Union for an Upstream Country

States such as the free cities of Hamburg and Bremen, Germany's trade entrepôts, remained outside of the customs union even after the foundation of the German empire in 1871, almost half a century after other German states had joined into a customs union. The prime reason is that revenues within the German customs union were distributed relative to population shares, neglecting their geographic position.

Proposition 4. *A country can loose from joining a customs union, depending on its promised share of the unions revenue.*

Proof. See appendix. □

(iii) Why Countries Join a Customs Union

We established that the decision whether to join a customs union depends on the sizes of customs union effects and the control over trade routes countries give up.

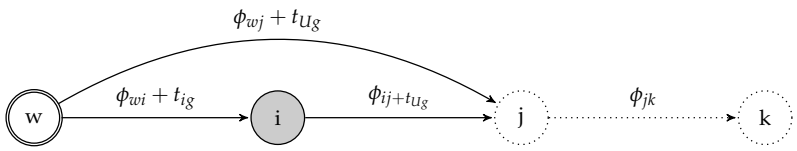

Figure 6: *Countries i faces a trade-off between control and customs union-effect*

Theorem. *Revenue-maximizing countries trade off geography-induced positive customs union effects from joining a customs union with their loss of revenue due to loosing an advantageous geographic position.*

Proof. See appendix. □

To summarize, our theoretical framework generates several testable hypotheses with respect to the formation of customs unions. First, the higher the share of a state's imports that pass via another state, the more the former would benefit from a customs union with the latter. Second, there may be competition between states or between customs unions over trade and tariff revenue. Specifically, the decision of one state to join a customs union can change the incentives of others to do so. However, this last hypothesis will be difficult to test, due to strategic complementarities. Therefore, in the next section, we provide evidence on the first hypothesis as well as anecdotal evidence on the second. This is followed by a section, where we calibrate our model and show that it can replicate the series of customs union formation and dissolution that preceded the formation of the Zollverein between 1818 and 1834, again in order to support our second hypothesis. Finally, we use this calibrated model to show that the Zollverein would not have formed if Prussia's political borders would have been set as wished by the king of Prussia and not as imposed by Great Britain.

C. Reduced Form Evidence

A central argument of our theory is that geographic location can determine a country's bargaining position, due to transit trade: the higher the share of a state's imports that pass via another state, the more the former would benefit from a customs union with the latter. Consider table 1. Our dependent variable is the year that any of the 34 German states signed a treaty to join the Zollverein. Given that revenue from colonial goods (sugar, tobacco etc.) accounted from 50 percent in 1822 to nearly 80 percent in 1831 (Onishi, 1973), we calculated least cost paths to London, assuming that all goods that are relevant for tariff revenue would enter from the Atlantic economy. We generate variables from GIS using state borders, coastlines and roads from Kunz and Zipf (2008), rivers from the European Environment Agency[9], and historical transport costs from Sombart (1902). The variable *Transit Through Prussia* is then coded one if the territory of Prussia is crossed on this least cost path, zero otherwise. This simple variable alone explains over 60% of the variation, and its negative estimate indicates that states whose transit would flow through Prussia would join the Zollverein earlier. This finding is robust if we control for other geographic indicators.

Keller and Shiue (2014) employ distance to oceans as an instrument for access to the Zollverein. We replicate their findings here and calculate *Distance to Oceans* as the distance between 1,000 random points generated within the state and the closest ocean in kilometer[10]. As all variables indicated 'Std.', this distance variable was then standardized to a mean of zero and a standard deviation of one. Regression (2) shows that states with better access to the ocean would indeed join the Zollverein later. As indicated by the smaller effect of the transit through Prussia, these two measurements are related, but also have joint explanatory power. In this regression, the fact that a state's transit goes via Prussia is equivalent to almost a two standard deviations change in the distance to oceans.

[9]The data can be downloaded here: `https://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes`

[10]This procedure makes this indicator robust against different sizes of states, as larger state by chance would have some point very close to the ocean.

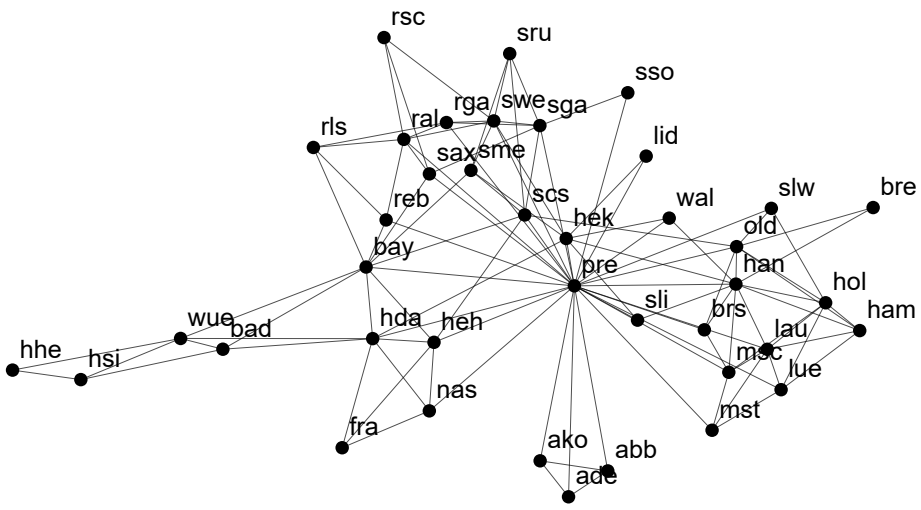

Figure 7: *Network graph of 1820 Germany and surrounding countries. Note the centrality of Prussia and the Hessian states. Abbreviations: ABB=Anhalt-Bernburg, ADE=Anhalt-Dessau, AKO=Anhalt-Köthen, AUT=Austria, BAD=Baden, BAY=Bavaria, BRE=Bremen, BRS=Brunswick, CHE=Switzerland, FRA=Frankfurt, FRC=France, GBR=Great Britain, HAM=Hamburg, HAN=Hanover, HDA=Hesse-Darmstadt, HEH=Hessn-Homburg, HEK=Hesse-Kassel, HHE=Hohenzollern-Hechingen, HOL=Holstein, HSI=Hohenzollern-Sigmaringen, KRA=Cracow, LAU=Lauenburg, LID=Lippe-Detmold, LIE=Liechtenstein, LUE=Luebeck, LUX=Luxemburg, MSC=Mecklenburg-Schwerin, MST=Mecklenburg-Strelitz, NAS=Nassau, NEU=Neuenburg (Neuchâtel), NLD=Netherlands, OLD=Oldenburg, POL=Poland, PRE=Prussia, RAL=Reuß Greiz, REB=Reuß-Ebersdorf, RGA=Reuß-Gera, RLS=Reuß-Lobenstein, RSC=Reuß-Schleiz, RUS=Russia, SAX=Saxony, SCS=Saxony-Coburg-Saalfeld, SGA=Saxony-Gotha-Altenburg, SHI=Saxony-Hildburghausen, SLI=Schaumburg-Lippe, SLW=Schleswig, SME=Saxony-Meiningen, SRU=Schwarzburg-Rudolstadt, SSO=Schwarzburg-Sondershausen, SWE=Saxony-Weimar-Eisenach, WAL=Waldeck, WUE=Wurttemberg.*

This means that a state that differs from any other state just due to the fact that the least cost path to the Atlantic Economy passes via Prussia behaves as if it was about 250 km further away from the sea. The significant result for *Distance to Rivers*, calculated analogous to its oceans counterpart using navigable rivers only, in regression (3) indicates that water transport in general mattered for the question of joining the Zollverein, and that better access to waterways would make states more reluctant to join. The effect of a standard deviation change of this variable is about half the effect estimated for the ocean. On the one hand, river transport, if it was downstream, was cheaper than ocean transport per ton-kilometer (see tab. 6 of the appendix). On the other, it is limited to trading partners on the same rivers and connection to world markets still dependent on sea harbors. The population of the states is not statistically relevant (column (4)). To control for the fact that some states look back at different cultural traditions due to their different heritages as Bavarian, Saxonian, Brandenburgian, or Hessian, we employ the 1150 map of the Holy Roman Empire from Huning and Wahl (2017), which leads to a vast increase in the model's saturation. The estimate for the Prussian transit is however even higher. This could capture the idea that the Saxonian and Thuringian states indeed could have found it easier to coordinate their decision based upon their common backround. This might have shifted the individual states joining by some years, however large alterations are unlikely. This map features 32 regions in Central Europe and is included as control variable in column (5). Moreover, it has been proposed (Onishi, 1973) that the Zollverein was attractive for rulers, because it generated revenues that were exempt from parliamentary control. Therefore, the political system might be relevant for the joining decision. We test for the effect of various political systems based on the dataset by Kunz and Zipf (2008), and find that only the dummy variable for absolute monarchy is significant, suggesting that absolute monarchs would join earlier. Finally, we test the idea by Dumke (1976) that the Zollverein was a tool to reduce the costs of tariff border protection. In regression (7), the length of the state border in kilometer shows a very low estimate and is also not significant. The same is true for the area of a state in square kilometers (column (8)) and the division of border length and area as proposed by Dumke.

There is also plenty of anecdotal evidence on the role of transit trade for trade policy. For example, in 1820, the delegate of Baden at negotiations in Darmstadt, Nebenius, complained that the Dutch set their transit tariffs up to the point that "'there would be just a small advantage left to trade colonial goods on the Rhine and that all natural advantage that this stream provides for the states in Southern Germany, would be lost to them"' (own translation after Eisenhardt Rothe and Ritthaler (1934, I, p. 402)). We mentioned already the role of transits through the Hessian hills as an alternative to the Rhine trade. When the Dutch started to reduce their tariffs in the wake of the Belgian revolution of 1830, the Rhine became much more attractive, which helped to convince Hesse-Cassel to join the Prussian Zollverein. The results in table 1 indicate a strong and robust relationship between the dependency of German states on transit through Prussia and the timing of their decision to join the Zollverein, supporting our central argument. However, our theoretical framework suggests that the sequence of joining is endogenous, because a reduction in trade costs between two states is likely to affect third states. Indeed, we have more direct evidence that the decision to join was strategic. For example, already in 1822, von Klewiz, the Prussian minister of Finance speculated about the strategic consequences of various states joining Prussia into a customs union. If Hesse-Cassel would join, this would be of "'greatest interest; it connects the two states"' (own translation afterEisenhardt Rothe and Ritthaler (1934, II, p. 49). After Hesse-Darmstadt had joined the Prussian Zollverein in 1828, the king of Bavaria

Table 1: *Reduced form evidence for the role of transit in states' decisions to join the Zollverein*

	Dependent variable: Year the Zollverein membership was contracted in								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Transit Through Prussia	-29.51***	-14.74*	-16.64**	-16.98**	-24.91***	-12.92*	-16.81**	-17.00**	-15.58**
	(4.023)	(5.599)	(5.337)	(5.308)	(6.103)	(5.146)	(5.469)	(5.354)	(5.494)
Std. Distance to Oceans		-7.624**	-7.935***	-8.096***	-11.46*	-8.731***	-7.897**	-8.042***	-8.273***
		(2.258)	(2.130)	(2.119)	(4.890)	(1.992)	(2.170)	(2.126)	(2.174)
Std. Distance to Rivers			-4.241*	-4.519*	-6.273***	-4.069*	-4.300*	-4.379*	-3.808
			(1.897)	(1.898)	(1.323)	(1.753)	(1.942)	(1.902)	(1.968)
"Cultural Heritage"				✓					
Absolute Monarchy						-7.900*			
						(3.037)			
Constitutional Monarchy						-2.511			
						(2.963)			
Std. Length of Border							0.717	-6.276	
							(2.967)	(5.475)	
Std. Area								12.68	
								(8.418)	
Std. Length of Border Per Area									1.188
									(1.366)
Constant	45.83***	34.61***	35.26***	36.60***	49.48***	35.77***	35.53***	37.40***	34.29***
	(3.651)	(4.595)	(4.334)	(4.449)	(4.657)	(4.077)	(4.544)	(4.617)	(4.490)
N	34	34	34	34	34	34	34	34	34
Adj. R^2	0.615	0.710	0.743	0.746	0.906	0.781	0.735	0.746	0.741
AIC	247.4	238.8	235.5	235.9	208.0	231.7	237.4	236.8	236.6

Note: This table depicts the significance of the fact that a state's imports from the Atlantic have to pass via Prussia on the least-cost-path from London, assuming there would be no transport costs except to move the goods physically. All variables indicated 'Std.' are standardized to mean zero and standard deviation of one. Standard errors in parentheses. Significance levels are indicated as follows: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Summary statistics of all variables are provided in table 5 of the appendix.

was outraged, because he had hoped that Hesse-Darmstadt would join the Southern Customs Union (of Bavaria and Württemberg) and thereby help to connect mainland Bavaria to the Bavarian Palatinate Eisenhardt Rothe and Ritthaler (1934, II, p. 241). Nevertheless, after Hesse-Darmstadt had joined Prussia, Bavaria and Württemberg signed shortly later a preliminary agreement with the enlarged Prussian customs union, while several other small German states attempted to prevent a further expansion of the Prussian Zollverein. A major concern was, as argued by the Cabinet of Hanover that "'their trade routes from and to other states would not be blocked"' by Prussia (own translation after Eisenhardt Rothe and Ritthaler (1934, II, p. 397)). In the next section, we show how we calibrated our theoretical model with historical data and used this to simulate the effects of various customs unions on revenues and hence the incentives to join or not to join the Prussian Zollverein.

D. SIMULATION: SET-UP

We cannot use data on trade flows, trade costs, and customs unions and estimate how revenues changed with access to a customs union. The first problem is the lack of data. The German state archive in Berlin has official tariffs for many goods and states on file, as exchanging such information was part of diplomatic exchange. However, the majority of political trade costs has never been recorded. The German states were just in the making of the tariff system, so that various systems of tariff collection were applied simultaneously. For example, the Northern harbor cities, like Bremen and Hamburg, for many years had an official tariff rate of zero. It would be wrong to assume this implied the absence of political trade costs. Handling fees and regulations created state revenue paid for by consumers in the hinterland. Other examples include staple rights, and road and river tolls, which added to the notoriously complicated tariff landscape. The same applies to trade flows. There are some exemplary route maps and notes kept by traders of the time that allow us understanding the cost structure of trading in our time period. But we lack systematic trade statistics for the German states before the formation of the Zollverein. The second problem is more fundamental. Even if we had complete data on trade flows, tariffs, and revenues, all would be the outcome of simultaneous strategic interaction and difficult to interpret.

Our approach is to use the available data to simulate tariffs, trade flows and revenues, given data on trade costs, population, the initial geography of state borders and given customs unions as of late 1827, before the formation of the Prusso-Hessian and the Southern customs unions in 1828. Next we use this to see whether our model can help to predict future decisions of states to join a specific union. We also explore how the Belgian revolution affected tariffs and in its wake incentives to join customs unions. Finally, we consider a counterfactual geography of state borders after 1815 to explore, how the British intervention might have affected the course of events.

The only truly exogenous variables we have in our model is the geography of the states, including their rivers, roads (which are exogenous in our small time window), and physical transport costs (which are exogenous under the assumption of perfectly competitive transport- and retail-sectors). We also assume that we can treat state borders after 1815 as exogenous as argued above, and also consumer's preferences and demand elasticity. We use population data as of 1820 and assume that people are mobile. It is safe to concentrate on those goods that created the bulk of the tariff revenue (see Onishi (1973)) and did not have a significant domestic competition: namely sugar, coffee, and alcohol. We assume that these goods are imported from London and fitted for each good a linear demand curve. Preferences were assumed to be common, and their consumption was not restricted to elites but already standard in large shares of population Ferber (1829). This gives us several parameters (see table 2) to simulate the environment in which state rulers set revenue-maximizing tariff rates.

Physical transport costs ϕ are calculated using GIS, employing maps by Kunz and Zipf (2008), per-kilometer rates from Sombart (1902) and the algorithm by Dijkstra (1959) [11].

[11] We are grateful for the contributors of the free and open source projects PostgreSQL (postgresql.com), PostGIS(postgis.org), PgRouting (pgrouting.org), and QGIS (qgis.com), which were used exclusively.

Table 2: *Parametrization of the Simulation*

Parameter	Letter	Description	Source
World market price	p_w	Average London prices 1822–1831[a]	Clark (2010)
Market size	D	Population data 1820[b]	Kunz and Zipf (2008)
Elasticity of demand	η	Pfister (2012) reports an elasticity of -0.5 using Hamburg prices for 1736-1798. Ewert and Pfister (2017) estimate a lower elasticity for the 19th century. The import elasticity is therefore assumed to be -0.85.	Pfister (2012)and Ewert and Pfister (2017)
Physical transport costs	ϕ	GIS map of central Europe 1820[c], including harbors, rivers, roads, and country shapes. Per-kilometer rates[d] are constant per weight, discriminated by transport mode. These are (in the order of increasing per-kilometer price) river transport with the stream, sea freight, river transport against the stream, land transport on paved roads, and land transport elsewhere. Switching transport modes is possible anywhere they cross. Transportation costs are independent of the quality and/or category of the good. The transportation costs of a liter is assumed to correspond to that of one kilogram. Gross weight equals tare weight.	GIS maps from Kunz and Zipf (2008) and own maps. Per-kilometer rates and transshipment costs from Sombart (1902)

[a] Values were standardized using reported prices in grams of silver.

[b] To account for the variation in the size of states, larger territorial states are split into their first geographical subdivision to analyze demand: Prussia (9 parts), Austria Hungary (9), Bavaria (8), Hanover (7), France (6), Baden (6), Saxony (5) Wurttemberg (4), Hesse-Darmstadt (3), Saxony-Weimar-Eisenach (2), Oldenburg (2), Saxony-Coburg-Saalfeld (2), and Sachsen-Gotha-Altenburg (2). A region's demand is assumed to be concentrated in it's capital.

[c] Rivers were turned into floating direction. Roads were added from own maps. Sea harbors were included.

[d] Values were converted using currency's silver content.

We calculate the demand for any region j using table 2. We weighted the price of coffee, sugar, and alcoholic beverages, using per-capita consumption in Prussia 1820–1830 from Dieterici (1846) and Ferber (1829). Price data uses the exogenous London price data from Clark (2010). The price consumers in j have to pay for a kilogram of this import basket p_w, the physical transport costs ϕ on the least cost path P_{wj} and the sum of the tariffs t of all states on this least cost path S_P. Demand elasticity is constant and given by ϵ. Assuming there is only that one bundle of import goods, any consumer would have a potential demand of DPC_j.

$$DPC_j = \beta(p_w + \phi_{P_{wj}} + \sum_{i \in S_P} t_i)^{\epsilon} \tag{11}$$

To simulate regional demand, we multiply per capita demand by population pop, assuming uniform income distribution. In order to allow for an optimal tariff below infinity, we enforce a choke quantity of DPC_C below which demand falls to zero (the intuition being that it does not pay to ship anything less to the region due to some fixed costs).

$$D_j = \begin{cases} pop_j DPC_j & \text{if } DPC_j > DPC_C \\ 0 & \text{else} \end{cases} \tag{12}$$

This demand function is known to all states, and so is geography. The choke parameter needs careful examination. A prohibitively high quantity of necessary imports would reduce the number of states that can generate any tariff revenue. A very low number generates unrealistically high tariff rates for some states. States which mostly generate income from import tariffs would find it beneficial to raise their tariff rate further since their own population cannot

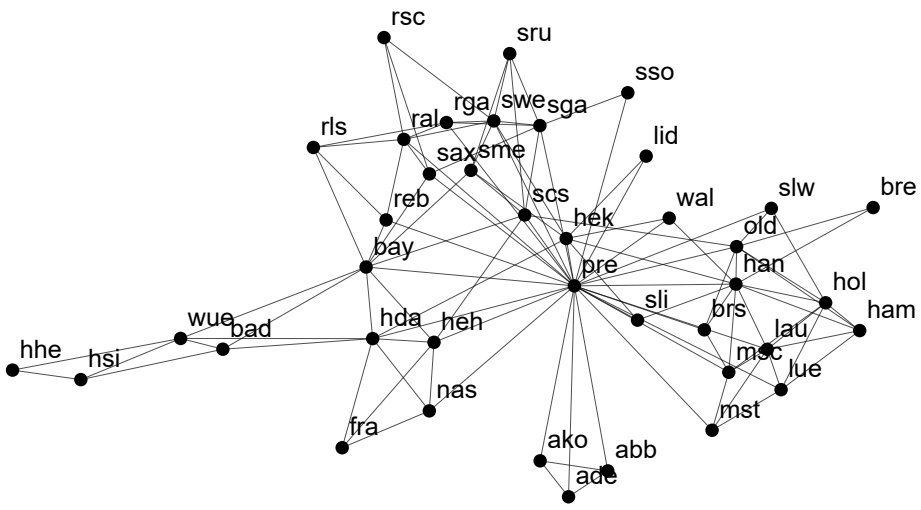

Figure 8: *Network graph of 1820 Germany and surrounding countries, edges denote that the two state are geographical neighbors. Note the centrality of Prussia and the Hessian states. Abbreviations: ABB=Anhalt-Bernburg, ADE=Anhalt-Dessau, AKO=Anhalt-Köthen, AUT=Austria, BAD=Baden, BAY=Bavaria, BRE=Bremen, BRS=Brunswick, CHE=Switzerland, FRA=Frankfurt, FRC=France, GBR=Great Britain, HAM=Hamburg, HAN=Hanover, HDA=Hesse-Darmstadt, HEH=Hesse-Homburg, HEK=Hesse-Kassel, HHE=Hohenzollern-Hechingen, HOL=Holstein, HSI=Hohenzollern-Sigmaringen, KRA=Cracow, LAU=Lauenburg, LID=Lippe-Detmold, LIE=Liechtenstein, LUE=Luebeck, LUX=Luxemburg, MSC=Mecklenburg-Schwerin, MST=Mecklenburg-Strelitz, NAS=Nassau, NEU=Neuenburg (Neuchâtel), NLD=Netherlands, OLD=Oldenburg, POL=Poland, PRE=Prussia, RAL=Reuß Greiz, REB=Reuß-Ebersdorf, RGA=Reuß-Gera, RLS=Reuß-Lobenstein, RSC=Reuß-Schleiz, RUS=Russia, SAX=Saxony, SCS=Saxony-Coburg-Saalfeld, SGA=Saxony-Gotha-Altenburg, SHI=Saxony-Hildburghausen, SLI=Schaumburg-Lippe, SLW=Schleswig, SME=Saxony-Meiningen, SRU=Schwarzburg-Rudolstadt, SSO=Schwarzburg-Sondershausen, SWE=Saxony-Weimar-Eisenach, WAL=Waldeck, WUE=Wurttemberg.*

react to an increase in the tariff except by reducing the quantity of imports consumed. Therefore, we can assess the quality of the assumed choke quantity best looking at states without transit revenues.

As our method is unusual, let us briefly describe the various steps of our simulation.

1. We start with some historical status quo, in terms of state and regional sizes, positions, and transport networks as given in table 2.
2. We group all states that form customs unions (either historically or counterfactually). These states will then take part the simulation as a single player, and can set only one tariff. All other states are independent players.
3. Initiate all tariffs with zero.

To account for the fact that all states react to all other states' tariffs, as their revenues and their possible revenues might be affected, we run a large number of rounds with the following steps.

1. Shuffle the order of players so that all players have exactly one turn. Start with the first player in line.
2. Retrieve the current players tariff and save it to t. Solve for the demand of all regions that would trade via the current player given all tariffs of other states do not change, and given t. Calculate the player's revenue. Store this result in a.
3. Generate a small random number $r > 0$.
4. Repeat step 2, but now given that the player sets tariff $min(0, t - r)$. Store the resulting revenue in b.
5. Repeat step 2, given the player sets tariff $t + r$. Anticipate that an increase in the current player's tariff rate might motivate other players to reduce their tariff in the next round by assuming that this other player would

immediately do so. Store the resulting revenue in c.

6. Choose the maximum of a, b, and c, and inform everyone that the current player's new tariff is unchanged if the maximum is a, $min(0, t - r)$ if the maximum is b, or $t + r$ if the maximum is c.
7. The next player starts with step 3. If all players had their turn, start a new round with step 1.

The outcome of the simulation yields an approximation of the optimal tariffs and the overall tariff revenue from the three goods for all the states and simulated unions S, given that the number of rounds is sufficient.

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The outcome of this simulation is a tariff that all states would set, demand by their respective consumers, and the resulting revenue. We will express the latter in per capita terms to make comparisons over time and across states and alternatives.

E. RESULTS

In this section we use our calibrated model to replicate the course of events that led to the formation of the Zollverein in 1833. Our model implies that any change in tariffs of any state can affect all others. Instead of exploring all possible strategic interactions we limit our attention to the observed chain of events and several alternative options as discussed in the contemporary debate. The results are shown in table 3.

Table 1 suggests an analytical narrative, that is both founded in our theory and in line with historical evidence. Let us assume that all states follow only the goal of revenues maximization over an infinite time horizon, except Prussia and to some extent Bavaria, as long as tariff revenues do not turn negative. For the Prussian finance minister Motz, in office since 1825, the main long-run challenge for Prussian finance was to connect the two separate territories. Indeed, still in 1829 he argued that a treaty with the Southern states and the Hessian states, could well lead to a short-run decline in tariff income, while the long-run financial and notably the political gains would more than outweigh this (Motz in **???**). Hence, Prussia can be seen as an agenda setter in the spirit of Ploeckl (2010). Similarly, Bavaria was eager to form a customs union with Hesse-Darmstadt, not only for fiscal purpose, but also to connect its mainland with the *Rheinpfalz* (see figure 1).

We start with the situation in late 1827, with a Prussian Customs unions that included its major enclaves but no other sovereign state. As shown in table 3, column 1, the Prussian Customs Unions generates substantial net-revenues per capita, higher than those in Bavaria, but lower than those in Hesse-Darmstadt and Hesse-Cassel, which benefit from their excellent location as a transit states between the eastern and western parts of Prussia and between Southern and Northern Germany. Wurttemberg instead suffers from the situation, due to multiple marginalization. We note that the Rhine was still nearly blocked for trade due to high Dutch customs. Column 2 shows the situation in January 1828, after the Kingdom of Wurttemberg and the Kingdom of Bavaria had agreed to form the Southern German customs union, the first modern customs union in Germany, where two sovereign partners agreed to set a

[12] Introducing randomness into the decision room of states (step 3) comes with several advantages for the simulation. First, concerning the number of steps we have to simulate. An alternative would be to name a discrete accuracy for the simulation. Let's say we would like the optimal tariff level to be accurate at a tenth of a gram of silver. Due to the kinks in the revenue function, we cannot stop the algorithm, for example if revenue starts decreasing while trying the effect for stepwise increasing of the tariff. This simulation would therefore give us a very exact, but incredible computer intensive solution. Using random steps, given the amount of steps is sufficiently large, the players make rather large changes in the beginning but the number of adjustments slows down (as r might be to to large by chance) until a stable solution is reached. Secondly, and most importantly, this randomness reflects the nature of the historical process. Dieterici (1846) reports that tariff adjustments were agreed upon and announced in rather small steps. Tax administration had a general idea if the current tariff was rather to high or to low or should not be adjusted, but they could not try out their decision to know exactly which changes their decisions would create. We argue that states, like the modern Federal Reserve most of the times, adjusts their decision variable in steps of equal size, and it is therefore reasonable to restrict their decision space to three options. Third, it would be unrealistic to assume, given different local currencies, and weights, that all states would use the same steps for the optimization.

Table 3: *Simulated tariff revenues of selected states per capita and the historic sequence of central decisions to join the German Zollverein*

	Late 1827: Prussian CU including enclaves	**January 1828**: Prussian CU with Southern German CU	**Counterfactual: February 1828**: Hesse-Darmstadt joins Southern CU	**February 1828**: Hesse-Darmstadt joins Prussian CU	**May 1829**: Southern CU signs preliminary agreement with Prussian CU	**March 1831**: formation of Belgium and Mainz Convention opens the Rhine, assumption: Southern CU stay out	**March 1831**: formation of Belgium and Mainz Convention opens the Rhine, assumption: Southern CU joins	**August 1831**: Hesse-Cassel joins Prussian CU, assumption: Southern CU stay out	**August 1831**: Hesse-Cassel joins Prussian CU, assumption: Southern CU joins
Prussian CU	40.78	44.17	49.32	42.03	27.15	34.49	31.02	38.33	22.19
Bavaria	14.34	7.31	9.76	9.84	27.15	-0.79	31.02	3.28	22.19
Wurttemberg	-3.85	7.31	9.76	9.84	27.15	-0.79	31.02	3.28	22.19
Hesse-Darmstadt	26.29	24.15	9.76	42.03	27.15	34.49	31.02	38.33	22.19
Hesse-Cassel	74.77	42.17	76.09	82.78	3.5	-8.05	-7.55	38.33	22.19

These simulations are based upon the GIS maps of the European geography and calibrated demand functions as depicted in table 2. The changes due to the Belgian revolution are included by replacing the shapes of the Netherlands 1820 by the Netherlands 1831 and Belgium 1831, each provided with population data of 1831.

common external tariff. Apparently, this union was more beneficial to Wurttemberg than to Bavaria, reflected in the fact that the initiative to this treaty came from Wurttemberg (Hahn, 1984, p. 41). But why did Bavaria agree to this? Bavaria was eager to integrate the small state of Hesse-Darmstadt into this Southern-German customs union, because it was the missing land-bridge to the Bavarian Palatinate (Rheinpfalz). We see that this customs union was slightly harmful to both Hessian states, as it limited their bargaining power with respect to a now larger united hinterland. But Hesse-Darmstadt was more oriented towards Prussia, as its main markets were in the Prussian Rhineland. Attempts by Hesse-Darmstadt to find a customs agreement with Prussia in earlier years had been rejected. Prussia had been so far reluctant to make any concessions to the tiny Hessian state, because it expected to benefit very little from this. The Prussian position until 1827 had been that any negotiations would have to include the larger Hesse-Cassel as well. This was because for Prussia, the territory of the latter provided the missing land-connection between the eastern parts of Prussia and its western provinces of Rhineland and Westphalia. Consider now columns 3 and 4 in table 3: in our simulation Hesse-Darmstadt benefitted from a customs union with Prussia but not from a customs union with the Southern Zollverein. In contrast, it would have been beneficial for the latter. Moreover, a comparison between column 2 and column 4 shows that the treaty with Hesse-Darmstadt was not beneficial for Prussia.

So why did Prussia agree to a customs union with Hesse-Darmstadt? A main strategic aim of Prussia was to get a land-bridge between its eastern and western parts. The Hessian states, but notably Hesse-Cassel were the missing link. After the formation of the Southern Customs Union, Prussia realized the possibility to exert pressure on Hesse-Cassel via a union with Hesse-Darmstadt and an agreement with the southern states, because this could divert trade away from Hesse-Cassel. But clearly, the sequence of decisions was crucial, as a customs union between Hesse-Darmstadt and the Southern Union alone would leave Prussia with no bargaining power. For Prussia then it was crucial to sign with Hesse-Darmstadt first. The treaty with Hesse-Darmstadt signed in February 1828 was remarkable not only because it was hardly beneficial to Prussia in the short run. Also, the small Hessian state was treated as an equal partner by the large Prussia. It was agreed that all tariffs required the consent of both partners. This was meant as a signal that Prussia would respect the political sovereignty of her trade partners. Now, the southern states realized that they had lost Hesse-Darmstadt but still could benefit from a union with the new Prusso-Hessian Union, given their own unfavorable geography. In May 1829, Bavaria and Wurttemberg signed with the now enlarged Prusso-Hessian customs union a preliminary agreement to prepare their future merger. Comparing columns 4 and 5 we see that this had the effect on Hesse-Cassel that Prussia had hoped for: the Hessian state would have suffered a very substantial decline in tariff income if both customs unions would have merged. But the negotiations continued, and the prince-elector of Hesse-Cassel, Wilhelm II tried everything to avoid a customs union with Prussia. In September 1828 he had formed an agreement with Saxony, Hanover and several other states to fend off what was seen as attempts of Prussian expansions with the *Mitteldeutscher Handelsverein*. At the same time, the economic situation of Hesse-Cassel deteriorated and many citizens demanded a change in policy and an agreement with Prussia. In September 1830 enraged citizens destroyed customs offices in Hesse-Cassel (Hahn, 1984, p. 60). Maybe more importantly, the situation along the Rhine changed fundamentally and with it all trade policy of the German states.

Since the start of the Belgian revolution, the Netherlands had been under pressure to give in to long-standing demands from states further upstream (in a geographical sense), notably from Prussia, for lower tariffs and a liberalization of shipping rules. The independence of Belgium was confirmed at the London Conference in December 1830 and with it the emergence of Antwerp as a competitor for the port of Rotterdam. After many years of negotiations, the Netherlands gave in and the riparian states on the Rhine signed in March 1831 the Mainz Convention to liberalize trade on the river. This as the last blow for Hesse-Cassel, as it essentially eliminated overland transit as its main source of income (compare col. 5 and 6 in our simulation). In August 1831 Hesse-Cassel signed an agreement to join the Prussian customs union, and Electorate Wilhelm II resigned in favor of his son Friedrich Wilhelm I. in September 1831. Consider columns 5, 6 and 7 of table 3. After Hesse-Darmstadt had joined the Prussian Customs union and the Southern Union had signed an agreement to join later, Hesse-Cassel had already suffered a decline in tariff-revenue. This turned negative in our simulation after the liberalization

of the Rhine, and this with or without a de facto merger between the Prussian and the Southern Customs Union. Hence, after 1831 Prussia was at the height of its influence. It finally exerted the full control over large parts of the Elbe and the Rhine and could use it to enforce the unification of its two territorial parts in terms of tariff policy. Moreover, it now had substantial influence over Southern Germany and used it to create the Zollverein in 1833 in separate negotiations with the Southern Customs Union, with Saxony and with the Thuringian states. We see from a comparison of columns 8 and 9 that the Zollverein was not immediately beneficial for Prussia, but it was for Southern Germany and Hesse-Cassel. However, by then the expectation in Prussia was that an enlarged market would facilitate an expansion of economic activity and trade that would pay of in the course of several years. Data from Onishi (1973) indeed suggests that this was the case.

Table 4: *Simulated tariff revenues of selected states per capita given a counterfactual geography of a Prussia that includes the whole of the Kingdom of Saxony, but excludes the Rhine Province and Westphalia, which act as an independent territory*

	Independent States of cf Prussia, Rhineland-Westphalia, Hesse, Southern CU	Merger between Prussia, Hessian states and Southern CU, excl. Rhineland	Formation of a West-German CU, excluding Prussia	Formation of a "Zollverein" between cf Prussia, Rhineland-Westphalia, Hesse, Southern CU
Prussian CU (incl. Saxony)	48.45	22.98	56.85	18.43
Bavaria	8.45	22.98	13.2	18.43
Wurttemberg	8.45	22.98	13.2	18.43
Hesse-Darmstadt	92.29	22.98	13.2	18.43
Hesse-Cassel	100.7	22.98	13.2	18.43
Rhineland-Westphalia	37.68	33.01	13.2	18.43

These simulations are based upon the GIS maps of the European geography and calibrated demand functions as depicted in table 2. The counterfactual is based only upon relabeling of terroritories in the factual historic borders. The two Prussian provinces *Rheinprovinz* and *Westfalen* where relabeled as not part of the Prussian state but act as an independent player. The kingdom of Saxony was relabeled as part of Prussia. The changes due to the Belgian revolution are included by replacing the shapes of the Netherlands 1820 by the Netherlands 1831 and Belgium 1831, each provided with population data of 1831.

How important was the westward expansion of Prussia as it was enforced by Britain in 1815? Consider the results in table 4. We focus our attention on four cases, each under the assumption of a counterfactual political geography, where Prussia is extended southwards to include the entire kingdom of Saxony, while Rhineland-Westfalia constitutes a new sovereign political entity (possibly as new seat of the king of Saxony). Moreover, to ease comparisons with the results above, we only consider situations where a Southern Customs Union has formed and with an independent Belgian state that competes with the Netherlands for trade, thereby limiting tariffs on the Rhine trade.

The main finding from table 4 is that all relevant states are better off if they set their tariffs independently, except the Southern German Customs Union, due to their hinterland position. Comparing col. 1 and 2 we see that a sovereign Rhineland-Westphalia would have had little incentive to join a customs union around Prussia that would include the Hessian states and the Southern German Customs Union. But such a union would likely not have formed in the first place, because the Hessian states had no incentive to join, nor would a counterfactual Prussia have had an interest in such an arrangement. More surprisingly, a West-German customs union similar to the boundaries of a West-German state as it formed after 1945 would also rather not have formed, unless the northern states, notably Bremen and

Hanover would have been part of this (not shown here). Finally, a counterfactual Zollverein that would merge the tariff systems of Prussia, the Hessian states, the Southern customs union and a sovereign Rhinleland-Westphalia would have been attractive only for southern Germany, not for anyone else. To summarize, under a counterfactual geography, the most likely outcome would have been a landscape of several smaller customs unions around a Prussian state including Saxony, possibly with a Southern German Customs Union but with an independent state on the Rhine and independent Hessian states. Without the westward expansion of Prussia, it would have been less attractive and more difficult for Prussia to use tariff policy as a means of increasing its political influence over other German states. Put differently, we conclude that Britain's strategy to install Prussia as a watchdog on the Rhine to keep France and Russia out of Germany indeed had a remarkable side-effect: unintentionally, Britain put Prussia into a position to force other states into an enlarged customs union, the Zollverein. It is unclear whether this would have succeeded without the Belgian revolution and the opening of the Rhine (but possible). In any case Prussia's position on the Rhine was clearly a necessary, if maybe not sufficient condition for the success. Britain helped to unify Germany, because it changed Prussia's geographic position relative to other German states.

F. CONCLUSION

In this paper we considered the factors behind the formation of the German Zollverein as an example of a customs union, and thus endogenous borders. We have argued that the rise of Prussia to dominate German tariff policy can be traced back to a change in "second nature" geography, namely the redrawing of the European map at the Congress of Vienna in 1814/15. Due to the intervention of Britain, Prussia gained large territories in the West. While this was against Prussia's intention, who wanted to gain the rich and densely populated Kingdom of Saxony, this had far-reaching consequences as Prussia was now in control of a large part of Germany's trade routes. Over time, for more and more states the gains from cooperation with Prussia started to outweigh the costs of losing sovereignty. Our argument is closely related to the literature on the size of nations following Alesina and Spolaore (1997) and Bolton and Roland (1997), who emphasize a trade-off between benefits of cooperation from economies of scale and the costs of loosing political control. We argue that a change in borders can trigger a cascade of changes in both dimensions. The intuition for this result was a basic trade-off between prospective gains from joining a large customs union with network effect and control over revenues. In 1815 all the German states that still existed as sovereign entities after the Napoleonic wars were in financial difficulties, including Prussia. All of them attempted to increase their state revenues, reduce costs, while keeping as much of their political sovereignty as they could. Notably they were eager to stay in control over their revenue. With the formation of the Prussian Zollverein in 1818 states had to weigh the potential gains from higher tariff revenue net of costs after joining into the Zollverein against the loss of control over these revenues, hence a loss of political sovereignty. The fact that Prussia controlled large parts of the German river system after 1815 considerably reduced the control that other German states had over their own tariff income, because much of their trade had to be routed over Prussian territory. Moreover, after Hesse-Darmstadt decided to join the Zollverein, all other German states are forced to follow suit. We used detailed GIS data on population, state boundaries, infrastructure and transport mode specific transportation costs to calculate first cheapest cost paths and next expected volumes of trade and transit flows between a set of 106 regions across Germany and neighbouring territories. Based on this we calculated expected changes in tariff revenue, tariff collection costs and changes in control over revenue for each sovereign state if he decided to join Prussia into a customs union compared to the situation outside the customs union. We use a calibrated GIS model to test whether these expected changes in revenue and revenue control can explain the pattern of joining decisions and find that this fits the observed data extremely well. Finally, we run a counterfactual using the estimated coefficients together with a counterfactual map of Germany in 1815: would the Zollverein have formed if Prussia would have gained Saxony instead of the Rhineland? We find very clearly, that the answer is no. While certainly unintended, Britain unified Germany.

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APPENDIX

A. MATHEMATICAL APPENDIX

1. Step-by-step reaction tariff

Given j is solving for it's optimal tariff anticipating t_i, it sets up

$$\frac{\partial \left[t_j \left(D_j - a\left(p_w + \phi_{wi} + t_i + \phi_{ij} + t_j\right)\right)\right]}{\partial t_j} = 0 \Leftrightarrow t_j = \frac{D_j - a\left(p_w + \phi_{wi} + t_i + \phi_{ij}\right)}{2a} \tag{13}$$

Country i would take transits to j into account, t_i^j by setting up its revenue function's first derivative w.r.t t_i^j,

$$\frac{\partial \left[t_i^j \left(D_i - a\left(p_w + \phi_{wi} + t_i^j\right) + D_j - a\left(p_w + \phi_{wi} + t_i^j + \phi_{ij} + t_j\right)\right)\right]}{\partial t_i^j} = 0, \tag{14}$$

replacing t_j from equation 13, and set its own tariff such that

$$\left[t_i^j \mid \phi_{wj} \to \infty\right] = \frac{\frac{2}{3}D_i + \frac{1}{3}D_j - a\left(p_w + \phi_{wi} + \frac{1}{3}\phi_{ij}\right)}{2a}. \tag{15}$$

2. Proofs

Proposition 1. *Countries may have to give up revenue from transit trade when setting the island-tariff*

If country i forfeits transit trade to j, the tariff rate t_i is retrieved as in the island case, $t_i = t_i^I$. Consider the tariff that country i can set allowing for transit trade to j, t_i^j. The condition $d_{ij}t_i \leq h_{\{i\}}^j$ can be either binding or not binding, and $t_i^j \leq h_{\{i\}}^j$. Consider the case that the condition is not binding, e.g. $h_{\{i\}}^j \to \infty$. Country i would only find this beneficial iff

$$t_{ig}^j \left(M_i\left(t_i^j\right) + M_j\left(t_i^j\right)\right) \geq t_i^I \left(M_i\left(t_i^I\right)\right) \tag{16}$$

Consider the case in which this tariff would be too high too allow for transit. If country i wants to allow transit from j, it has to set $h_{\{i\}}^j$. Else, if this tariff is lower than the detour costs anyway, country i can set the tariff as in the surrounded case,

$$t_i^j = \begin{cases} [t_i^j \mid h_{\{i\}}^j \to \infty] & \text{if } [t_i^j \mid \phi_w \to \infty] \leq h_{\{i\}}^j \\ h_{\{i\}}^j & \text{else} \end{cases} \tag{17}$$

Monotonicity of demand for each of the countries w.r.t. tariffs imposes that this is optimal. The binary decision of allowing for transits to j is therefore expressed as

$$d_{ij} = \begin{cases} 1 & \text{if } t_i^j \left(M_i \left(t_i^j \right) + M_j \left(t_i^j \right) \right) \geq t_i^I \left(M_i \left(t_i^I \right) \right) \\ 0 & \text{else} \end{cases} \tag{18}$$

Proposition 2. *Two countries can engage in Bertrand competition over the least cost routes between world market and a third country. The decision whether any country will find it beneficial to engage in competition depends on their relative size and position*

Consider the case that D_k is sufficiently large and transport costs ϕ_{ij} and ϕ_{kj} are sufficiently low, so that both i and k would find it beneficial to allow for transit trade to j. As long as t_i is below $h^j_{\{i\}}$, country k would have to set a negative tariff rate (which cannot be revenue-maximizing). Additionally, country i can safely increase its tariff above the level of $h^j_{\{i\}}$ to the point it expects k to lower its tariff rate to attract the transit. The maximization is given by

$$R_{ig} = \max_{t_i, d_{ik} \in \{0,1\}} (t_i^j (M_i \left(t_i^j \right) + d_{ij} M_j \left(t_i^j \right)) \text{ s.t. } d_{ij} t_i^j \leq h_{\{i\}} + t_k^j \tag{19}$$

while i has to be aware that j will decrease its tariff rate below the island tariff to attract transit if this comes with a positive revenue effect, so that

$$t_j = \begin{cases} t_j^I & \text{if } \left(t_i - h^k_{\{i\}} \right) \left(M_j \left(t_i - h^k_{\{i\}} \right) + M_k \left(t_i - h^k_{\{i\}} \right) \right) < M_j \left(t_j^I \right) \\ \left(t_i - h^k_{\{i\}} \right) & \text{else} \end{cases} \tag{20}$$

which in turn means that i can safely raise its tariff until it expects k to be indifferent between $R_k \left(t_k^I \right)$ and $R_k \left(t_k^j \right)$.

Proposition 3. *The decision of any country to join a customs union depends on the absolute and relative geographic position of the country, compared with the absolute and relative geographic position of the customs union.*

Proof. We have to show under which conditions the sum of independent revenues is smaller than the revenues of the customs union,

$$R_U - \left(R_i + R_j \right) \geq 0.$$

Regarding the customs union, we retrieve the tariff charged analogous to the independent maximization,

$$t_u = \frac{D_i - a \left(p_w + \phi_{wi} \right) + D_j - a \left(p_w + \phi_{wi} + \phi_{ij} \right)}{4a}. \tag{21}$$

Import volume M_u can then be calculated by solving equations 1–3 in reverse order. Multiplying this volume with t_u as in equation 4, yields the union's revenues R_u. We set up the revenue function of independent j by inserting equation 6 into equation 13 to retrieve t_j, solve for M_j from equations 1–3 (as pictured in figure 2), and insert t^j_{ig} and M_j into equation 4. This yields optimal t_j, the resulting imports M_j, and finally R_j. Revenue R_i can then be calculated by inserting the tariff from 6, transit M_j, and imports M_i (from equations 1–3 reversely) into the revenue equation 8.

We spare the reader the complete formula for the customs union effect[13] and rather employ some comparative statics to understand it. To understand the effect of relative size (relative demand), we express D_j in terms of D_i.

[13] Please find the algebra for all revenues, and the following comparative statics, in the technical appendix.

This yields $D_j = D_i - \delta$, while $\delta \lesseqgtr 0$ is just the difference, so that δ can proxy relative size. Replace $D_i - \delta$, and consider first and second derivatives of the customs union effect w.r.t. δ. This shows that the relationship between the customs union effect and the relative size is convex. With increasing inequality in sizes, the customs union effect becomes positive.

Focus on the effect of physical transport costs, in absolute and relative terms. Assume a negative shock on the absolute level of physical transport cost, e.g. through technological progress. Replace ϕ_{wi} by $\phi_{wi} - \tau$, and ϕ_{ij} by $\phi_{ij} - \tau$. First and second derivative w.r.t. τ reveal a convex link.

The first and second derivative of the customs union effect w.r.t. ϕ_{ij} yield a concave function. The effect is smallest at either extremely low or extremely high costs ϕ_{ij}. Consider the extreme case of no physical transport costs, then there would be no gain from cooperation. As physical transport costs approach infinity, shortest paths and detours converge in relative terms.

□

Proposition 4. *A country can loose from joining a customs union, depending on its promised share of the unions revenue.*

Proof. Assuming a customs union $u = \{i, j\}$ would distribute revenues as follows

$$\pi_i^u = \frac{D_i}{D_i + D_j}. \tag{22}$$

Compare figures 2 and 5. Consider the case in which state i has a strong geographic advantage over j, so that $h_{\{i\}} > t_{ig}^j$ (equations 16 and 6). When deciding over joining the union, i faces the trade-off (equation 10),

$$\max_{\gamma_i^u \in \{0,1\}} \left((1 - \gamma_i^u) R_{ig} + \gamma_i^u \frac{D_i}{D_i + D_j} R_u \right) \tag{23}$$

We set up the revenue function[14] from independent i and the union u, and undertake some comparative statics as in proposition 3. The intuition is the following. The country gives up its geographic position, and control over transit trade. It receives a share of union's revenues that is independent of the income when independent, as transit trade is neglected. The control the country gives up when joining is higher when physical transport costs (hence the detour costs) are high so that transport costs represent a considerable share of the price to the consumer.

□

Theorem. *Revenue-maximizing countries trade off geography-induced positive customs union effects from joining a customs union with their loss of revenue due to loosing an advantageous geographic position.*

Proof. Consider figure 6. There exists a customs union $U = \{j, k\}$. Country i can decide whether to form a customs union $U' = \{i, j, k\}$. From equation 10 it follows that i faces a binary decision between the revenue from staying independent, R_i, and it's exogenous determined share $\pi_i^{U'}$ of the customs union's revenue $\pi_i^{U'} R_{U'}$.

We established that there is a positive effect from joining the customs union (proposition 3). In contrast, if a country is in total control of access to world markets, there is a loss from joining the customs union 4. As outlined in the two country case, there is also Bertrand competition over routes that limits the tariff rates.

With increasing world market price, the network effect grows faster than the control effect. To proof this, set up first derivative of network effect and the control effect w.r.t p_w. The first derivative of the difference between customs union effect and control effect can never be negative under the assumption that all variables are positive and there is demand in all countries. Therefore with increasing world market price, the union becomes more attractive. □

[14] Please find the algebra in the appendix.

B. TABLES

Table 5: *Summary statistics of the exercise in chapter "Descriptive evidence"*

	Mean	SD	Min	Max
Transit Through Prussia	.7774498	.4228409	0	1.095041
Distance to Oceans	247.139	129.2661	13.75594	477.2779
Std. Distance to Oceans	0	1	-1.805446	1.780349
Distance to Rivers	20.58066	14.39199	3.113955	78.0745
Std. Distance to Rivers	0	1	-1.213641	3.99485
"Cultural Heritage" FE	17.02128	8.771221	1	32
Absolute Monarchy	.3469388	.4809288	0	1
Constitutional Monarchy	.2857143	.4564355	0	1
Length of Border	984.3847	1546.424	74.10594	9487.874
Std. Length of Border	0	1	-.5886346	5.498807
Area	19183.48	50658.91	105.8058	275099.7
Std. Area	0	1	-.3765908	5.051752
Length of Border By Area	.3229386	.260623	.0183537	1.125486
Std. Length of Border By Area	0	1	-1.16868	3.079344
N	49			

Table 6: *Estimates for per-kilometer freight rates from (Sombart, 1902)*

Type	**Cost [Pf/tkm]**
Country road	120
Paved roads ('Chausee')	30
River, downstream	0.7
River, upstream	1.8
Sea freight	0.95