*How Britain 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".

JEL Codes: C31, F13, N73

Why do sovereign states cooperate or even merge, while others break up? On a most general level, the benefits from cooperation will stand against costs arising from more heterogeneity (Alesina and Spolaore (1997), Bolton and Roland (1997), see Spolaore (2014) for a recent survey). But states will typically differ

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in their geographic position. In this paper we show how ex ante differences in natural geography imply asymmetric costs and benefits from cooperation and hence affect the incentives to cooperate. In turn, the institutional consequences of this can be highly persistent. As already noted by Adam Smith "(t)he commerce besides which any nation can carry on by means of the river (...), which runs into another territory before it reaches the sea, can never be very considerable; because it is always in the power of the nation to possess that other territory to obstruct the communication between the upper country and the sea" (Smith, 1776, p. 19). In a nutshell, a state's sea and river access leads to control over trade, revenues, and growth of other states in the hinterland. We develop a model where states with asymmetric geographic positions engage in spatial competition to maximize revenues. We show that states with a geographical advantage can impose their policy on states in the hinterland and force them into cooperation.

Our theoretical framework rests on two conditions, which were met over most of European (and indeed world) history. First, transit and thereby routing mattered. A major source of state revenue well into the 19th century originated from trade, notably from tariffs on trade flows. Until the Barcelona Statute of 1921 (Uprety, 2006, p. 48ff) these tariffs were levied on all trade flows passing a customs office, including transit trade. A state ruler, aiming to maximize tariff revenue therefore had to anticipate how tariffs would affect not only trade flows but also trade routes and tariff rates abroad, depending on geographic position. Second, before the spread of the railway in the mid of the 19th century, transportation costs were predominantly shaped by access to waterways, such as rivers and sea routes. This increased the role of natural geography for policy. We show that under these conditions revenue maximization results in spatial competition between states similar to Hotelling (1929) and gives rise to endogenous tariffs.

Specifically, we show how our theoretical model helps to explain the economic and political unification of Germany during the 19th century, which 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 this rise of Prussia to become the dominating power within Germany can be traced back to the redrawing of the European map at the Congress of Vienna in 1814/15. Against its own strategic plans, but enforced by Britain, Prussia gained large territories in the West. Clark (2007) claims that the consequences of these new borders were "momentous", but "entirely unforeseen by the negotiators at Vienna, who assigned little weight to economic factors when they redrew the map of Germany" (p. 389ff.). Figure 1 shows the map of Germany after 1815.

With the new 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. We argue that this put other German states under pressure to follow Prussia into the Zollverein, a customs union under Prussian dominance. After Prussia formed a preliminary union with Hesse-Darmstadt in 1828, this pressure increased again and by 1835 all German states placed between the two Prussian territories or to the South of them had joined into the Zollverein. Our theoretical model can explain this result and the sequence of decisions that led to it. However, in the model with many states, the selected equilibrium is typically not pinned down by fundamentals but depends on the sequence of decisions. This is why our empirical strategy rests on a calibration and simulation exercise. Basically we calibrate the model to historical and GIS data on territories, infrastructure, population and tariffs

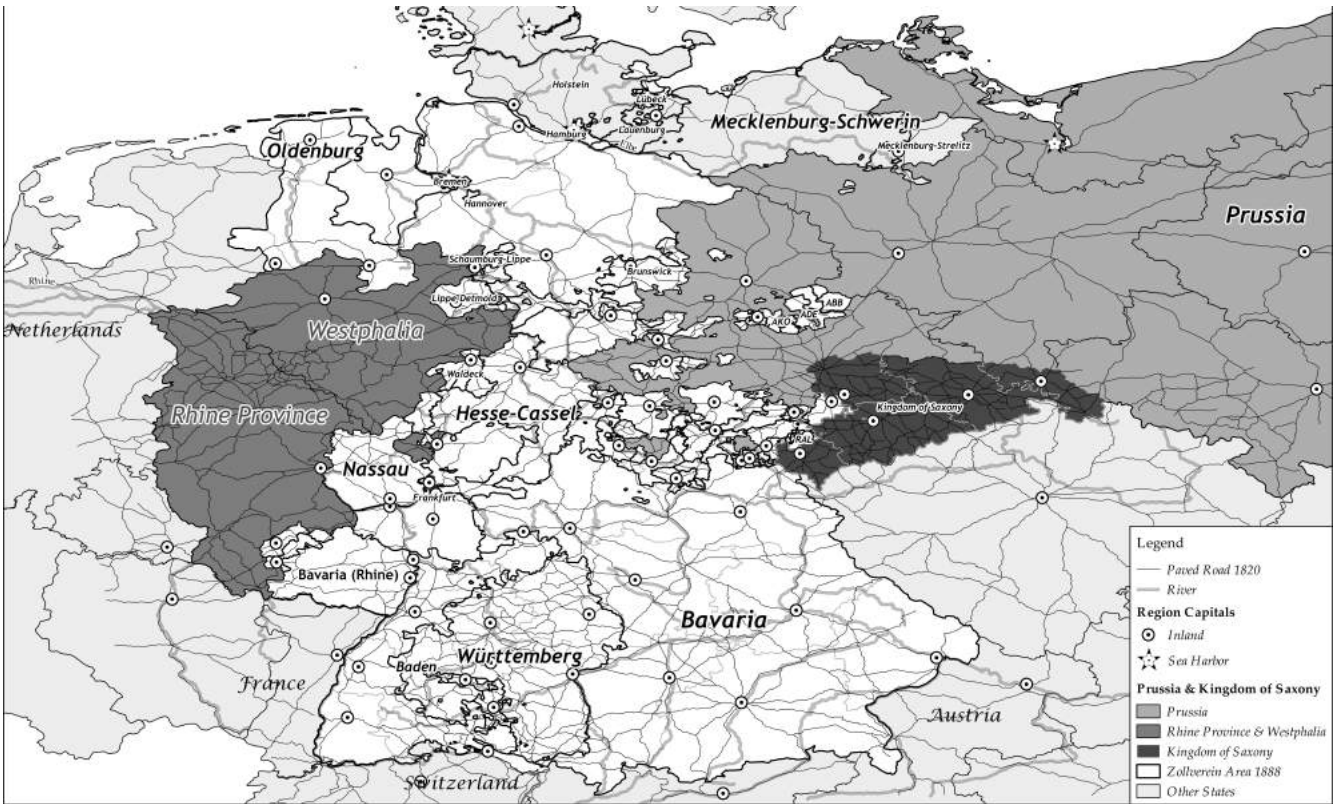

Figure 1: *Map of the German lands after the Congress of Vienna including the rivers and the 1820 road network*[1]

and show how the incentives of state planners change in response to a change in state boundaries and varying coalitions. The key here is 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 many German states had an incentive to join a customs union with the factual borders of 1815. Instead, with a counterfactual Rhineland state, the situation would have been very different. The same states would have had higher incentives to form a customs union with such a Rhineland state than with Prussia, while in turn a counterfactual Rhineland state would not have joined a counterfactual Prussia in a customs union. We also provide evidence that the result is robust to various alternative customs unions that were discussed at the time. 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 possibly also paved the way to Germany's political unification in 1871 under the leadership of Prussia, if only by fostering Prussia's industry (Wehler, 1989, pp. 125ff).

Our paper is related to several strands in the literature, notably on trade 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 large literature on trade agreements, including Ossa (2011, 2012) and Antràs and Staiger (2012), argues that trade agreements can reduce negative

externalities from tariffs due to profit-shifting, firm-delocation 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 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. Instead, 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 model, with tariffs on transit trade, trade routes are crucial for tariff 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 quantiative 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). Related to this, we derive a theoretical model that can be calibrated to historical data and simulated to assess its explanatory power. Moreover, while trade costs are typically treated as exogenous in the recent literature on economic geography, in our framework, trade costs are endogenous.

Next, our paper is related to the recent literature on national building and endogenous political borders in the wake of Alesina and Spolaore (1997) and Bolton and Roland (1997). Both studies 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 strand in the literature 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 (1997, 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 closely related to

Redding et al. (2011) and Bleakley and Lin (2012) on geographical lock-in and Michaels and Rauch (2013) on the long-run effects of geographical fundamentals for the dynamics of urban networks.

Last but not least, 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. Next, Ploeckl (2010) explores in an insightful study the negotiations over Zollverein membership and argues that Prussia could act as an agenda setter in a bargaining game. In particular he provides 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. Finally, Keller and Shiue (2014) estimate the effect of the Zollverein on the integration of grain markets, 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 effect on the integration of grain markets. Our contribution to this literature is twofold. First, we provide a new theoretical framework that can be seen as a synthesis of these ideas but matters beyond the specific historical context of the Zollverein. Second, we are the first to trace the specific formation of the Zollverein 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 present our theoretical framework on the trade-off between benefits and costs of custom unions in a world with endogenous tariffs on imports and transits. We start with a very basic framework on the role of geography for a revenue maximizing state that is step by step generalized to finally include a large number of states, many goods and the possibility to form coalitions. In section b. we briefly discuss some relevant historical background on the Congress of Vienna, the economic and political situation in Germany around 1815, the trade regime, the role of river navigation before the age of the railway and the events leading to the formation of the Zollverein. In section c. we discuss our empirical strategy, describe our data and explain how we used historical data and GIS data to calibrate and simulate the model. Section d. contains our main results on the fit and explanatory power of the model and a discussion of several counterfactuals. We conclude in section e.

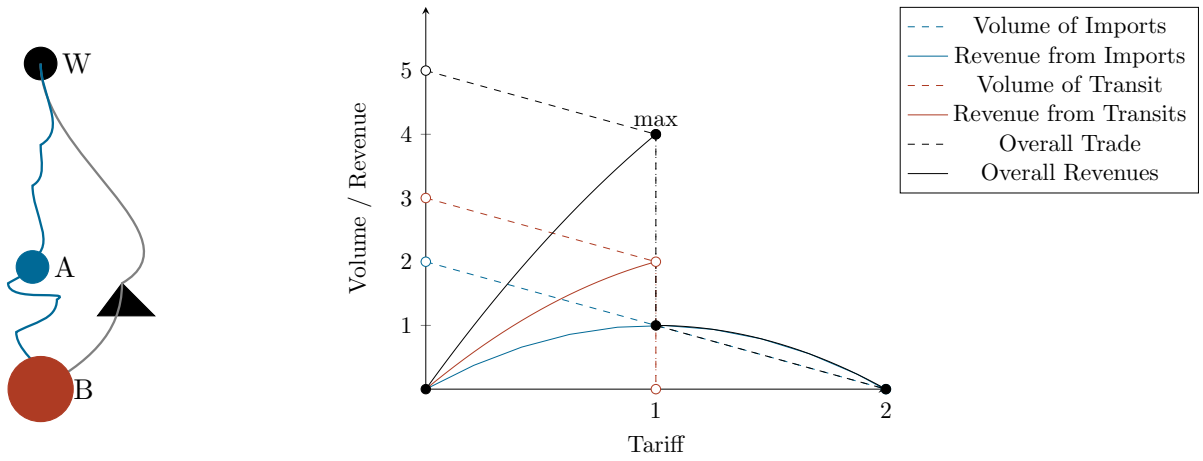

Figure 2: *The left sketch shows the stylized geography of two states A and B, in which there is demand for products from the world W. The blue line indicates a river that allows transport one monetary unit cheaper than via the land road (indicated in gray). The optimization of state A is depicted in the graph on the right. A has initial domestic demand (imports, dashed blue), indexed to one. Assume that state B's demand satisfied via A is depicted in dashed red. With any one unit increase in tariffs, consumers react by demanding one units less. A can get revenues from imports (solid blue), and transits to B (solid red). Overall trade, the sum of imports and transits, is depicted in solid black. From 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.*

A. Theoretical Framework

The theoretical framework explains the role of geography for revenue-maximizing states, and their benefits from cooperation. In a first step, we will outline different ways in which one state affects another state's revenues. The intuition here is the following. Tariffs are in the end paid for by consumers. States therefore have to anticipate consumers' reply to changes in tariffs included in the price of the good (as outlined by Irwin (1998)). Additionally, consumers from other countries are indifferent between the routes a good took to reach them, and will only purchase the cheapest good. A state therefore faces spatial competition between its own routes and routes that go around it, as trade will only take the cheapest route. Differences in geographical centrality induce different elasticities of transit trade w.r.t. tariffs [2]. A more central position of any state A relative to another state B induces a lower transit trade elasticity w.r.t. tariffs, and state A can therefore raise more revenues. Two or more states might actually increase their revenues when cooperating, depending on their geography relative to each other and third states. This cooperation is exemplified in a second step, employing the customs union as one way to cooperate.

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

[2] The framework captures not only costs de jure codified as tariffs. Transit trade was subject to all kinds of taxes, tolls, and fees, which states gained revenue from. Larger states, such as Prussia (Onishi, 1973) or Bavaria (Schögl, 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.

To abstract from real world geography, we employ figures and algebra known from network theory, which focuses on objects, our states, and connections between them, our trade routes. We will lead the reader by moving from a single country case to a world of many countries and many goods[3].

To reduce complexity, we take free on board (f.o.b.) prices as exogenous, and presume a simple demand structure. We include physical trade costs, which we take to be exogenous before the emergence of the railways. Historically, due to the vast technological advantage of sea and river transport, sea harbors and river access where the most important geographic advantage. As such, we assume that there are no investments into changing the physical transport costs that states can undertake. We outline the foundation of the customs union in a static way. The decision of rulers features setting a revenue-maximizing tariff rate, and considering potential transit trade in this decision. These endogenous political trade costs induce differences in the need for cooperation, and therefore the formation of a customs union.

1. Demand for Imports

Consider any state i in which import volume M_{ig} exists for any good g in a continuum of import goods $G = (g_1, .., g_{|G|})$ at price p_{ig}. Transport technology induces that prices of import goods are high, and imports are low. Consumers in i spend a small share of their monetary income Y_i on the purchase of imports M_i. The majority is spent on consuming domestic goods, or services, C_i,

$$Y_i = C_i + \sum_{g \in G} \left(p_{ig} M_{ig} \right). \tag{1}$$

All of these goods in G are final goods, non-rivaling, and their prices are independent of each-other. As we focus on a small time period, demand for imported goods is independent of income. Their price and demand is independent of C_i, as there is no domestic substitute. We assume that for each good in G, demanded volume depends on price p_{ig} in a linear way. Considering the small geographic area, assume similar preferences, uniform income distribution, and equal price elasticity of demand across countries. Therefore, the slope of the demand function only depends on the good, and is given by $a_g > 0$, and the intercept of the demand function $D_i > 0$ is a proxy for the size of the country only. D_i is independent of the good and accounts for the size of the state. This imposes

$$M_{ig} = \begin{cases} D_i - a_g p_{ig} & \text{if } D_i \geq a_g p_{ig} \\ 0 & \text{else} \end{cases}. \tag{2}$$

Assume the good is produced elsewhere at price p_{wg}, and that the states are too small to affect p_{wg}. Markets are perfectly competitive. Transport of the good from w to i comes with positive per-unit cost $cost_{wi}$. These costs are specific, hence non-iceberg (as they do not depend on the price of g). Traders

[3]However, the analysis in this paper focuses on import goods without domestic substitutes. This is motivated by the revenue structure of states, as outlined in the historical background. We do not account for difference in preferences, as the model's geographical scope is limited.

are fully informed and cost-minimizing at no arbitrage. 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

$$p_{ig} = p_{wg} + \min_{r \in W_{wi}} (cost_r). \tag{3}$$

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_{ig}, which are costs associated with the crossing of any border of state 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 states on a route is given by $r = (r_1, .., r_{|r|})$. Assume that states are just points in space (bearing no area), and that these points are connected via different routes. For any two states i and j, the costs of any route r in W_{ij} is the sum of all physical and political costs,

$$r \in W_{ij} \Rightarrow r_1 = i \text{ and } r_{|r|} = j \qquad cost_r = \sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} + t_{r_n g} \right). \tag{4}$$

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

2. One State, or Island Tariff

Following the lead of Irwin (1998), we view the tariff rate as the choice variable of revenue-maximizing states. His model is based upon linear demand and its reaction to an increase in a tariff that has to be absorbed by customers as part of the price. The question in that paper was to explain 19$^{\text{th}}$-century US tariff policy. That is why Irwin does not account for geography, nor for transit trade—his solution can only explain the revenue of an isolated country, an island. None of the neighbor states of the US depended on transit through their territory in the 1800s. We understand an island as a state without any transit passing through, and direct access to world market. Any such island i can gain revenue by charging a tariff t^I_{ig} such that it maximizes revenue

$$R^I_{ig} = \max_{t^I_{ig}} \left(t^I_{ig} M_{ig} \left(t^I_{ig} \right) \right). \tag{5}$$

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The revenue-maximizing island tariff t^I_{ig} is retrieved by inserting equations 2 – 4 into equation 5, and taking the first derivative w.r.t the tariff rate,

$$\frac{\partial \left[t^I_{ig} \left(D_i - a_g \left(p_{wg} + \phi_{wi} + t^I_{ig} \right) \right) \right]}{\partial t^I_{ig}} = 0 \Leftrightarrow t^I_{ig} = \frac{D_i - a_g \left(p_{wg} + \phi_{wi} \right)}{2a_g}. \tag{6}$$

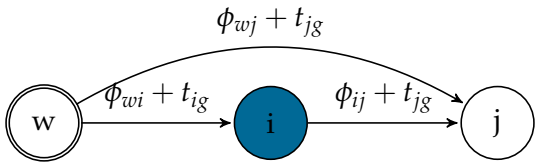

Figure 3: *Two states and the world. If the direct edge from w to j is more costly than via i, i gains potential revenue. If wj would be infinitely expensive, j would be an enclave of i.*

The total revenues any state i collects from tariffs is retrieved by summing up the revenues per good

$$R_i = \sum_{g=1}^{|G|} R_{ig} \tag{7}$$

3. Two States

Two states can either have access to world market at the same cost, or one state can have better access. In the latter case, their geographic position is asymmetric. Depending on their magnitude, asymmetries in geography determine transit trade.

(i) Symmetric Geography

Assume there exist two states i, and j, and there are no tariffs to begin with. There are two alternative routes from world markets to j, one direct and one via i, so that $W_{wj} = \{(w, j), (w, i, j)\}$. If the exogenous physical costs are symmetric, $\phi_{wi} = \phi_{wj}$, traders will be indifferent whether to import goods to j directly from w or via i. Hence, any tariff $t_{ig} > 0$ would incentivize traders to use the direct route. Therefore, i can not gain positive transit revenues.

(ii) Asymmetric Geography, No Transit Trade

Consider figure 3. Assume that $\phi_{wj} = \phi_{wi} + \phi_{ij}$. In the absence of any tariffs, traders are indifferent on which route to choose. It cannot be optimal for a revenue-maximizing state i, that can only raise income from tariffs, to set its tariff to zero to attract visitors. Rulers would hence optimize independently and there would be no transit trade at $t_i > 0$. Due to the higher transport costs of products from w, thus lower import demand, tariff revenue of j would be lower than tariff revenue of i at equal sizes $D_i = D_j$.

(iii) Transit Trade

Consider figure 3 once more. Now assume the more interesting case that asymmetry in physical transport costs is sufficiently large to allow for transit. The difference between the minimal costs of a path around i and the minimal costs of a path via i is positive,

$$h^j_{\{i\}} = \min_{r \in W_{wj}, \{i\} \not\subset r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) - \min_{r \in W_{wj}, \{i\} \cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) > 0 \tag{8}$$

Defining h with the set $\{i\}$, we can also formalize detours around more than one country, which will be in focus later. Substituting the physical costs as in figure 3, this yields

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

Due to relative geography, there is the possibility of transit trade of j's imports via i. In the absence of political costs, it would be certain. Whether traders find it cheapest to transit through i depends on the relationship of the detour costs and the tariff in state i. The higher $h^j_{\{i\}}$, the more expensive it is for trade to j to detour i, and the higher the threshold for t_i. As surveyed in the historical outline, transport technology on land relative to on rivers made it very probable that detour costs outweigh accepting political costs. State i can hence gain tariffs from transit, due to its relative geography. We call j being in the geographic hinterland of i, since traders would find it cheaper to satisfy demand in j via i, given a t_i below detour cost.

In the case that $t_{ig} < h^j_{\{i\}}$, traders would find it cheapest to route j's imports via i. State j, setting the revenue-maximizing tariff, has to include the tariff from i as part of the price of the imports. Therefore, the tariff that j will set is dependent on t_i, analogously to equation 6,

$$\frac{\partial \left[t_{jg}\left(D_j - a_g\left(p_{wg} + \phi_{wi} + t_{ig} + \phi_{ij} + t_{jg}\right)\right)\right]}{\partial t_{jg}} = 0 \Leftrightarrow t_{jg} = \frac{D_j - a_g\left(p_{wg} + \phi_{wi} + t_{ig} + \phi_{ij}\right)}{2a_g}. \tag{9}$$

From this it follows that both M_i and M_j depend on t_{ig}. Assume states do not discriminate between imports and transit, so that the same tariff applies to both. Therefore, allowing for imports, $h^j_{\{i\}}$ restricts state i's tariff level to the detour costs. This induces a trade-off between imports and transits, since detour costs would also limit the tariff on domestic imports. Specifically, state 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, or setting t_{ig} above $h^j_{\{i\}}$ and force traders to detour i[4]. The maximization problem of i can hence be spelled out as

$$R_{ig} = \max_{t_{ig}, d_{ijg} \in \{0,1\}} \left(t_{ig}(M_{ig}\left(t_{ig}\right) + d_{ijg} M_{jg}\left(t_{ig}\right))\right) \qquad \text{s.t. } d_{ijg} t_{ig} \leq h^j_{\{i\}}. \tag{10}$$

Proposition 1. *State planners face a trade-off between imports and transit trade when setting the tariff*

Proof. If state i forfeits transit trade to j, the tariff rate t_{ig} is retrieved as in the island case, $t_{ig} = t^I_{ig}$. Consider the tariff that state i can set allowing for transit trade to j, t^j_{ig}. The condition $d_{ijg} t_{ig} \leq h^j_{\{i\}}$ can be either binding or not binding, and $t^j_{ig} \leq h^j_{\{i\}}$. Consider the case that the condition is not binding, e.g. $h^j_{\{i\}} \to \infty$. State i would set the tariff allowing for transits to j, t^j_{ig} by setting up its revenue function's first derivative w.r.t t^j_{ig},

[4] As a tie-breaker, we assume that at equal overall trade costs, traders find it more convenient to use the route with the lowest physical trade costs.

$$\frac{\partial \left[t_{ig}^{j} \left(D_i - a_g \left(p_{wg} + \phi_{wi} + t_{ig}^{j} \right) + D_j - a_g \left(p_{wg} + \phi_{wi} + t_{ig}^{j} + \phi_{ij} + t_j \right) \right) \right]}{\partial t_{ig}^{j}} = 0, \tag{11}$$

replacing t_j from equation 9, and set its own tariff such that

$$\left[t_{ig}^{j} \mid h_{\{i\}}^{j} \to \infty \right] = \frac{\frac{2}{3} D_i + \frac{1}{3} D_j - a_g \left(p_{wg} + \phi_{wi} + \frac{1}{3} \phi_{ij} \right)}{2 a_g}. \tag{12}$$

Compare this tariff with the island tariff from equation 6. The resulting tariff can be higher, or lower than the island tariff, depending on the relative size of the countries, and the transport costsϕ_{ij}. The larger D_j is relative to D_i, the higher the tariff t_i^j. Neglecting relative size (e.g. $D_i = D_j$), the larger transport costs from w to j relative to w to i (since $\phi_{ij} > 0$), negatively affect t_i^j. State i would only find this beneficial iff

$$t_{ig}^{j} \left(M_{ig} \left(t_{ig}^{j} \right) + M_{jg} \left(t_{ig}^{j} \right) \right) \geq t_{ig}^{I} \left(M_{ig} \left(t_{ig}^{I} \right) \right) \tag{13}$$

Consider the case in which this tariff would be too high too allow for transit. If state 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, state i can set the tariff as if the detour costs would be infinity,

$$t_{ig}^{j} = \begin{cases} [t_{ig}^{j} \mid h_{\{i\}}^{j} \to \infty] & \text{if } [t_{ig}^{j} \mid h_{\{i\}} \to \infty] \leq h_{\{i\}}^{j} \\ h_{\{i\}}^{j} & \text{else} \end{cases} \tag{14}$$

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

$$d_{ijg} = \begin{cases} 1 & \text{if } t_{ig}^{j} \left(M_{ig} \left(t_{ig}^{j} \right) + M_{jg} \left(t_{ig}^{j} \right) \right) \geq t_{ig}^{I} \left(M_{ig} \left(t_{ig}^{I} \right) \right) \\ 0 & \text{else} \end{cases} \tag{15}$$

□

4. Three States

The inclusion of a third state introduces competition over trade routes. This is insightful, as we observe very low tariff rates in the harbor cities Bremen and Hamburg, which were two of Germany's gates to world trade. Changes in geography, as we will outline afterwards, can throw a state that maximized its revenue conveniently as an island into competition over trade routes.

Consider k as our third state, as in figure 4. There are three routes $W_{wk} = \{(w,k), (w,i,k), (w,j,k)\}$. The cheapest route goes via i, the second cheapest route goes via j, and the most expensive route is the direct one,

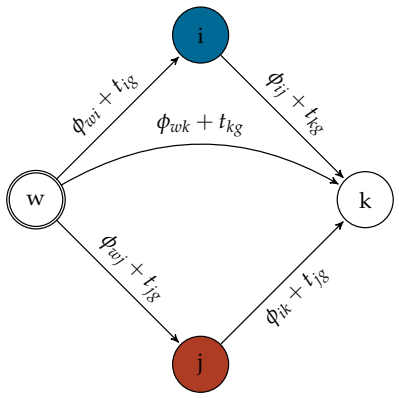

Figure 4: *Given that the direct route from w to k is very expensive, i and j might compete over transits*

$$h^k_{\{i\}} = \min_{r \in W_{wk}, \{i\} \not\cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) - \min_{r \in W_{wk}, \{i\} \cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right)$$

$$h^k_{\{i,j\}} = \min_{r \in W_{wk}, \{i,j\} \not\cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) - \min_{r \in W_{wk}, \{i,j\} \cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right)$$

This implies that traders face three options satisfying the demand in k,

$$min(cost_{wk}) = \begin{cases} \phi_{wi} + \phi_{ik} + t_{ig} + t_{kg} & \text{(cheapest route via i)} \\ \phi_{wi} + \phi_{ik} + h^k_{\{i\}} + t_{jg} + t_{kg} & \text{(second cheapest, detour i, via j)} \\ \phi_{wi} + \phi_{ik} + h^k_{\{i,j\}} + t_{kg} & \text{(detour both i and j)} \end{cases} . \tag{16}$$

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

Proof. Assume that D_k is sufficiently large and transport costs ϕ_{ik} and ϕ_{jk} are sufficiently low, so that both i and j would find it beneficial to allow for transit trade to k,

$$t^k_{ig} \left(M_{ig} \left(t^k_{ig} \right) + M_{kg} \left(t^k_{ig} \right) \right) \geq t^I_{ig} \left(M_{ig} \left(t^I_{ig} \right) \right)$$
$$t^k_{jg} \left(M_{jg} \left(t^k_{jg} \right) + M_{kg} \left(t^k_{jg} \right) \right) \geq t^I_{jg} \left(M_{jg} \left(t^I_{jg} \right) \right)$$

The optimal response of states concerning tariff policy becomes strategic, as i and j are competing for the transit flows of k. As long as t_i is below $h^k_{\{i\}}$, state j would have to set a negative tariff rate (which cannot be revenue-maximizing). Additionally, state i can safely increase its tariff above the level of $h^k_{\{i\}}$ to the point it expects j to lower its tariff rate to attract the transit. The maximization is given by

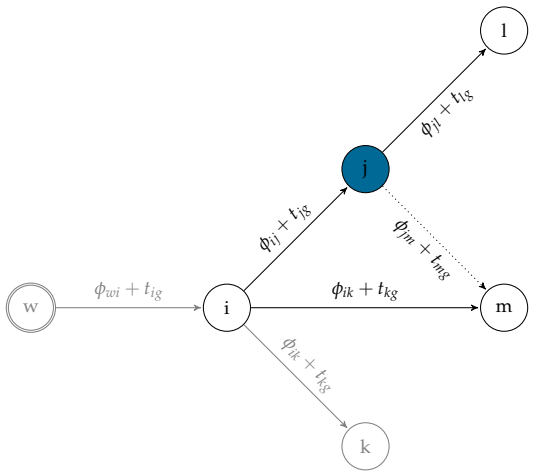

Figure 5: *State j can observe the price at i, all states that import via j, and also states that would import via j at a lower t_{jg} (dotted). Nonetheless, it cannot observe how the price at i is constructed. Also, it cannot observe other states that import via i (grayed out), and hence cannot anticipate i's decision*

$$R_{ig} = \max_{t^k_{ig}, d_{ikg} \in \{0,1\}} \left(t^k_{ig}(M_{ig}\left(t^k_{ig}\right) + d_{ikg} M_{kg}\left(t^k_{ig}\right))\right) \text{ s.t. } d_{ikg} t^k_{ig} \leq h_{\{i\}} + t^k_{jg} \tag{17}$$

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

$$t_{jg} = \begin{cases} t^I_{jg} & \text{if } \left(t_{ig} - h^k_{\{i\}}\right)\left(M_{jg}\left(t_{ig} - h^k_{\{i\}}\right) + M_{kg}\left(t_{ig} - h^k_{\{i\}}\right)\right) < M_{jg}\left(t^I_{jg}\right) \\ \left(t_{ig} - h^k_{\{i\}}\right) & \text{else} \end{cases} \tag{18}$$

which in turn means that i can safely raise its tariff until it expects j to be indifferent between $R_j\left(t^I_j\right)$ and $R_j\left(t^k_j\right)$.

□

5. Many States

The existence of more than three states introduces the possibility of coordination failure, and also multiple equilibria. We will continue with outlining some setups in which the model would yield different outcomes, depending on the sequence of decision, followed by the formal definition for many states.

(i) Incomplete Information and Coordination Failure

Consider figure 5. Imagine physical transport and/or relative sizes would be such that i would find it beneficial to allow for transits to j and l, but not for j alone. Now assume that concerning only it's own maximization problem, j would find it beneficial to exclude l from transits as well. In 1815, there exists

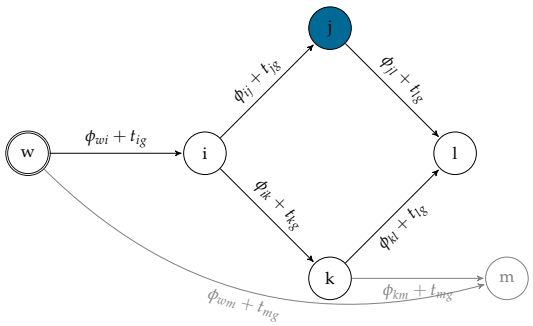

Figure 6: *State j does not observe m. If j and j compete over l, and m binds the tariff that k would set, the sequence of decisions matters.*

a lack of information regarding trade geography and statistics. States observed their hinterland, they observed where goods were coming from and also their prices, but they did not observe this for all the states on the way, nor other states' marginal demand necessary to not set island transits. We have to assume that j is not aware of i's reaction on setting $d_{jlg} = 0$, and hence cannot anticipate it. This is at the core of the historical problem—as we will show in the empirical analysis, this can explain the very large detours trade had to take after the Congress of Vienna.[5]

(ii) Sequentiality of Decision Making

The framework is closed up to three states, since in any such constellation one player has no options [6]. This reduces the number of decision makers to two, the standard in any game theoretical model. Once a fourth state is introduced, there can be constellations in which three states' decisions depend on each other.

Consider figure 6. Assume the the cheapest route to$m$ is (w, i, k, m), and the detour of m around k, ϕ_{km} is only marginally more expensive than (w, i, k, m). The sequence of decision matters: If j decides first, it's expectation on k is too high , since it cannot observe m. k will follow and gain also l. If k decides first, it would reveal m, and j would set its island tariff. Hence, two equilibria exist.

(iii) Initial Situation

State planers were constantly optimizing their tariff rate, so it is reasonable to assume that the sequence of decision-making is random. However, the initial situation[7] of the framework is exogenous: a starting point has to be defined, since it cannot be computed. As outlined in the historical background, tariffs after the Continental Blockade were extremely high, so we assume the inital state to be all states charging the island tariffs. Many states had very low supply of import goods. After the blockade, tariffs went down

[5] A theoretical solution would be either to coordinate between$i$ and j, however this would involve a credible information on each others decisions. Also, k and j could coordinate with i. Lump sum transfers would be another solution.

[6] A state without a hinterland does not have any decisions, and its tariff will be only dependent on geography other's tariff, as in equation 18. No state will go into "hunger strike" to force the other states to lower their tariff rate.

[7] We use the term "condition" in the sense of the state of a model in simulation, to avoid confusion with the political entity "state".

rapidly, which can be explained endogenously. States saw the opportunity to attract transit trade, and lowered their tariff to allow for demand from their landlocked hinterland.

(iv) Formal Definition for Many States

For many states, we are interested in the physical costs of the outside world markets w to any state i without crossing any other country of the set of states S considered. If there is no such direct link, costs are infinite,

$$\forall i \in S : \exists \phi_{wi} \qquad 0 < \phi_{wi} \leq \infty. \tag{19}$$

We add the direct route between any two considered states i and j,

$$\forall i, j \in S : \exists \phi_{ij} \qquad i \neq j, 0 < \phi_{ij} \leq \infty \tag{20}$$

This induces that traders have a set of routes to choose from to connect any two states. For any subset of states H that lie on the cheapest route from w to i, there are positive costs $h_i^H \geq 0$ of detouring H,

$$\forall i \in S \text{ and } \forall H \subset r \exists h_H^i = \min_{r \in W_{wi}, H \not\subset r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) - \min_{r \in W_{wi}, H \cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) \geq 0 \tag{21}$$

Finally, any state i would be maximizing their tariff revenue $R_i = \sum_{g=1}^{|G|} R_{ig}$. For any state j on which i lies on the cheapest cost path from w, state i anticipates the reaction tariff, so M_{jg} depends on t_i only. For any competitor k, state i has to anticipate Bertrand style competition over trade routes,

$$R_{ig} = \max_{t_{ig}, \forall_{j \in S \setminus \{i\}} d_{ijg} \in \{0,1\}} \left(t_{ig} \left(M_{ig} \left(t_{ig} \right) + \sum_{j \in S \setminus \{i\}} d_{ijg} M_{jg} \left(t_{ig} \right) \right) \right) \qquad \text{s.t. } \forall j \in S \setminus \{i\} : d_{ijg} t_{ig} \leq h_{\{i\}}^j + \min_{k \in S \setminus i} \left(t_{kg} \right). \tag{22}$$

Since competing states cannot coordinate, state j anticipates the reaction of its strongest competitor k. State k can set either the tariff to attract the transit t_{kg}^j, or a higher one $\left(t_{kg}^j + \epsilon \right)$ with $\epsilon > 0$,

$$t_{kg} = \begin{cases} t_{kg}^j & \text{if } \left(t_{ig} - h_{\{i\}}^j \right) \left(M_{kg} \left(t_{ig} - h_{\{i\}}^j \right) + M_{jg} \left(t_{ig} - h_{\{i\}}^j \right) \right) > M_{jg}^I \left(t_{kg}^I \right) \\ \left(t_{kg}^j + \epsilon \right) & \text{else} \end{cases} \tag{23}$$

6. Customs Union

The decision of any state i to join a customs union U is a trade-off between the network effect of the union, and its own geographic control. We will continue with each separately, and then establish the trade-off.

Definition 1. Following Viner (1950), a customs union is a set of states U that agree on a single tariff rate for imports and transits, and abolish internal borders.

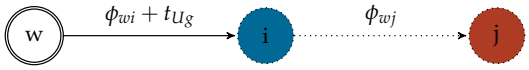

Figure 7: *A potential customs union between i and j would eliminate tariffs between i and j*

(i) Benefits from Joining a Customs Union: Coordination Benefit

In the above framework, the foundation of a customs union would be a vehicle to combine geographical advantages by bettering access to world markets. They would also create a larger domestic market (proposition 2). The possible set of customs unions is given by the powerset of S. Assume that a customs union faces the same optimization problem as given above, and any state would get a share π with $\forall_u : \sum_{i \in u} \pi_i^u = 1$ of its revenues. Any state i faces another binary decision $\gamma_i^u \in \{0, 1\}$, zero being staying independent and one joining the customs union, and the comparison of both revenues

$$\max_{\gamma_i^u \in \{0,1\}} \left(\left(1 - \gamma_i^u\right) R_{ig} + \gamma_i^u \pi_u R_{ug} \right) \tag{24}$$

Proposition 3. *The foundation of a customs union can create extra revenue, depending on relative size, position, the slope of the demand curve, and the absolute and relative levels of physical transport costs*

Proof. If two states i and j found a customs union $U = \{i, j\}$, they benefit from coordination[8].

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

$$R_{Ug} - \left(R_{ig} + R_{jg}\right) \geq 0.$$

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

$$\frac{\partial \left[t_{ug} \left(D_i - a_g \left(p_{wg} + \phi_{wi} + t_{ug} \right) + D_j - a_g \left(p_{wg} + \phi_{wi} + t_{ug} + \phi_{ij} \right) \right) \right]}{\partial t_{ug}}$$

$$\Leftrightarrow t_{ug} = \frac{D_i - a_g \left(p_{wg} + \phi_{wi} \right) + D_j - a_g \left(p_{wg} + \phi_{wi} + \phi_{ij} \right)}{4 a_g}. \tag{25}$$

Import volume M_u can then be calculated by solving equations 2–4 in reverse order. Multiplying this volume with t_{ug} as in equation 5, yields the union's revenues R_{ug}.

We set up the revenue function of independent j by inserting equation 12 into equation 9 to retrieve t_j, solve for M_{jg} from equations 2–4 (as pictured in figure 3), and insert t_{ig}^j and M_{jg} into equation 5. This yields optimal t_{jg}, the resulting imports M_{jg}, and finally R_{jg}. Revenue R_{ig} can then be calculated by inserting the tariff from 12, transit M_j, and imports M_i (from equations 2–4 reversely) into the revenue equation 10.

The difference[9], the network effect, is then given by

[8] In the context of industrial organization, this effect is known as "double marginalization", which can be avoided with vertical integration (see (Church and Ware, 2000, p. 685))

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

$$R_{ug} - \left(R_{ig} + R_{jg}\right) = \frac{-10D_i^2 + 32D_iD_j - 13D_j^2 - a_gD_i\left(12p_{wg} + 12\phi_{wi} + 56\phi_{ij}\right) - a_gD_j\left(6p_{wg} + 6\phi_{wi} + 58\phi_{ij}\right) + a_g^2\left[p_{wg}\left(9p_{wg} + 18\phi_{wi} + 114\phi_{ij}\right) + \phi_{wi}\left(9\phi_{wi} + 114\phi_{ij}\right) + \phi_{ij}\left(71\phi_{ij}\right)\right]}{144a_g}. \tag{26}$$

We will employ some comparative statics to analyze this network effect. Replace D_j by $D_i - \delta$, and consider first and second derivatives of the network effect w.r.t. δ. This yields that the relationship between the network effect and the relative size is convex. With increasing inequality in sizes, the network 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. As absolute transport costs decrease, it becomes more socially beneficial to found a customs union.

One main argument of the theoretical framework is to provide a background on the shift in relative physical transport costs. First and second derivative of the network effect w.r.t. ϕ_{ij} yield a concave function. The network effect is smallest at either extremely low or extremely high costsϕ_{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.

□

(ii) Losses from Joining a Customs Union: Geographic Control

Proposition 4. *Consider a state with a strong geographic position. The state will not join a customs union that distributes revenue proportional to state size*

Proof. It is puzzling how states such as Hamburg and Bremen, Germany's trade entrepôts, remained outside of the customs union even after the foundation of the German empire, almost half a century after others states. Primarily for administrative constraints, but also since Prussia imposed this distribution, revenue in the Zollverein was distributed per head. Therefore, a customs union $u = \{i, j\}$ would distribute revenues as follows

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

Compare figures 3 and 7. Consider the case in which state$i$ has a strong geographic advantage over j, so that $h_{\{i\}} > t_{ig}^j$ (equations 13 and 12). When deciding over joining the union, i faces the trade-off (equation 24),

$$\max_{\gamma_i^u \in \{0,1\}} \left(\left(1 - \gamma_i^u\right) R_{ig} + \gamma_i^u \frac{D_i}{D_i + D_j} R_{ug} \right) \tag{27}$$

We set up the revenue function[10] from independent i and the union u, and undertake some comparative statics as in proposition 3.

The effect of relative size is concave. The smaller the absolute $\delta = D_i - D_j$, the larger the control effect.

Considering the level of relative physical costs, we find a negative link between control effect and ϕ_{ij}, bearing the same intuition as with the network effect. □

(iii) Trade-off Between Network Effect and Control

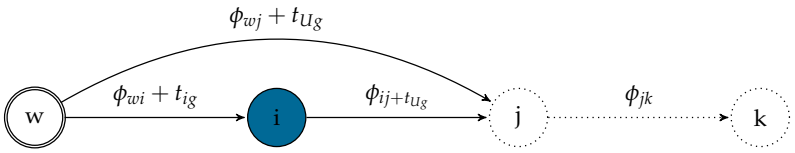

Figure 8: *State i faces a trade-off between control and network-effect*

Theorem. *Revenue-maximizing states face a trade-of between network effects and control when deciding whether or not to join a customs union. The decision is based upon its relative size and position.*

Proof. Consider figure 8. There exists a customs union $U = \{j, k\}$. State i can decide whether to form a customs union $U' = \{i, j, k\}$. From equation 24 it follows that i faces a binary decision between the revenue from staying independent, R_{ig}, and it's exogenously determined share $\pi_i^{U'}$ of the customs union's revenue $\pi_i^{U'} R_{U'}$.

We established that there is a positive network effect from joining the customs union (proposition 3). In contrast, if a state 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 and second derivative of the network effect (equation 26 and the control effect (27) w.r.t p_{wg}. The difference of first and second derivative of network effect and control effect can never be negative under the assumption that all variables are positive and there is demand in all countries. This yields that with increasing world market price, the union becomes more attractive. We will exploit this property later in the empirical strategy to abstract from world prices.

□

7. Many Goods

Assume that the set of goods traded $G = (g_1, g_2, ...)$ is conveniently ordered by price elasticity in increasing order, so that $a_{g_1} < a_{g_2}$, etc. Historically, the majority of tariff revenue was generated with coffee, sugar, and alcoholic beverages (Onishi, 1973). What all these goods have in common is their extremely low price elasticity: they are all drugs. Concerning substitutes, only negligible European supply existed. Consider now that the tariff t is a not continuous variable, but discrete. First, coins are not infinitely dividable.

[10] Please find the algebra in the technical appendix.

Second, control of tariffs comes with specific per-unit controlling costs. In the Prussian tariff forms that survived in the archives to the day, traders had to fill out their taxable carriage. As follows from equations 5 and 12, optimal per-unit tariff and price elasticity are negatively linked. Hence, there is a good at which the per-unit control costs are not paid by the carriage, and hence the tariff would be set to zero to save the control costs. In the Prussian Law from 1818, this is true for trees, wood, milk, fruits, and also stones (Prussian Customs Law, 1818).

To estimate the effect of different coalitions or shifts in geography, we can therefore start with the good with g_1, and proceed through the the set of goods. Any included good will have, through the elasticity, lower effect on the revenue of the state.

B. From the Congress of Vienna to the Zollverein

We will apply our theoretical framework to the formation of the Zollverein. In a broader context, it is well known that the success of some places is not only induced by their local characteristics, but their position relative to others. 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. First, we will outline why we consider the events at the Congress 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 highlight 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. In our empirical section we will use our model to replicate 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, 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[11]: In order to ease the defense of its territory and capital, he intended to finally

[11] This military-strategic argument was already developed by Friedrich II (1712–1786), probably during the Seven Years War

annex the Kingdom of Saxony (Clark, 2007, p. 389). Castlereagh consented under the condition that Prussia would support the British position in the Polish Question[12], so does Metternich[13]. 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 a new war. The response was a defense alliance between Great Britain, Austria and France against Prussia and Russia and a serious risk 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 expansion to the west. 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). 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. 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. 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. In this 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.

(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).

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

[13]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.).

Trade policy was at center stage for government revenue at the time. 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 on the detour routes, such as the Hessian states, this was a large source of income.

Traders were often willing to pay transit tariffs, because they lacked alternatives. In the early 19th 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. Railroad construction started in Germany only in 1835, where 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 relatively 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. Second, all these goods are 'drug-alike', which suggests that demand should respond relatively little to variation in prices. Domestic produce of wine and spirits accounted only for a seventh of demand (Dieterici, 1846). Coffee, unlike tobacco that accounted for half of domestic demand (Dieterici, 1846), could not be grown. According to Onishi (1973) these three goods alone accounted for more than half of Prussia's revenues from tariffs in the 1820s.

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. As already noted by Adam Smith, "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[14]. (Wilson, 2016, p. 469) views the inability to coordinate Rhine states as a major failure of the Holy Roman Empire. Running

[14]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.

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."[15]. This outlines a central motive of Prussia—exploiting the geographic position to raise tariff revenues *induced by, and not in spite of* trade liberalization. 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 small German states' debt 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, W ürttemberg, 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 the interests of Baden and Hesse-Darmstadt diverged too far from those of Bavaria and Württemberg. Calls upon Austria in the early 20's to lead a tariff union, prominently 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

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

small state itself was divided into two territories and economically more dependent than others on the neighboring Rhineland, now under Prussian control. A first push 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 exchange to Hesse-Darmstadt's agreement to adopt the Prussia customs law of 1818, in February 1828 the two states formed a customs union between two equal sovereign partners, where changes in tariff policy would have to be agreed unanimously (Hahn, 1984, p. 46). The strategic value of this can be seen in the externalities of this Prusso-Hessian customs union on other states, foremost on Southern Germany. 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 desperate. 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. 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 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 use the benefits from the industrializing regions in the West for its rise as a military power. In the next section we show that our theoretical model can explain many of these historical facts: 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 and how the liberalization of the Rhine in the wake of 1830/31 mattered for this. Crucially, the model also highlights that a different outcome of the Congress of Vienna would have likely prevented the formation of the Zollverein altogether.

C. Empirical Strategy

A key challenge for our empirical work is that states decisions to join the Prussian Zollverein (or not) were not independent of each other. We argued how some states' decisions (notably Prussia's) were less constrained than others, and that many states reacted on Hessian decisions, which in turn also were dependent. This interdependence was caused by trade flows, since traders would adapt to changes in tariff geography. Given the overall scarcity of observations, this rules out the use of the common econometric tool box, such as panel models on binary choice outcomes. Instead, our strategy is to test our theory by calibrating the theoretical model with historical trade data and historical geography, then simulate the model under various settings of political borders and customs unions and compare the outcome with the historical facts.

We will first outline the effect that we expect to find in our empirical analysis, before we explain the calibration. This is then followed by the outline of geographies we test assuming first that all states act autonomously. Building on the results for autonomous states, we run simulations on different custom unions.

1. Expected Effects of the Congress of Vienna

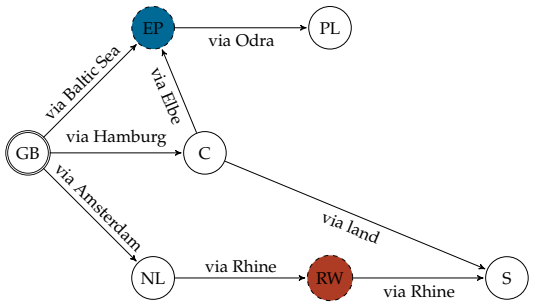

Figure 9: *Network position of Pre-1815 (Eastern) Prussia (EP), the Rhineland and Westphalia (RW). If Prussia would have stayed an Eastern European state, its direct sea access and relatively minor hinterland of Congress Poland (PL) would have motivated it to focus on domestic demand. Central Germany (C), a group of states acting autonomously, Southern Germany (S), also a group of states, and Rhineland and Westphalia would have possibly developed autonomously.*

Given the complexity of the framework, it is useful to formulate the expected simulation results. The central claim of this paper is that in the absence of events in Great power politics in 1815 that can be considered to be exogenous from a perspective of any German state, Prussia would have been in no position to unify Germany. The shift in geography due to the Congress of Vienna is displayed in figure 9. In the borders that Hardenberg was aiming for, Prussia would have controlled the river Elbe, with a relatively minor hinterland. The large population of 1.5 mio. that remained Saxon, would have contributed to Prussia's domestic demand if Hardenberg would have been successful. Also, the mouth of the Elbe is Hamburg. The Baltic Sea harbors Prussia controls directly, and also the Odra, would have allowed Prussia to act independently of other German states, but also be without influence over them. The model would predict that Prussia would set its tariffs relatively autonomously, and show no interest in the politics of the tariff policy of smaller German states. Rhineland and Westphalia, and also Southern

Germany, would be more likely to collaborate without the participation of Prussia, notably due to their waterway links. The large market of the Netherlands with as much as 2.6 million inhabitants would have allowed it to concentrate on its domestic demand, putting less emphasis on transit trade.

From the Belgian revolution in 1830/31, we expect from the model that the Netherlands, about split in two halves with competing harbors, adjust their tariffs downwards as each of their domestic demand shrinks relative to possible transit flows. This should weaken the position of the Central German states, notably the Hessian states, as trade via the Rhine becomes relatively cheaper.

We will test whether our theory can capture the perceived importance of the Hessian states, and to what extent their position is weakened by the Belgian revolution. Also, we will test whether a customs union between Prussia and Hesse-Darmstadt would have been as disastrous for Southern Germany as the historical narrative suggest. Next, we will test whether a customs union between the two Hessian states and Prussia indeed leaves the Southern German states without a choice but to also join. This includes to test whether this was different for German states closer to the coast. And finally, we will run all these tests also for the counterfactual geography of Prussia that received the whole Saxony, and not the Rhine, at the Congress of Vienna.

2. Calibration

We calibrate our model assuming that one unit equals one kilogram of a good. 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) [16]. Physical transport costs 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, transshipment costs taken from Sombart (1902). To account for the variation in the size of states, larger territorial states are split into their first geographical subdivision to analyze demand[17]. A region's demand is assumed to be concentrated in it's capital.

We face strong restrictions induced by the calculatory complexity, which forces some assumptions upon us. The calculation of the detours around states is not trivial. Consider any route crossing the states r. The amount of detours around each (or a subset of) these states, is the cardinality of the powerset without the destination i (that cannot be detoured) minus the one case for the full set, $|\mathcal{P}(r \setminus i)| - 1 = 2^{|r|-1} - 1$. For the 1820 map of Central Europe alone, 116,547 detours were calculated.

Assuming uniform income distribution and preferences across states, we can compute demand per-capita, and aggregate this over the population in the states (or customs union). Following the theoretical framework, we assume demand to react on price in a linear way. For the three goods of interest, coffee, sugar, and alcoholic beverages, we fitted per-capita consumption in Prussia 1820–1830 from Dieterici (1846) and Ferber (1829) with London price data from Clark (2010) to infer the demand curve for the three

[16] 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.

[17] Prussia (9 parts), Austria Hungary (9), Bavaria (8), Hanover (7), France (6), Baden (6), Saxony (5) W ürttemberg (4), Hesse-Darmstadt (3), Saxony-Weimar-Eisenach (2), Oldenburg (2), Saxony-Coburg-Saalfeld (2), and Sachsen-Gotha-Altenburg (2)

goods as[18]

$$M_i = \begin{pmatrix} M_{i\,\text{coffee}}[kg] \\ M_{i\,\text{sugar}}[l] \\ M_{i\,\text{wine}}[l] \end{pmatrix} = \begin{pmatrix} pop_i \left[1.1054 \frac{kg}{capita} - 0.1065 \left(8.986 \frac{\mathbb{M}}{kg} + \min\limits_{r \in W_{wi}} \left(cost_r \left[\frac{\mathbb{M}}{kg} \right] \right) \right) \right] \\ pop_i \left[8.3785 \frac{kg}{capita} - 4.2379 \left(1.555 \frac{\mathbb{M}}{kg} + \min\limits_{r \in W_{wi}} \left(cost_r \left[\frac{\mathbb{M}}{kg} \right] \right) \right) \right] \\ pop_i \left[1.3057 \frac{l}{capita} - 0.0527 \left(5.397 \frac{\mathbb{M}}{l} + \min\limits_{r \in W_{wi}} \left(cost_r \left[\frac{\mathbb{M}}{l} \right] \right) \right) \right] \end{pmatrix} \tag{28}$$

Tariffs were not set in a continuous way, e.g. due to natural limitations of divisibility of money. Historically, specific tariffs were administered in form of tables displaying good categories and specific tariff rates. In the case of Prussia, this was part of the customs law (Prussian Customs Law, 1818). The run-time of the simulation grows in a quadratic way with increasing precision of the tariff rate[19]. We therefore assume that adjustments of tariffs were taken in steps of one percent of the island tariff. The outcome of the simulation yields the optimal tariffs and the overall tariff revenue from the three goods for all the states and simulated unions S,

$$\text{Solve for all } i \in S : R_i = \sum \begin{pmatrix} t_{i\,\text{coffee}}[\frac{1}{kg}] \left[\sum\limits_{j \in S} \left(M_{j\,\text{coffee}} | d_{j\,\text{coffee}} = 1 \right) [kg] \right] \\ t_{i\,\text{sugar}}[\frac{1}{kg}] \left[\sum\limits_{j \in S} \left(M_{j\,\text{sugar}} | d_{j\,\text{sugar}} = 1 \right) [kg] \right] \\ t_{i\,\text{wine}}[\frac{1}{l}] \left[\sum\limits_{j \in S} \left(M_{j\,\text{wine}} | d_{j\,\text{wine}} = 1 \right) [kg] \right] \end{pmatrix}. \tag{29}$$

With this, the outcome vector of the simulation features the optimal routes (d_{ij}, with endogenous tariffs t_i, all states' imports $[M_j | i = j]$ and transit trade $[M_j | j \neq i]$, and also their overall revenue R_i.

3. Simulation for Autonomous States

The calculation treating all states as autonomous represents the basis for comparisons between different customs unions.

The model requires to be provided an initial condition from which all states can then endogenously determine tariff rates. A natural starting point is the trade situation in 1815, which was also a watershed in trade history. The Continental Blockade just ended, trade volumes were extremely low. We assume that every state only considered the demand of its own territory in its optimization. This of course results

[18] The form is a corollary of equations 2 and 3 of the theoretical framework. 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.

[19] Let $|S|$ be the amount of states, and $|T|$ the amount of possible tariffs. For any good, $|S|$ states set $|T|$ tariffs, anticipating $(S-1)$ states' reactions (in the worst case), which yields a limiting behavior of $\mathcal{O}\left(|T| * |S|^2\right)$. A one-digit increase in precision comes at the cost of a hundredfold run-time.

in very high tariff rates. Countries with sea access set the highest tariffs, single landlocked states react by setting theirs, and all states that are double or more than double landlocked face zero import demand (and hence zero tariff revenue). Directly after the war, state planners considered transit trade, and indeed there was a trend of lowering tariff rates. In our simulation, we represent this by running five rounds of tariff setting. In each round, all states set their tariff rates as outlined in the model, deciding in random order (hence the outcome of the simulation is non-deterministic). As predicted by the model, we find a decrease of average tariff rates in each of these rounds. We disregard the outcome of these five rounds as 'post war chaos'.

After five rounds, we assume that the initial state is sufficiently 'washed out' by the random order of decision making. In most of the simulations, only minor changes in tariff rates were registered already in round three, so these situations were relatively steady[20]. For each state, this yields the average of tariff rate set, and expected revenue. These data is used to compare both between different cases of autonomous states. Also, these data are the reference point for the decision on a customs union.

We consider four different states of geography, leaving population constant at its 1820 level using data from Kunz and Zipf (2008) and Mitchell (2007). This is justified since population growth in the 1820's was relatively similar across states and migration in the period was highly regulated, and mostly directed towards Prussia (Nipperdey, 1983, p. 110f.). Also, as outlined by Venables (1999), migration is endogenous to tariffs, and the effect of migration should have the same direction as the argument of our model. We simulate four different shapes and sizes of Central Europe:

A1 **Factual 1815 Map**, the state of Germany and its surrounding 1815, the Netherlands, the six most Northern départements of France, Switzerland, Neuchâtel, Austria Hungary, Krakow, and Congress Poland. All other states are islands in the sense of the model.

A2 **Hardenberg's 1815 Map**, the geography as of **A1**., altered by the counterfactual that Prussia would have consisted of its Eastern territories plus the Kingdom of Saxony, but Rhineland and Westphalia form a new single, autonomous state.

A3 **Factual 1831 Map**, case **A1**, but with Belgium and the Netherlands as two autonomous countries, as after the Belgian revolution.

A4 **Hardenberg's 1831 Map**, case **A3** with the alterations to the Prussian geography as of **A2**.

4. Simulated Customs Unions

Any state that joins a customs union compares current income with income after joining. Therefore, the simulated customs unions are calculated starting with autonomous states, and then run five rounds of optimization.

For the customs union, we assume that there is only one common tariff for the union. The simulated customs unions follow the factual and counterfactual constellations as proposed by the historical narratives,

[20] Again, the simulation is very intense in calculation. With any new round, the routes are more competitive and more anticipation has to be calculated. Hence, iterating until the steady state comes with rising costs per round. The results are acceptably steady already after round three.

U1 **The Factual Zollverein**, as observed after the Belgian revolution, based upon the factual 1831 Map **A1**.

U2 A counterfactual **Early Zollverein**, a customs union under Prussia's leadership that would have been founded already before the Belgian Revolution. Its calculation is based upon the factual 1815 Map **A1**.

U3 A counterfactual **Hardenberg's Zollverein**, a customs union under Prussia's leadership that excluded the Rhineland and Westphalia, based upon Hardenberg's 1831 case **A4**.

U4 The **Southern German Zollverein**, a customs union between Bavaria, Württemberg, and Baden, that proved to be unstable. It is based upon the factual 1831 Map **A3**.

U5 The factual **Prussian-Hessian customs union of 1828**, in its situation after the Belgian revolution, based on **A3**.

U6 A counterfactual customs union between **Prussia and Hesse-Darmstadt**. It is based upon the factual 1831 Map **A3**, so that we expect the Dutch trade policy to be relatively open.

U7 A counterfactual customs union between **Prussia, Hesse-Darmstadt and Hesse-Cassel**, as argued by historians the worst fear for Southern Germany. It is also based upon the factual 1831 Map **A3**.

U8 A counterfactual **Western German Zollverein**, a customs union between Rhineland-Westphalia, Bavaria, Württemberg, based upon the factual 1831 Map **A3**. Note that this union includes the core of the Federal Republic of Germany 1948–1990.

D. RESULTS

In this section we use our theoretical model, calibrated to historical data, to answer three main questions on the formation of the German Zollverein: why did some German states decide to join the Prussian Zollverein, while others decided against this? Why did this not happen immediately after the congress of Vienna in 1815 but only in the 1830's? And finally, was Prussia's "relocation to the Rhine" Nipperdey (1983) causal for the formation of a German Zollverein? As the relevant outcome variable for revenue maximizing state rulers, we always consider the revenue per capita under different circumstances.

1. Geography, and Revenue of Autonomous States

In a first step we consider the revenue per capita assuming autonomous states for the factual political borders, both in 1820 and after the independence of Belgium in 1831. Table 1 shows the results for some key states. We see that overall states closer to the coast are much better off than states further south, and that according to our model, the Belgian revolution had only a very minor impact on the structure of trade across German states. We will see however that these results change, once we take the various customs unions into account.

Table 1: *Per-capita revenue of selected states in the calibrated GIS model assuming each states optimizes autonomously*

P.c. revenue	Factual 1820	Hardenberg 1820	Factual 1831	Hardenberg 1831
Bremen	141.69	98.47	126.96	99.58
Baden	2.91	1.79	1.57	2.51
Bavaria	1.18	0.58	1.08	0.85
Hanover	10.68	14.84	16.04	10.76
Hesse-Darmstadt	5.41	5.08	4.52	6.37
Hesse-Cassel	8.01	2.52	9.15	3.90
Luebeck	25.77	28.54	28.87	29.16
Oldenbourg	5.91	7.72	6.60	6.23
Prussia	3.77	3.20	3.44	3.25
Saxony	0.11	3.57	0.58	5.24
Württemberg	0.53	0.81	0.79	0.91

Table 2: *Simulated per-capita revenue with the calibrated GIS model considering different factual and counterfactual customs unions. Income as distributed within unions set in italics.*

P.c. revenue	Southern German C.U.	Pr. & H.-D.	Pr., H.-D. & H.-C.	Zollverein 1840
Bremen	154.71	79.18	45.66	5.98
Baden	*9.84*	0.00	1.07	*6.40*
Bavaria	*9.84*	0.70	0.38	*6.40*
Hanover	13.07	7.38	2.78	*6.40*
Hesse-Darmstadt	1.04	8.82	*10.45*	*6.40*
Hesse-Cassel	4.88	*7.56*	*10.45*	*6.40*
Lübeck	11.73	32.24	32.75	36.93
Oldenbourg	6.90	7.95	7.46	*6.40*
Prussia	3.60	*8.82*	*10.45*	*6.40*
Saxony	0.69	0.07	0.15	*6.40*
Württemberg	*9.84*	0.47	0.25	*6.40*

2. Simulated Customs Unions

Based on the results for autonomous states as described in the previous section, we now simulate the effect of customs union on trade and the resulting revenue per capita (table 2). We assume throughout that each customs union distributed tariff income among its members proportional to population shares. Again we consider the same list of states, but now with changing membership in the different customs unions. Let us first consider the formation of the Southern German customs union. Compared to the situation in 1820 of autonomous states, our model suggests that this customs union was very beneficial to Southern Germany while it did little to change the position of Prussia, that it put pressure on the Hessian states, notably on Hesse-Darmstadt, and that it hardly affected the coastal states. In this light, the customs union between Prussia and Hesse-Darmstadt looks according to our model as the obvious answer. Compared to the benchmark of autonomous states in 1820, this is very beneficial to both Prussia and Hesse-Darmstadt, largely at the expense of the Southern states. Instead, the coastal states are hardly affected at all. Once we consider the extension of this customs union by Hesse-Cassel in 1831 we see that this is beneficial for all three members involved, but again at the expense of the Southern states. In both cases we also see that Saxony suffers from facing a new trading bloc on its way to the coast that can hardly be detoured. In consequence, the model suggests that Saxony sees its revenue from trade decline. Given this, the final outcome of the Zollverein, encompassing Prussia, the Hessian states, Saxony and the Southern German states (as well as several minor states) from 1834 onwards is a clear improvement for the former outsiders. It is according to our model however less clear, why the Hessian states, notably Hesse-Cassel, agreed to this. In this vein, our model suggest that the Zollverein was considered by Prussia not only as a tool for maximizing tariff revenues but to generate other benefits as well.

3. Simulation with Counterfactual Borders

Table 3: *Simulated per-capita revenues with the calibrated GIS model assuming an independent Rhineland-Westphalia and a Prussia that includes the whole of Saxony*

P.c. revenue	Autonomous 1820	Autonomous 1831	Zollverein 1840
Bremen	98.47	126.96	48.54
Baden	1.79	1.57	*6.00*
Bavaria	0.58	1.08	*6.00*
Hanover	14.84	16.04	8.10
Hesse-Darmstadt	5.08	4.52	*6.00*
Hesse-Cassel	2.52	9.15	*6.00*
Luebeck	28.54	28.87	33.25
Oldenbourg	7.72	6.60	3.78
Prussia	3.20	3.44	*6.00*
Rhineland-Westphalia	3.57	0.58	5.05
Wurttemberg	0.81	0.79	*6.00*

Lastly, let us consider the implications of a couterfactual set of political borders (table 3). If we assume that count Hardenberg, the Prussian negotiator at the Congress of Vienna, would have succeeded with

his strategy to "arronde" Prussia with the Kingdom of Saxony and instead create in exchange a new state 'Rhineland-Westphalia', would the Zollverein have formed? For this thought experiment, we first generate revenue per capita for autonomous states in 1820 and 1831 (after the Belgian revolution) based on such a counterfactual map. Against this we then compare the revenue per capita resulting from the formation of various customs unions. To start with we see that the coastal states would have again been in a more comfortable situation compared to their central and southern German counterparts. In both 1820 and 1831, their revenue per capita is higher than in the South. We also note that our model now suggests an improved position for Hesse-Darmstadt. It is clearly less dependent on Prussian trade and can according to our model generate higher revenues from autonomous trade policy. Let us now consider the effect of the formation of the Zollverein (which is actually the same as above under factual borders) to several alternatives. A counterfactual Zollverein excluding the Saxon state on the Rhine would have been less attractive than the factual Zollverein, but also rather less likely to emerge in the first place.

E. 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. TABLES

Table 4: *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

Table 5: *States (partially) enclaved by Prussia ordered by decreasing share of affected territory. GIS calculations.*

State	Share [%]
Anhalt-Dessau	100
Hohenzollern-Hechingen	100
Anhalt-Köthen	100
Schwarzburg-Sondershausen	61.7
Schwarzburg-Rudolstadt	19.5
Sachsen-Weimar-Eisenach	3.4
Braunschweig	3.1
Sachsen-Gotha-Altenburg	2.3
Lippe-Detmold	2
Mecklenburg-Schwerin	0.7