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Abstract

This paper explores the pattern of agricultural productivity across 19th century Prussia to gain new insights on the causes of the "Little Divergence" between European regions. We argue that access to urban demand was the dominant factor explaining the gradient of agricultural productivity as had been suggested much earlier theoretically by von Thünen (1826) and empirically by Engel (1867). This is in line with recent findings on a limited degree of interregional market integration in 19th century Prussia.

JEL Codes N53, O43, O47, Q13, R12.

Keywords: Prussia, Agricultural Productivity, Industrialisation, Market Access

I. Introduction

The literature on the historical origins of differential economic development, especially the debate on the "Great Divergence" between Europe and Asia (Pomeranz 2000) has recently sparked a new interest in the roots of differential development within Europe. A growing number of empirical studies (Clark 1987; Allen 2001, 2009, pp. 25-56; Pamuk 2007) supports the older historiography's thesis that an emerging gradient of economic development from North-West Europe to the East of the continent unfolded from about the Late Middle Ages onwards (Gerschenkron 1962; Pollard 1981). However, our knowledge of the factors that can account for this divergence is still rather limited. In this paper we will explore to what extent agriculture mattered for this differential development across the European continent. Specifically, we consider the case of 19th century Prussia, a state that was then spanning over nearly 1200 km from regions located today in Belgium to regions in today's Russia.

Agriculture plays a dominant role in explaining the historical roots of Central and Eastern European backwardness (Warriner 1939; Wallerstein 1974; the contributions in Aston and Philpin 1985; Chirot, 1989; Gunst 1996). In turn, differences in agricultural productivity feature prominently in this debate. Taking Great Britain's development as the role model for 19th century-Europe a preceding agricultural revolution is often considered as a 'conditio sine qua non' for successful industrialisation elsewhere in Europe. In this view governmentally enforced liberal agrarian reforms that created an institutional framework for capitalist agriculture based on free labour and private ownership of land were seen as an essential pre-condition to trigger urbanisation and industrialisation. Without it Central and Eastern Europe failed to catch-up to the West (paradigmatically Komlos 1989).

On the other hand, it has long been argued that causation might run the other way: demand from cities with non-agricultural activities such as crafts, proto-industry, trade, and later on industry generated incentives for an intensification of agriculture. Early prominent exponents of an (urban)-demand induced agricultural development were the classical economists, notably Adam Smith (1776) and Johann Heinrich von Thünen (1826). These classical ideas have recently been invoked again to explain the rise of North-Western Europe to the world's most productive agricultural region until 1800 (De Vries 1974; Wrigley 1987, 1988; Grantham 1989a, 1999; Kussmaul 1990; Hoffman 1996; Van Zanden 1999; Allen 2000, and notably Campbell 2010). Obviously, the same argument can be applied to the performance of farming outside of North-Western Europe. In this view, a lack of 'thick-market externalities' resulting from expanding urban-industrial agglomerations (Krugman 1991) might have prevented a more dynamic agricultural development.

On the following pages we consider the interaction between agricultural and wider economic development in the context of Central and Eastern Europe. More specifically we want to do two things. First, we aim to map the differences in agricultural development at a fine level of geographical detail across large parts of the continent in a strictly comparable way. Second, we want to test, to what extent the observed pattern can be explained by differences in access to urban (or non-agricultural) demand as opposed to other factors such as institutional differences and their legacies or variation in natural conditions.

We argue that the Kingdom of Prussia is well suited to shed light on these issues, because we have good data on a lot of regional variation along all the crucial dimensions: agricultural productivity, access to urban demand, quality of soil, and institutional legacy. After the congress of Vienna in 1815 Prussia was the only European Empire which simultaneously encompassed regions belonging to the European 'growth nucleus' in the North-West as well as regions that were part of the 'Central-Eastern periphery'. Prussia was spanning over nearly 1200 km from areas left of the Rhine which today belong to Belgium (Eupen-Malmedy) to the Memel territory east of the river Neman which is now divided between Lithuania and Russia. The detailed statistics provided by the Prussian state on its very different regions can be readily compared.

The Prussian data also allows us to explore the effect of institutional variation on agricultural development. To start with, Prussian agrarian reforms were not only seen by Lenin in his theory of the 'Prussian way' but equally by many liberals and 20th century-historians as most successful in inducing capitalist agricultural and industrial growth compared to other Eastern European Empires like Austria-Hungary and the Tsarist Empire (Boserup 1972). The Prussian state of 1815 encompassed not only regions that had experienced such liberal reforms, but also regions affected by very different forms of agrarian reforms in the late 18th century and the beginning of the 19th century. In the newly gained large Western and Eastern (Baltic) territories the Prussian reform legislation after 1815 legalized the results of various preceding policies to abolish the Agarverfassung (agrarian institutions) of the 'ancien regime'. Thus, we find nearly the entire possible spectre of ways to replace the Grundherrschaft (seigniorial system) and Gemeinheiten (commons) by a system of full private property ownership covered within the Prussian state after 1815. This stretched from expropriation of peasants without any seigniorial compensation, through different ways of abolishing seigniorial rights against peasants' redemptions to their former lords in money or land, to the abolition of seigniorial rights without any redemption to the nobility as result of the French revolution. In consequence, due to different historical legacies, there was a strong and persistent variation in terms of average farm sizes from small family farms predominant in the West to large estates in the East, especially east of the river Elbe ("East-Elbia"). Hence, despite its regional diversity the Prussian reform legislation after 1820 created a rather uniform legal framework for the entire Prussian Kingdom literally from the river Maas to the river Nemen, which took these historical legacies in terms of property rights as given. For that reason agricultural performance can be analysed under the condition of a uniform institutional framework founded on private property of land and liberalised labour markets but with significant variation in institutional legacies as reflected in farm sizes.

Our analysis is based on a highly standardised data set comprising the entire Kingdom of Prussia. On behalf of the Prussian government the Prussian statistician and scholar August Meitzen collected and published in four out of eight volumes on more than 2000 pages agricultural statistics covering all of Prussia, disaggregated into 342 Prussian counties in 26 administrative districts and 8 provinces before the border changes after the wars of 1864 and 1866 (Meitzen 1868ff). Until now a quantitative analysis of this excellent data is still outstanding. This data allows us to consider several indicators for agricultural productivity in a cross-section around 1865 at the county level. A notable feature of the data is that it provides a direct measure of the profitability of land, i.e. of land rents for various types of farm land subdivided by soil quality. It also includes demographic and economic indicators at a regionally highly disaggregated level. This is related to the fact that the data have been collected in the course of re-estimating the Prussian land tax 1861/65 (Grundsteuergesetz vom

21. Mai 1861), which aimed at taxing the income derived from land holdings deliberately under consideration not only of variations in soil fertility but also market access. Hence, in difference to nearly all existing historical studies this enables us to analyse the determinants of that share of agricultural output that was actually marketed, which should be the relevant variable to study the interaction between agriculture and general economic development.

In the next section, we will put our ideas in the context of the (large) earlier literature on agricultural productivity and development of Prussia. Section III describes our data on agricultural productivity and its spatial pattern across Prussia around 1865. In section IV we present data on several candidate factors that might explain the observed pattern, including a measure of access to urban demand, soil quality and institutional legacies. Section V presents a simple theoretical framework in the spirit of von Thünen (1826). This framework delivers some testable hypotheses to guide our empirical analysis in section VI. We estimate the key hypotheses; especially that – controlling for several other factors - agricultural productivity will be largely a function of access to demand outside of agriculture, where aggregate productivity is largely driven by changes in crop mix and changes in factor intensity. This section also contains robustness checks, notably instrumental-variable-estimates to deal with possible endogeneity bias in our estimates. We summarize our results in section VII and conclude with an outlook on further research.

II. A brief review of the literature on Prussia

We argue in this paper that agricultural productivity across Prussia is best explained in the framework of a land-use model building on von Thünen (1826). This is in stark contrast to the conventional perspective that prevails in the literature on Prussia. Until the 1970s the historiography on Prussian agrarian reforms and agricultural development 1800-1870 was strongly influenced by the institutional economics approach of the *Younger Historical School* represented by scholars like Georg Friedrich Knapp (1887), Max Weber (1906) and Werner Sombart (1903). Besides making the liberal agrarian reforms responsible for the rise of an East Elbian rural proletariat as a result of legalized mass evictions of peasants these authors were convinced that the development of highly productive capitalist large estates in the East allowed to feed the growing (industrial) German population in the West (Sartorius von Waltershausen 1923, p. 124). In this literature, agricultural productivity in the East is considered to be superior to that in the western part of Prussia, albeit this claim has never been backed by much empirical evidence. Overall, 19th century Prussia was seen as a successful 'Continental' twin of England by realizing an intransigent but highly effective growth policy, which - despite high social costs in the medium run - represented an alternative way to escape the Malthusian trap. It provided the labour force for German industrialisation and created a domestic market for consumers industries as well as for food.

This institutional approach has been challenged. To start with, East German historians have shown empirically that East-Elbian agricultural growth accelerated long before the agrarian reforms (Harnisch 1984, 1986). A reform-induced agricultural take-off could not be identified. Moreover, recent studies on the Prussian province Westphalia have shown that agrarian reforms had little impact on growth or structural change in farming within that region. Instead, before and after the reforms the dynamics of market integration processes played the decisive role. After 1830 the different pace at which regions began to participate in supra-regional trade, with the fast expanding urban-industrial demand centres concentrated at the Ruhr, explains more than anything else the pronounced regional differences of agricultural growth within Westphalia. The extension of the railways was of decisive importance for the speed of a region's agricultural development. Regional agricultural growth as well as farming intensity was highly correlated to proximity to the demand centre increasing the number of "cash-products", which could be profitably produced for the market. Moreover, the pronounced regional growth differences within Westphalia cannot be explained in terms of differences in the fertility of the soil. Rather, the decisive factor was that not all areas were similarly affected by access to the Ruhr (Kopsidis and Hockmann 2010; Kopsidis 2006, pp. 324-362).

On the other hand, studies on regional differences in 19th century Prussia have revealed a clear-cut West-East specialisation (Hohorst 1980; Frank 1994), where agriculture dominated in the Eastern parts of Prussia and industry in the Western provinces Rhineland and Westphalia as well as in the Prussian province Saxony. This seems to support the idea that the agrarian Prussian East had "fed the West" as argued in the older literature. Here, East-Elbian farming is assumed to be more advanced and productive due to allegedly stronger developed market relations east of the Elbe (Harnisch 1986, p. 59). Also, the fact that during the 19th century East-Elbian agriculture exported more of its produce than agriculture in Western parts of Prussia is sometimes taken as evidence for its superiority. But there is reason to doubt this. First, even if the East would have been exporting due to a *comparative* advantage in agriculture, this does not prove anything in terms of *absolute* productivity differences. Second, there is new evidence that the East was exporting only some particular products (grain) to some particular markets (especially Britain), but hardly to Western parts of Prussia. Recent studies show that during the 19th century domestic Prussian grain markets stayed highly fragmented (Kopsidis 2002; Uebele 2009). Even after the political unification of Germany in 1871 there is evidence for a high degree of internal fragmentation, especially a strong internal east-west divide in domestic trade in agricultural as well as in other commodities (Wolf 2009).

All available data on trade flows confirm that long-distance trade played no major role in feeding the densely populated Western provinces of the Prussian Empire (Kopsidis 2011). Moreover, the railway-based "transport revolution" after 1840 enabled a tremendous increase in domestic agricultural trade within Northwest Germany but did little to increase food imports from outside. Despite improving connections between the Western and Eastern parts of Prussia, contemporary German sources suggest no major grain shipments going from the Prussian east to the west during the 1850s or 1860s, neither by train nor by ship. When during the 1870s Northwest German grain production could not further satisfy the rise in domestic demand, grain imports from overseas rather from the Prussian east filled the gap (Meitzen 1871a, p. 272; Köttgen 1890, p. 4; Fremdling and Hohorst 1979, pp. 64-65; Müller-Wille 1981, p. 249). From the beginning of Britain's industrialisation until the 'European grain invasion' East Elbia exported grain mainly to the British market (Jacobs und Richter 1935, p. 276; Sharp 2006), and to Central European centres of industry such as Berlin.

In the historiography grain exports via its Baltic ports to Great Britain feature prominently (Wehler 1987, 83-90). Liberals like Max Weber as well as Marxist historians concluded that early and strong international market integration contributed significantly to give grain cultivating export oriented East Elbian large estates an advantage not only in market orientation but productivity as well.

Prussian grain exports to Great Britain mainly meant wheat.[1] Indeed, Prussian wheat exports to Great Britain impressively increased between 1831/35 to 1856/60 from 25.405 tons to 163.673 tons per year (Engel 1861, 285). However, considering contemporary estimates of Prussian gross crop production around 1860 - carried out in the course of the land tax assessment by the famous mathematician Gauss - strongly modifies the role of wheat as an engine of agricultural growth. Estimates for the entire Prussian kingdom from Gauss and the scholar Zachariae v. Lingenthal provide that considering the entire Prussian Kingdom wheat only accounted for 4.6% respective 3.1% of total grain production (Engel 1861, pp.280-287, Meitzen, 1871a, 386-389). Moreover, generously assuming that the entire wheat production of the two Baltic provinces Prussia and Pomerania was destined for export trade around, 1860 this would have been no more than 14.5% of all grain production (or about 6% of the entire gross crop production) of these two provinces.

Hence, it looks as if the interaction between agricultural and wider economic development must have been predominantly shaped by local factors over most of the 19th century. We will argue that this fits into a picture where progress in agriculture is determined largely by the demand side – predominantly by local demand from cities. This is in line with our finding that agricultural productivity in the western parts of Prussia was clearly ahead of the East.

III. Agricultural productivity in 19th century Prussia: concepts, data source, data critique and descriptive evidence

Our main indicator for agricultural productivity is the so called “Grundsteuerreinertrag” (GRE), defined as the income from agrarian use of land less all costs of farming (Engels 1866, 1867; Meitzen 1868, pp. 36-44).[2] The GRE was stipulated by the tax administration as tax base for the land tax. In assessing the GRE the tax administration explicitly aimed at determining the net earnings per Prussian acre land for different kinds of farm land (arable, pasture, meadow, and horticulture) subdivided into varying land classes in different parts of the state.

In contrast to nearly all other land tax assessments the Prussian GRE is not a standard value, based on schematic computations. Rather, the assessment of the net income per acre (GRE) depended on the judgement of experienced experts assembled in so called Veranlagungskommissionen (land tax assessment commissions). These land tax commissions were established for every county. Their

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[1] Looking at Prussian trade statistics rye and barley exports were much lower than for wheat but still substantially around 1860. However, according to contemporary sources and statistics nearly all exported rye comprised transit trade coming from Poland. Less than half of barley exports originated from East Elbia traded via Baltic harbours (Engel 1861, 286-287).

[2] For the land tax assessment of 1861/65 the income out of forestal use of land was also determined, which is not of interest for our purposes. The costs of farming included interest debt only insofar as it related to investments in soil improvements (like for example draining). In contrast, it was forbidden to include debts accruing from acquiring an estate, because this was not treated as a land rent increasing investment.

members were explicitly required to consider all factors which could affect a county's farming income.[3] They had to travel intensively through their counties to assess for all kind of (farm) land and land classes the (farm) income per acre before tax (GRE or Klassifikationstarif). For this purpose the commissions were obliged to pinpoint representative 'exemplary parcels of land' (Mustergrundstücke) for every class of horticultural, arable, meadow and pasture land, but also for woodland and inland waters. For example there were eight classes of arable land (Bonitätsklassen) representing different soil qualities reaching from '1st class wheat land' to the worst called '3rd class rye land'. The assessed GRE of the 'exemplary parcels of land' had to be compared thoroughly with collected local tenures and prices of land for consistency. This was the most important check of the commissions' results. We have data at the level of all 342 Prussian counties on total GRE, and separately on GRE on farming, horticulture, pastures, and meadows.

To determine the GRE according to the official guidelines for assessing the land tax, the operating costs (Bewirtschaftungskosten) had to be subtracted from the monetary gross output (Rohertrag), which corresponds to the total gross crop production (including straw and all feeding crops) from horticultural, arable and grassland (Engel 1867, 94). While the law prescribed a list of obligatory aspects which had to be taken into account when assessing the costs of farming,[4] the local tax commissions were not obliged to calculate separately every single position (Engel 1867, 118). Beside the unified capital costs all output and input positions had to be priced with long term average local commodity prices (1837-1861) documented for every Prussian county by Meitzen and local agrarian wages (Engel 1866, 11). A detailed knowledge on local farming systems was necessary to carry out the land tax assessment. This knowledge had been accumulated on the local and top level of the

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[3] Detailed and highly standardised 'county reports' (Kreisbeschreibungen) encompassing meteorological, agrarian, demographic, transport infrastructure, and economic data as well as extensive information on farmers' market access had to be prepared ex post to explain and justify the commission's taxation to higher authorities.

[4] The operational costs include sixteen positions namely all costs of cultivating the land ([1] ploughing and harrowing, [2] manuring including the monetary value of used manure, [3] sowing, and [4] all tasks between sowing and harvesting), the costs of harvesting and mowing ([5] harvesting, [6] putting the harvest to the barn, and [7] threshing), [8] the costs of on-farm storage, and [9] the costs of transport to the next market outlet. In addition as imputed costs the annual depreciation and imputed interests of all real farm capital and circulating capital apportioned to units of land should be taken into account to determine the operating costs per Prussian acre ([10] annual depreciation of farm buildings, [11] imputed interests on capital fixed in farm buildings, [12] annual depreciation of the remaining 'dead' and 'living assets' like tools and livestock, [13] the related imputed interests, and [14] the imputed interests on the circulating capital). The Prussian land tax assessment of 1861/65 deliberately saw the produce of the soil not as a 'gift of nature' but as the result of the coordinated use of the three production factors land, labour and capital. Thus the return on 'yield enhancing capital use' (ertragswirksames Kapital) determined by an annual rate of 5% had to be included to the production costs (Engel 1866, 2). Costs of insurance [15] and management [16] were part of the operational costs as well (Engel 1867, 117). Explicitly investments into soil improvements should be considered as part of the real farm capital.

Prussian bureaucracy in the course of the agrarian reforms because it was essential to determine the redemption payments of manorial peasants to their former lords (Engel 1867, 117).

However, animal production and yields from livestock farming have not been examined. The Prussian land tax regulation of 1861/65 considered income from animal production only indirectly via its impact on arable farming and the profitability of grassland. This bias in the data will tend to limit the effect from urban demand on agriculture. However, Engel (1867) among others suggested that the indirect effects from animal production, which are reflected in our GRE-data must have been large. The profitability and hence the spatial extension of high-yielding intensive farming systems as well as the success of grassland farming were driven mostly by an increase in feed demand of an expanding animal sector (Thünen 1826, 99-129; Engel 1867, 103-116; Grantham 1978; Kopsidis 2006, 117). Thus, the Prussian GRE does reflect effects from animal farming on arable and grassland farming to a large extent, but might still understate the effects of urban demand for animal products on agricultural productivity.

Table 1 shows the data aggregated to the level of provinces. It also contains additional information from (Engel 1867) on farming costs, which is only available at this higher level of aggregation.

[Table 1 about here]

Overall, the Prussian GRE, which approximates net farm income per acre before taxes, corresponds to the concept of a land rent. A land rent is generally defined as a surplus of monetised outputs over monetised inputs. Hence, differences in GRE between counties principally reflect regional disparities in agricultural total factor productivity.[5] According to several studies, long-run time-series on real land rents based on data on land leases and net farm income per unit land roughly reflect secular developments of agricultural TFP (McCloskey 1972, 1975; Allen 1992, 227-231; Hoffman 1996; Clark 2002). However, while the GRE will be highly correlated with TFP, the correspondence is imperfect if there are confounding price effects on the output or input side. To correct for output price effects we deflate the nominal GRE with a (county-specific) crop price index in some of our tests, but it will turn out that this deflation makes little difference to our results.[6] When it comes to input prices, we note that based on estimations of Ernst Engel on the level of Prussian provinces the variations of farming costs per acre showed only a quarter of the variation of gross yields (Engel 1867, 154, see also table 1, column 2). Thus, by far the largest part of differences in land rent (GRE) between

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[5] The GRE or land rent is given by GRE = (Output Index – Input Index). Instead, TFP is given by TFP = (Output Index / Input Index).

[6] We construct a county-specific agricultural crop price index for Prussia based on average prices 1837-1860 per county for a Prussian bushel wheat, rye, and potatoes as well as for a Prussian centner meadow hay published by Meitzen (1869, 199-271). Rye was the most important cultivated crop in 19th century Prussia, not only in the East but in general. Whereas the rye price has been weighted by the factor 0.4 the remaining three commodity prices have been weighted each by the factor 0.2. Given that the individual price series show very similar patterns across counties, this particular weighting scheme is not critical for any of our results.

counties stemmed from variation in factor productivity. Differences in land rent (GRE) will therefore correctly reflect the ranking of counties' TFP, but will tend to overstate the variation in TFP. Notwithstanding these caveats, the Prussian GRE as a land rent reflects regional differences in agricultural TFP to a degree that at least it allows us to discriminate between low-, medium- and highly productive regions within the Prussian monarchy. [7]

A further caveats is in order. One might suspect that the GRE assessment was not carried out equally strict throughout the monarchy, because there is reason to believe that the powerful Junkers of the East were given some preferential treatment. If so, this could bias the data on productivity in the East relative to other parts of Prussia. The land tax was a substantial source of income for the Prussian state; it counted for around 30% of all Prussian tax revenues. By abolishing most exemptions from the earlier land tax which heavily privileged the Eastern provinces and its nobility, the land tax reform of 1861 met a central demand of the Liberals, which were especially influential in the West. It speaks in favour of a just tax assessment that the tax reform was part of a political deal between the Liberals and the Prussian crown. Expensive military reforms could be financed only with additional tax receipts, which needed the consent of the Prussian parliament. In return the royal government reorganised the land tax according to the demands of the liberals. In fact, according to recent research 92% of the additional land tax burden fell on the Eastern provinces (Spoerer, 2004, p. 67). Similarly, Engel (1867) concluded from his in-depth investigation that the large regional differences in GRE can hardly be explained by differences in tax authorities' treatment. Furthermore, the Grundsteuerreinertag (GRE) was widely used by agricultural banks to determine the debt margin of a property or to estimate land prices. Even scholars who were very critical about the Junkers' privileges like Max Weber used the GRE data without restrictions. All contemporary experts attested to the Prussian tax administration a thorough and incorrupt determination of the Grundsteuerreinertrag (Schiller, 2003, pp. 223-230). Finally, a recent study on the Westphalian land market 1830-1860 concludes that no variable explains variations in observed land prices better than the Prussian GRE-data, which was used by contemporaries as an important benchmark to agree on land prices (Fertig 2007, 181-202). To sum up, we conclude that the GRE data from the land tax records 1861-1865 are a valuable source to explore regional differences in agricultural productivity across Prussia.

We refer to average GRE or land rent per unit farm land as the most comprehensive measurement of agricultural productivity available from our data which can easily be computed out of Meitzen's comprehensive data (Meitzen 1869, 1-120). Farm land comprises four categories: arable and horticultural land, meadows and pastures. Let us now consider the geographical patterns in the data. Table 2 and map 1 clearly suggest that there were huge differences in agricultural productivity as measured by the GRE (table 2, columns 10-12) and its possible determinants (table 2, columns 1-8). Some counties achieved not more than one quarter of the Prussian average in terms of the real

7 Most authors use the term Ricardian surplus as equivalent for land rent. However, strictly speaking Ricardo's theory of land rent refers only to differences in soil fertility to explain variation in land rent. Thuenen was the first who developed a theory of land rent where market access as a function of transport costs is a decisive factor to explain spatial variations in land rent. Whereas a change in the strict assumptions of Ricardo's land rent model can fundamentally change its implications, the conclusions of Thuenens model of the 'isolated state' hold even if central assumptions like equal soil quality and transport infrastructure within the area are relaxed (Peet 1969, 1970).

GRE whereas others exceeded it more than three times (column 12, lower panel). Even if we assume that variation in TFP is only about a fifth of the variation in GRE, this suggests that agricultural TFP in the most productive counties was still between two and three times the level of TFP in the least productive ones.

[Table 2 about here]

[Map 1 about here]

Map 1 shows that agricultural productivity (real GRE per Prussian Morgen) follows a clear West-East gradient of decreasing performance only interrupted by Central Germany and a minor region in Silesia. Three compact regions with outstanding performance can be observed: (1) the Northern Rhineland and parts of the bordering Westphalian Hellweg stretching as a broad strip located close to the Southern Westphalian uplands around 100 km from Bochum to Lippstadt, (2) nearly the entire Central German province of Saxony, and (3) a sizeable area in the Western part of Silesia. A large regional block of average productivity can be identified in the provinces Brandenburg, the rest of Silesia and the Western half of Pomerania. The adjacent most eastern provinces of the Prussian Kingdom Posen and the province of Prussia formed a large area with lowest productivity - with very few exceptions around Danzig and Königsberg as well as the Eastern half of Pomerania. However, even in the Rhineland and Westphalia smaller low productive regions could be located either in the unfertile uplands or distant from the Rhine-Ruhr industrial belt in Northern Westphalia. In the next section we consider data on some of the potential factors behind this pattern.

IV. Potential determinants of agricultural productivity

A first view on the data in table 2 suggests several determinants of variations in agricultural productivity. Especially differences in soil quality as measured by the percentage share of top soils in total usable land (column 1) and population density (column 5) seem to be highly correlated to variation in productivity. Map 2 shows that the pattern of soil quality is roughly similar to the pattern of GRE per area. The best soils can be found in the Western territories, in Saxony and in Silesia.

[Map 2 about here]

The GRE data seems also to vary systematically in access to the expanding food markets of urban-industrial agglomerations. GRE per area is highest in provinces with highest population density (column 5), which in turn depends on the number and size of cities. But population, especially urban population, from neighbouring regions should matter as well. To capture this, we construct a simple measure of access to urban demand or “market potential” in the spirit of Harris (1954), where the urban market potential of any given county in the sample is the distance-weighted sum of potential urban demand from the entire geographical neighbourhood, approximated by the size of their urban populations (as documented in Meitzen, 1869):

$$MP_i = \sum_{j=1}^{n} \frac{UrbanPop_j}{dist_{ij}}$$

Note that we take not only the Prussian urban population into account but also that of all adjacent foreign territories (a total of about 50 European regions from Kurland in the North-East, Sweden and Denmark in the North over the Netherlands, Belgium and Alsace-Lorraine in the West, Bavaria in the South and the Kingdom of Poland in the East). Table 2, column 8 and map 3 presents the results given as market potential relative to the sample average.

[Map 3 about here]

The data show again a clear west-east pattern with generally the best access to urban demand in the Rhineland, Westphalia and Saxony, but also fairly high levels of market potential in the neighbourhoods of Berlin and Danzig. However, within these larger regions there exist notable differences. For example in the Province Rhineland the two southern administrative districts (RB = Regierungsbezirke) Trier and Koblenz lagged far behind RB Duesseldorf or RB Cologne. These variations should help us to identify the effect of market access on productivity controlling for other factors. In addition, we note that our measure of market potential shows a spatial pattern of "rings" around major agglomerations, most visible in the Prussian West but detectable as well in the East with Saxony and the greater area of Berlin at the centre.

Most of the remaining potentially important factors affecting productivity like population and cattle density, or transport infrastructure showed systematically higher values in the Western parts of Prussia (including Saxony) and seem to be positively correlated to GRE (see tables 1 and 2). The East was superior only with respect to farm horse density, especially East and West Prussia, which were famous horse breeding areas. Furthermore, all these variables show a large variance within relatively small areas. Looking at the descriptive statistics in table 2 this is true for soil quality (map 2), market potential (map 3) and transport infrastructure but as well to a lesser degree for cattle and farm horse density.

Finally, let us consider differences in farm structures. It is still an open question to what extent this affected variations in productivity within 19th century Prussia, not at least because the data is limited. Table 3 gives data on the size distribution of farms across Prussian in 1882 at the level of provinces (aggregated from data on 25 administrative districts). The data suggests that the relationship between farm structure and productivity in 19th century Prussia was far from clear-cut. Whether small or large farm units could operate more efficiently seemed to be conditioned by factors like soil quality and market access. It has been argued that 19th century European industrialisation improved the conditions for the expansion of family farming driven especially by the demand patterns of urban-industrial consumers (Van Zanden 1991, 216, 236-238; Grantham 1989b, 14; Kopsidis 2006, 324-362). Indeed, the leading areas in the Prussian West and even more in Saxony came very close to the model of a highly diversified farm structure dominated by viable full time family farms of very different sizes, including estates between 75ha and 150ha as envisioned by von Thünen (1826, p. 555). However, there is no rule without exception. A smaller region of highly productive large estate farming seemed to exist around Breslau in Silesia. Moreover, a dominance of large estates (> 100ha) with shares of up to 80% in all farmland like in parts of Pomerania around Stralsund did at least not rule out an above average productivity despite the prevalence of poor soils and a below average market access. However, there is little evidence that the Rhineland or Westphalia were negatively affected by the lack of large estates or even lagged behind East Elbia.

[Table 3]

This pattern of farm sizes is directly related to the various institutional legacies in different parts of Prussia. It has often been argued (for a recent contribution see Acemoglu et al, 2010) that establishing full private property in land through liberal agrarian reforms was a revolutionary institutional change that caused an "agricultural take off" followed by wider economic growth. Moreover, it has been fiercely debated whether the 'French' or the 'Prussian' or some other type of reform was the most efficient and successful strategy to foster economic development. As already mentioned in the introduction, we observe legacies of very different agrarian reforms in Prussia. To consider the impact of different variants of agrarian reforms on agricultural productivity we explore the effect of the following four variants that cover all of our 342 counties:

1) 'Swedish Pomerania': radical eviction of the peasants close to the English model (we code a dummy variable = 1 for all four counties of the administrative district of Stralsund)

2) East Elbian 'Prussian reforms': abolition of seigniorial rights against redemption mainly in land (we code a dummy = 1 for 239 counties of the Eastern and Central provinces of the Prussian Kingdom except Swedish Pomerania)

3) West Elbian 'Prussian reforms': abolition of seigniorial rights against redemption mainly in money (we code a dummy = 1 for 52 counties for the provinces Rhineland and Westphalia not annexed by France before 1815)

4) 'French revolution': abolition without redemption of the nobility (we code a dummy variable = 1 for all 47 Rhenish counties annexed by France before 1815)

Unsurprisingly, there is a clear relationship in the data between farm sizes (as of 1882) and historical legacy. Average farm sizes are highest in those regions, where peasants were evicted without compensation (1) and lowest in regions, where the former rights of the nobility were abolished without redemption (4). Swedish Pomerania came to Prussia only after 1815 forming the administrative district (*Regierungsbezirk)* Stralsund. In contrast to older Prussian territories Swedish Pomerania like Mecklenburg did not know any royal protection for peasant farms (*königlicher Bauernschutz*) during the 18th century. Before 1815 Swedish Pomerania was ruled by its nobility not affected by a royal central power demanding for soldiers and revenues. Hence, in contrast to the older parts of Prussia due to the weak legal position and missing property rights of the serfs in their farmsteads the commercially very active nobility was able to evict a large mass of peasants without compensating them during the decades after 1750 and to carry out very quick farm amalgamation on a large scale. Thus, Stralsund at the Baltic shore was the only Prussian administrative district, which developed closely following the "English way" of an 18th century 'landlords' revolution' as described in Robert C. Allen (1992). In contrast, against fierce resistance of the nobility, the Prussian agrarian reforms at the beginning of the 19th century were implemented in a way that the majority of the peasants became full owner-occupiers of their farms. In exchange, they had to redeem their former lords either by land and payments as in most parts east of the Elbe (2) or only by payments without any losses in land like in the Prussian West (3). It is a myth that East of the Elbe the Prussian reforms caused the disappearance of the peasantry. Even if peasant lost land east of the Elbe a large class of family farmers could emerge standing loyal to the crown (Harnisch 1984).[8] After 1815 Prussia gained territories on the left bank of the Rhine, which previously had been annexed by revolutionary France. Here the seigniorial system had been abolished without any redemption to the former lords (4). The Prussian government approved this legislation after 1815 to keep public peace.

When it comes to the mechanisms by which the reform legislation might have affected productivity, especially the enclosures are of interest. For legal reasons related to legislation on enclosures – the so called Gemeinheitsteilungsordnung of 1821 – and motivated by the attempt of the Prussian bureaucracy to avoid social unrest in the newly gained Western territories, the traditional lay out of fields even in regions with fully fledged open field systems was not affected by land privatisation. In the course of enclosures land consolidation to block fields took place on a large scale only in East Elbia when peasant land and Junkers land have been separated. Thus, one effect of enclosures that might have enhanced productivity - the abolition of fragmentation of fields into narrow strips - did occur only in the Prussian East and somewhat earlier in Swedish Pomerania. In the Rhineland and Westphalia land consolidation started on a larger scale only during the Kaiserreich (Kopsidis 2006, 370-373). Hence, among other things our data allows us to test to what extent enclosures affected productivity in Prussian agriculture.[9]

To summarize, there are many potential factors that might have contributed to the observed variation in agricultural productivity across Prussia. What we need to explore are the channels or mechanisms by which they might have affected productivity and the relative significance of those different channels. Especially, we need to understand how access to markets outside of agriculture - conditioned by variations in geography (soil quality) and institutions (and hence average farm sizes) - would affect the geographical pattern of agricultural productivity. In the next section we propose a simple model in the spirit of von Thünen (1826) that will guide our further empirical work.

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[8] One argument of liberal minded (and peasant friendly) reformers that was especially convincing during mobilisation of rural Prussia in the course of the French Wars 1813-1815 was that Prussia as a European power only could survive if a depopulation of rural areas like in the Baltic territories could be avoided.

[9] Legal constraints which nearly prevented any consolidation of farms in the Western parts of Prussia has been abolished not till 1872 but even than land consolidation started only slowly in certain areas not before 1910. For example in Westphalia only 31,013 out of around 1.4 million ha farm land in 1870 had been consolidated 1874-1883 (own calculation, Gudermann 2009, 150-156, Schlitte 1886, 482).

V. A simple, testable von-Thünen-framework

We want to explore how agricultural profitability (as measured by the GRE) varies with distance to urban demand, soil quality and possible other factors such as institutional legacies. To guide our empirical investigation, we first and foremost need to clarify the relationship between land rents and distance to cities of varying size. We consider a simple theoretical framework in the spirit of von Thünen (1826). First, we take demand as given and explore how supply decisions will be shaped by distance from the location of demand. Next, we close the model with a simple demand function that depends on city size.

Building on the land use model of Beckmann (1972), let us assume that agricultural production is a function of two factors, land and labor, with constant returns to scale. All production is shipped to a central market (the city) to be sold there. Except from the location of cities, geography is a featureless plain, hence we abstract for the moment from additional input factors such as capital or local characteristics such as differences in soil quality, institutions and the like. However, in our empirical investigation we will add these features as control variables. With this, we can formulate output per acre as a function of labor per acre (labor intensity) as

(1) $$\frac{output}{acre} = \phi\left(\frac{labor}{acre}\right),\ \ or\ y = \phi(x),\ \ where\ \phi'(x) > 0,\ \phi''(x) < 0, and\ \phi - x\phi' > 0.$$

Rent per acre g(r, x) is then given by output valued at local prices net of factor costs, or

(2) $$g(r, x) = p(r)\phi(a, x, r) - wx.$$

This formulation is very close to the GRE-rent in our data, where land rents were calculated as the profit per acre valued at local prices, net of input costs (such as wages). The rent g(a, r, x) in (2) is sometimes called “bid-rent” because it reflects the maximum price a farmer can bid for an acre of land at distance (r) from the city. This can also be seen as the minimum profitability for a farmer needed to compete with other land uses in the vicinity of a city such as the location of industrial plants.

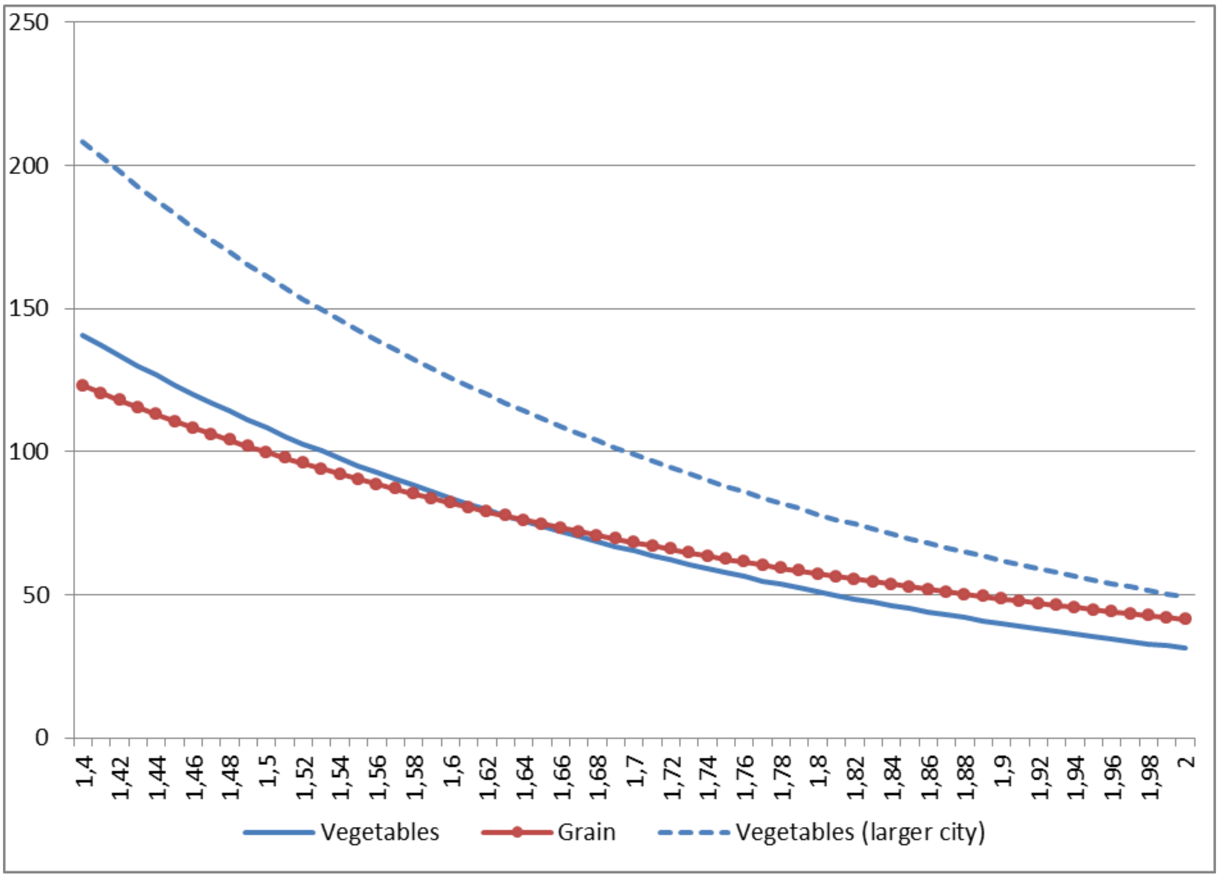
The parameter a in (2) reflects the product-specific total factor productivity and is used to distinguish between particular agricultural products, as explained below. Also, we value output at local prices, p(r). This is the per unit price of the good at the farm gate, hence net of transport costs at distance r from the market. In difference to Beckmann (1972) we assume that transport costs are of a most general form. First, there is an ad valorem component (t_1) in the spirit of Samuelson (1954, 1983), which increase in proportion to the value of goods shipped. Second, we allow for a per unit component (t_2) of transport costs that is independent from the value of transported goods. If we denote the price at the central market by (p) and the price at the farm gate at distance (r) from the central market by p(r) we have $p(r) = \frac{p - t_2 r}{(1+t_1)r}\ \ or\, p(r) = \frac{p}{(1+t_1)r} - \frac{t_2}{(1+t_1)}$. Note that the second term that includes the per unit component of transport costs does not vary in distance. However, the impact of that constant term on farm gate prices and therefore on land rents will increase with distance from the central market.

With a Cobb-Douglas production function, we can express output per acre as a function of labour intensity as $\phi(x) = ax^{\alpha}, with\ 0 < \alpha < 1$. It is straightforward to show that profit-maximization implies an increase in employment per acre the closer we move to the city (for details see the appendix). Profit-maximizing labour intensity x* can then be expressed as a function of parameters, prices and distance to the central market as $x^*(r) = \left[\frac{\alpha a}{w}\left(\frac{p}{(1+t_1)r} - \frac{t_2}{(1+t_1)}\right)\right]^{\frac{1}{1-\alpha}}$. With this, the profit maximizing rent per acre g* is decreasing in distance to the city:

(3) $g^*(r) = (1-\alpha)\left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}}\left[\alpha a\left(\frac{p}{(1+t_1)r} - \frac{t_2}{(1+t_1)}\right)\right]^{\frac{1}{1-\alpha}}$.

Consider now the case of two types of agricultural products, for example vegetables and grain. These two goods differ in terms of their per-unit transport costs (t_2) and in (a), their output per acre with one unit of labor input. In addition it seems intuitive to assume that vegetables sell at a higher price per unit compared to grain, but none of our results depend on this assumption. Figure 1 shows how the rent per acre changes for such two goods that differ only in their product per acre (a) and the per unit transport costs (t_2).

Figure 1: the “bid-rent” function for vegetables and grain and distance from the central market



Consider first the two solid lines. The figure suggests that close to the city it will pay to grow products with high profits per acre but higher per unit transport costs (vegetables, eggs, or dairy products). In contrast, at some distance from the city, it starts to be more profitable to produce goods with lower transport costs and lower profits per acre (grain, cattle). We note that this takes already into account that profit-maximizing farmers will change the factor input according to distance from the city: as land becomes more expensive the closer we move to the city center, farmers will produce with more intensive (land-saving) methods the closer they are to the city.

Furthermore, we can extend the model to show how the size of the city (N) will matter for farm profits. Ceteris paribus – that is given endowments, product-specific technology, and wages (which we assume to be set outside of agriculture) - it is intuitive to assume that a larger city population will lead to higher prices for agricultural products. The resulting land rents at any distance will be higher for a larger city (see dotted line in the figure). Given total supply and under some assumptions on the functional form of demand (which we provide in the appendix to this paper) the central market prices will increase linearly in city size as

$$(4)\quad N = \theta p, \quad with\, \theta = \pi^{\frac{1}{\beta}}\left[\left(\frac{1}{1+\alpha}\right)^{\frac{1}{\beta}}\frac{\alpha}{w}\right]^{2} > 0.$$

At distance (r) from the central market, rents will increase in city population N, weighted by distance (r), or

(5) $$g(r) = (1-\alpha)\left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}}\left[\alpha a\left(\frac{N/\theta}{(1+t_1)r} - \frac{t_2}{(1+t_1)}\right)\right]^{\frac{1}{1-\alpha}}.$$

With this, our simple model has three testable implications. First, it obviously suggests that rents will increase in the neighborhood of cities, all else given. But more specifically, the model implies that rents will increase by more in the neighborhood of larger cities. We can approximate this relationship by a locations' access to urban demand or urban "market potential", which is given by the distance weighted sum of urban population around any given location in our sample as formalized in section IV above. Second, the model implies that labor intensity will increase the closer we move to a city. According to the model, this is due to factor substitution in response to increasing land prices in the neighborhood of cities. And finally third, the model suggests that the increase in average rent per acre will be partly due to the change in factor-input, partly due to an increase in farm gate prices (because of both, lower transport costs and higher demand) and partly due to a change in crop mix towards higher yielding products that are more costly to transport. In the next section we will use our data to test these three implications.

VI. What explains agricultural productivity across Prussia?

In all our regressions we exploit our data on all 342 Prussian counties around 1865. In a first step we simply regress (the log of) the GRE per area at the county level on a constant and on (the log of) accessible urban demand, measured in terms of market potential as explained in section IV. Table 4, columns 1-4, gives the result of a simple OLS regression (with robust standard errors).

[Table 4 about here]

In column 1, the dependent variable is the nominal GRE (in logs); in column 2 we deflate the GRE using a county-level index of agricultural prices. Access to urban demand alone explains between 36% and 44% of all variation in terms of GRE, depending on whether we deflate the GRE data or not. Next, in columns 3 and 4 we add several variables to control for differences in soil quality, institutional legacies (as captured by the dummies 1-4, where we exclude 2 as an omitted category), as well as horses per area to proxy for capital, and transport infrastructure per area. All variables are significant at conventional levels and come with the expected sign. Adding these control variables reduces the coefficient on market access somewhat, but it stays large, positive and highly significant. In the last column of table 4 we modify the model to allow for a differential effect of distance-weighted urban demand from nearby compared to distance-weighted demand from urban centers further away. To be specific we distinguish between the effect of access to urban markets in a range up to 150km, up to 300km, up to 450km and above. The results show that access to more local urban demand exerts a much stronger effect on productivity than access to centers further away.

This simple regression explains about 2/3 of the sample variation in terms of productivity. It strongly suggests that access to urban demand is a crucial factor for agricultural productivity. Moreover, the results concerning our institutional variables - especially the significant positive impact of our variable 'Swedish Pomerania' on land rents - suggest that under certain conditions similar to England peasant mass eviction, labour-shedding and farm amalgamation as key elements of a 'landlord revolution' (Allen, 1992) formed as well a successful strategy to rise agricultural productivity and profitability in early 19th century Prussia. Most notably this seemed to be true for the Baltic regions. Still around the middle of the 19th century these coastal areas produced on a large scale grain for the British market. The prevailing farming system in this region was a variant of the convertible husbandry system (*Koppelwirtschaft*). Compared to the form of farming seen in the West and Central German Prussian regions, it was quite extensive and labour-saving. In fact, this has already been analysed by Thünen who explicitly concluded that the highly intensive - so called 'Belgian farming model' recommended by many agricultural experts for all of Germany - would necessarily lead to the economic ruin of Baltic large estates (Thünen 1826, p. 112). Moreover, both Thünen and Engel argued that under the conditions of profit maximisation rising farm intensity would inevitably mean strongly decreasing farm sizes especially close to cities (Engel 1867, p. 153). This conclusion seems to be confirmed by modern research showing that 19th century industrialising Western and Northern Europe experienced a rise of family farming.[10]

In contrast, the results so far do not suggest that grain exports from other parts of Prussia, such as Pomerania or the provinces of East and West Prussia exerted any positive influence on agricultural productivity. To test for this more directly, we also run a regression where we control for the average (and alternatively the minimum) distance to the five major grain export ports in the Baltic around the time, namely Memel, Pillau, Danzig, Swinemünde and Rostock. If indeed grain exports had a positive effect on productivity, we would expect to see that average (resp. minimum) distance to these major export ports should tend to reduce the GRE per area. Instead, we find that (the log of) distance to major ports comes with a significantly positive coefficient, whether we add this as an additional control to the variables in table 4, columns 3 or 4, whether we simply regress productivity on this distance variable alone, or whether we restrict the sample to counties east of the Elbe only. While our findings on the effect of access to urban demand and the other variables remain largely unchanged, we cannot find any evidence that grain exports via the Baltic ports had a positive effect on agricultural productivity.

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[10] One might wonder, whether the coefficients in table 4 are actually comparable given the large differences in means and standard deviations of the dependent variables and the independent variable (as shown in table 2). The fact that we estimate the model in logs helps to overcome most of the problem. An alternative is to repeat the estimation of table 4 in columns 3 and 4 with standardized coefficients (where from each variable we substract the mean and divide this by the standard deviation). This approach can be criticized because a one-standard deviation increase in soil quality might not be equivalent to a one standard deviation increase in horse-density. In any case, with this we find that access to urban demand has a (significant) standardized coefficient of about 0.55 in each case, followed by coefficients of around 0.3 for soil quality and our proxy for capital (horse-density). We also find a significant standardized coefficient for areas affected by the French revolution of around 0.2 and of about 0.1 for areas affected by the radical evictions in Swedish Pomerania. We conclude that the impact of access to markets was indeed the dominant factor that shaped the pattern of agricultural productivity across the Prussian state.

In a next step, we explore whether access to urban population matters for agricultural productivity indeed through the channels suggested by our model, namely through variation in labour intensity and crop mix. To see this, we re-run the regressions from table 4 but add variables that should capture at least part of the effect of market access. To this end, we first create variables “cropmix1”, “cropmix2” and “cropmix3” to capture variation in the type of agricultural output on which we have data. “Cropmix1” is defined as a county’s GRE derived from horticulture (such as vegetable and fruit production) relative to the county’s total GRE. In turn, “cropmix2” is defined as a county’s GRE derived from meadows and “cropmix3” a county’s GRE derived from pastures relative to the county’s total GRE. Given that horticultural products tend to have higher transport costs per unit of weight but also higher value per unit, we expect that the share of the first will increase in the neighborhood of urban demand. In contrast, output derived from both meadows and pastures is most land intensive and hence its share should decrease in the neighborhood of urban demand, where land prices tend to be higher. Hence, we expect that these variables capture at least some part of the effect of access to urban demand on output per area, the first with a positive sign in the regression, the second and third with a negative sign. In addition, we include controls for the number of pigs and milkcows per agricultural area to capture a bit better the large indirect effects that animal production in the vicinity of cities should have on farming (see Grantham 1989, pp. 51-52). In line with our theoretical framework we also add a control for labour intensity, measured as agricultural labour per agricultural area in a county. This should capture the effect in the model that profit maximizing farmers in the neighborhood of a city will try to adjust to the change in relative factor prices and substitute labour for land. Finally, whenever we use nominal values of GRE as dependent variable, we also add a control for the index of agricultural prices at the county level, which should capture the price-level effect of city size in the model. We expect prices to increase in the neighborhood of cities and hence enter with a positive sign.[11]

In table 5, columns 1 to 4 we show to what extent we can explain the effect of access to urban markets on agricultural productivity by these various channels, without and with adding the remaining controls for soil quality, capital, transport infrastructure and institutional legacy. Columns 1 and 2 show the effect using nominal GRE, hence adding a control for price effects, while columns 3 and 4 show the effect using deflated GRE.

[Table 5 about here]

As suggested by theory, cropmix, labour intensity and price effects rise in the neighborhood of large urban demand. Moreover, all these factors affect agricultural productivity as measured by nominal or deflated GRE per area in the expected way. As suggested in the earlier literature on Britain and

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[11] The rich Prussian sources on agricultural prices clearly show that prices were the highest in densely populated deficit areas, concentrated in the West and the Province of Saxony. While the average rye price 1837-1860 was 64 Silbergroschen for Bochum at the Ruhr, it was only 54 Sgr in remote rural Westphalia (Ahaus) and just 39 Sgr in rural West Prussia (Löbau) (Meitzen 1869, 199-271).

France, Prussian agriculture adjusted to changing demand patterns by an intensification of production and corresponding changes in specialization towards higher yielding crops (see Grantham 1989, Campbell 2010). We can "explain" the effect of access to urban demand on agricultural productivity to some extent by controlling directly for the various channels suggested by theory. The coefficient on market access declines - depending on the specification - by 40% with additional controls for institutional legacy, soil quality and others (compare coefficients in table 4, columns 3 or 4 to those in table 5, columns 2 and 4); or by up to 60% without these controls (compare coefficients in table 4, columns 1 and 2 to those in table 5, column 1 and 3). The fact that access to urban demand continues to affect agricultural productivity after controlling for several channels probably reflects the limitations of our data. For example, we capture variation in the composition of agricultural production very imperfectly, based on a distinction between net output from the four categories horticulture, farming, pastures and meadows only. Obviously, there were differences within these four categories that we cannot capture. Moreover, there might be additional channels, which are neglected in our theoretical framework, through which large cities affected their agricultural hinterland. Most notably, we do not take into account that there might have been spillover effects of technological and organizational change from urban-industrial agglomerations on agriculture.

Before we can conclude that access to markets indeed mattered for agricultural productivity, we need to address the issue that causation might have run the other way – not from urban demand to increases in agricultural productivity, but rather from agricultural productivity to the formation and growth of cities. Put differently, is it possible that urban demand (and its location) is actually endogenous to agricultural productivity? If so, our results in table 4 and 5 would be spurious. To deal with this, we use an instrumental variables approach. We need to address the issue that both the size of cities and their location might be endogenous to agricultural productivity. Hence, we need an instrument that is correlated to both the size and location of cities but exogenous to agricultural productivity. We propose to use the number of workers in industries that are heavily dependent on the existence of mineral resources, namely miners and workers in metal-processing industries, as an instrument for size and location of city population. To be specific, we construct a variable "access to miners and workers in metal processing" in the same way as we constructed the variable "access to urban population", now calculated as the distance weighted sum of miners in a county and all other counties in the sample and use this as an instrument.

$$MP\_mm_i = \sum_{j=1}^{n} \frac{(Miners_j + Metalworker_j)}{dist_{ij}}$$

Table 6, columns 1-2 show that this leaves our results largely unaffected. To show that the instrument is quite strong, we report the F-stat form of the Cragg-Donald statistic as suggested by Stock and Yogo (2002) as a test for weak instruments. The values of that statistic are far above the critical value.

[Table 6 about here]

With an IV-estimator, the coefficient on access to urban demand gets stronger, while notably our proxy for infrastructure weakens. This might suggest that the instrument captures some variation in the data that is related to access to urban demand but otherwise unaccounted for. A plausible candidate would be exactly the interaction between variations in infrastructure or other features affecting transport costs and urban demand that we capture in this setting only partially. Arguably, under the conditions of pre-industrial agriculture science-based industrial inputs, technological and organizational spill-over effects of the urban-industrial economy on agriculture did not yet exist. In Prussia around 1870 the prevailing biological-technical change was largely based on new crop rotations, seeds and breeds as well as all inputs that nearly completely came out of the agricultural sector itself (Uekötter 2010, 133-181). However, important spill-over effects of the urban economy on agriculture seemed to exist in agricultural trade that could benefit from a dense and often complex food trading network, which substantially reduced transaction costs (Kopsidis 2012). While we could try to improve on the measurement of access to markets, this would most likely leave our main result unaffected: access to urban markets is a key determinant of agricultural productivity and not by itself explained by productivity.

VII. Conclusion and Outlook

Our results suggest that the pattern of agricultural productivity across Prussia is to a very significant extent driven by variation in access to urban demand – fully in line with the claims made by Ernst Engel 150 years ago (1866, 173; 1867, 108). Wheat exports were a much weaker engine of growth compared to the production of high-value added foodstuffs like meat and dairy products for the internal market. Hence, we find that the centers of Prussian agricultural development during industrialization c. 1830-1870 were not located in East Elbia as assumed by most of the German historiography but mainly in Western and Central German areas. Variation in access to urban demandaffected agricultural productivity mainly through changes in the crop mix towards the needs of city populations, changes in factor intensity and price level effects. Using an IV-approach we could show that there is little evidence for an endogeneity bias in these results. Given that the Prussian state in 1865 stretched over much of Central Europe well into Eastern Europe, and given the wide variation in conditioning factors such as soil qualities and institutional legacies, we think that this result has a meaning beyond Prussia. 19th century agriculture was apparently able to react to market conditions, provided it paid to do so. In the neighborhood of large cities, farmers generally adjusted to demand for vegetables, meat, and dairy products, and in part had to in order to compete with industry for land. This finding of agriculture being driven by local demand ties in with many recent studies that find surprisingly local agricultural markets on the European continent still in the last third of the 19th century, based on both evidence from trade flows (Wolf 2009) and price dynamics (Kopsidis 2002, Uebele 2009). In this perspective and according to our results even the famous Prussian liberal agrarian reforms that fully established land and labour markets seemed to have played only a supporting function to agricultural growth. Moreover, the evidence suggests that the fundamental regional differences in the way how the old seigneurial system was abolished were of secondary importance to agricultural development.

In the context of Europe's "little divergence" we think that this suggests shifting attention to the causes of differential industry and city growth across the continent. Some recent work has looked into the origins of the European city system (Bosker and Buringh, 2010), while little has been done recently on the factors behind differential city growth over the 19th century. Also, the evidence on industry growth across Europe remains limited to what Sidney Pollard compiled some 30 years ago (Pollard 1981), complemented by some national and regional studies. What is missing are studies that would explore systematically the factors that can account for the large variation between and within nations in terms of industrial growth. The work by Allen (2009) on Britain's Industrial Revolution that stresses biased technological change due to differences in relative factor prices can clearly provide a guide for this.

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Technical appendix

We build on the land use model of Beckmann (1972) and assume that agricultural production is a function of two factors, land and labor, with constant returns to scale. All production is shipped to a central market (the city) to be sold there. Except from the location of cities, geography is a featureless plain, hence we abstract for the moment from differences in soil quality and the like (in our empirical investigation we will add these features as control variables). With this, we can formulate output per acre as a function of labor per acre (labor intensity) or

(A1) $$\frac{output}{acre} = \phi\left(\frac{labor}{acre}\right),\ or\ y = \phi(x), where\ \phi'(x) > 0,\ \phi''(x) < 0, and\ \phi - x\phi' > 0.$$

Rent per acre g(a, r, x) is then given by output valued at local prices net of factor costs, or

(A2) $$g(r,x) = p(r)\phi(a,x,r) - wx.$$

This rent is sometimes called "bid-rent" because it determines the maximum price a farmer can bid for an acre of land at distance (r) from the city. The parameter a in (A2) is a productivity shifter, which is used to distinguish between particular agricultural products. The local price is given by p(r). This is the per unit price of the good at the farm gate, hence net of transport costs at distance r from the market. In difference to Beckmann (1972), we assume that transport costs are of a most general form, where we have both an ad valorem component (t_1) in the spirit of Samuelson's iceberg formulation (Samuleson 1954, 1983) and a per unit component (t_2) of transport costs. If we denote the price at the central market by (p) and the price at the farm gate by p(r) this implies

(A3) $$p = p(r)(1+t_1)r + t_2 r\ or\ p(r) = \frac{p}{(1+t_1)r} - \frac{t_2}{(1+t_1)}.$$

We note that the second term, which includes the per unit component of transport costs does not vary in distance. However, the impact of that constant second term on farm gate prices and therefore on land rents will increase with distance from the central market.

Next, we assume a Cobb-Douglas production function of $\phi(x) = ax^{\alpha}, with\ 0 < \alpha < 1$. With this functional form, profit maximizing employment per acre x* will increase the closer we move to the city as:

(A4) $$x^*(r) = \left[\frac{\alpha a}{w}\left(\frac{p}{(1+t_1)r} - \frac{t_2}{(1+t_1)}\right)\right]^{\frac{1}{1-\alpha}}.$$

The profit maximizing rent per acre g* is then decreasing in distance to the city. If we insert (A4) into (A2) using the price formulation (A3) we find

(A5) $$g^*(r) = (1-\alpha)\left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}}\left[\alpha a\left(\frac{p}{(1+t^1)r} - \frac{t^2}{(1+t^1)}\right)\right]^{\frac{1}{1-\alpha}}.$$

Furthermore, we can extend the Beckmann-model to show how the size of the city (N) will matter for farm profits. Given land endowment, technology, and wages (which we assume to be set outside of agriculture), a larger city population will lead to higher prices for agricultural products. Let us assume that demand for a given agricultural good is a function of city size, price and some product-specific demand shifter λ. We assume for simplicity that this latter is increasing with the product-specific productivity parameter (a), such that

(A6) $$D(p) = \lambda \left(\frac{N}{p}\right)^{\beta},\ with\ \lambda = a^{\rho}, and\ \rho,\beta > 0.$$

Now consider supply. The simplest case is that of a single city with an agricultural hinterland located on a one-dimensional line with length r (where r=0 is the city center). In this case supply would be given by π times the integral from the center (where output per acre is maximal) to the point where it is zero. In two-dimensional space, we assume that the agricultural hinterland forms a circle around the city with radius (r). Hence total supply S(p) = Φ is given by

(A7) $$S(p) = \pi[\int_0^r d\phi(r)]^2 = \pi\left[\frac{a}{(\alpha+1)}\left(\frac{\alpha a p}{w}\right)^{\frac{1+\alpha}{1-\alpha}}\right]^2$$

To simplify the algebra we set β =(1+α)/(1-α) > 0 and ρ=4/(1-α) > 0. With this, the equilibrium price for an agricultural product (given wages w and productivity a) increases linearly in city size N as

(A8) $$N = \theta p,\quad with\ \theta = \pi^{\frac{1}{\beta}}[\left(\frac{1}{1+\alpha}\right)^{\frac{1}{\beta}}\frac{\alpha}{w}]^2 > 0.$$

Together with A5 this implies that at distance (r) from the central market, rents will increase in city population N, weighted by distance (r), or

(A9) $$g(r) = (1-\alpha)\left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}}\left[\alpha a\left(\frac{N/\theta}{(1+t_1)r} - \frac{t_2}{(1+t_1)}\right)\right]^{\frac{1}{1-\alpha}}.$$

Figure 1 in the text is based on the following parameters: α=0.66, β =(1+α)/(1-α), ρ=4/(1-α), t_1=0.1. As explained in the text, “vegetables” and “grain” are distinguished according to the productivity per labor (a) and the per unit transport costs (t_2). Vegetables have a higher (a), that is a higher output per acre and one unit labor compared to grain: a(vegetables)=1, and a(grain)=0.85. Instead, while we assume that the ad valorem transport costs are the same for both goods (t_1=0.1), vegetables have higher per unit transport costs compared to grain: t_2(vegetables)=1 and t_2(grain)=0.1. Finally, population in the benchmark case is set to N=8, and in the case of a larger city it is N=9. Wages are set in all cases to w=1, which implies prices of 17.88 (N=8) and 20.11 (N=9) respectively.

Table 1: Gross yields, farming costs and land rent (per Prussian acre) and labour intensity, 1865 (ranking in brackets)

Province	Gross yields (in Taler)[1]	Farming costs (in Taler)[2]	Land rent (GRE in Taler)	Labour Intensity[3]	Share of income from horticulture in all farm income
Prussia	17.30 (7)	16.50 (7)	0.80 (8)	20.5 (7)	1.25% (7)
Pomerania	18.67 (6)	17.64 (6)	1.03 (6)	16.3 (8)	1.00% (8)
Posen	16.27 (8)	15.39 (8)	0.88 (7)	22.5 (5)	1.36% (6)
Brandenburg	19.60 (4)	18.41 (4)	1.19 (5)	20.5 (6)	2.55% (3)
Silesia	19.43 (5)	17.80 (5)	1.63 (4)	36.3 (2)	2.34% (4)
Saxony	24.03 (2)	21.58 (3)	2.45 (1)	22.4 (4)	1.71% (5)
Westphalia	23.33 (3)	21.60 (2)	1.73 (3)	28.4 (3)	3.62% (1)
Rhineland	26.50 (1)	24.12 (1)	2.38 (2)	40.8 (1)	3.35% (2)
μ[4]	20.64	19.13	1.51	25.96	2.15%
Standard deviation	3.68	2.98	0.65	8.53	0.98%
Variation coefficient	0.1734	0.1558	0.4305	0.3285	0.4588
Minimum	16.27	15.39	0.80	16.32	1.00%
Maximum	26.50	24.12	2.45	40.79	3.62%
Kingdom of Prussia	20.30	18.92	1.38	25.1	2.39%

Source: Engels (1867, 104-107), Meitzen (1869, 116-117) table 1 and own calculation.

Notes: 1 = annual average monetary gross output per Prussian acre arable land, 2 = annual average costs of farming a Prussian acre arable land, 4 = labour units per 100 hectare farm land, 4 = μ is an unweighted average (number of observations = 8).

Table 2: Agricultural performance and its important potential determinants in Prussian Provinces, about 1865

	1	2	3	4	5	6	7	8	9	10	11	12
Province	Soil quality[1]	Cattle density[2]	Farm horse density[3]	Rail- and water-ways[4]	Popu-lation density[5]	Horse man ratio[6]	Land man ratio[7]	Market potential (relative)[8]	Prussian agricultural crop price index (Pr. =1.0)	Thünen-surplus (GRE, in Taler, nominal) 9	Thünen-surplus (GRE, in Taler, real)10	Thünen surplus (real) relative, (Prussia = 100)11
Prussia	13.6	61.5	20.9	0.0223	47.8	0.40	19.1	59%	0.86	0.80	0.93	67.4%
Pomerania	6.6	51.1	14.6	0.0230	47.1	0.35	24.0	80%	0.95	1.03	1.09	79.2%
Posen	7.9	63.2	14.9	0.0237	52.1	0.26	17.4	89%	0.93	0.88	0.95	68.9%
Brandenburg	8.9	70.0	16.6	0.0465	64.2	0.32	19.1	113%	0.98	1.19	1.20	87.5%
Silesia	30.6	119.3	16.1	0.0333	86.3	0.17	10.8	88%	0.94	1.63	1.73	125.4%
Saxony	38.0	78.3	16.3	0.0471	79.9	0.29	17.5	127%	1.02	2.45	2.40	174.5%
Westphalia	25.7	106.7	16.8	0.0442	81.8	0.23	13.8	117%	1.10	1.73	1.57	113.9%
Rhineland	31.4	141.0	13.9	0.0608	123.4	0.13	9.6	129%	1.15	2.38	2.08	150.8%
Descriptive statistics by county (327 observations)												
μ[12]	25.9	96.8	16.7	0.041	80.0	0.26	15.9	100%	1.00	1.70	1.65	120.1%
σ	26.0	42.2	5.9	0.047	56.7	0.13	6.5	58%	0.11	1.17	1.05	76.1%
min.	0.0	2.8	1,4	0.0	24.9	0.02	5.1	42%	0.73	0.31	0.34	24.9%
max.	99.7	271.9	41.9	0.369	467.1	0.75	64.6	760%	1.26	6.59	6.18	448.9%

Source: Own calculations based on Meitzen (1869). *Notes*: 1 = Share of high quality soils in the total area (in %), 2 = cattle per 1000 acres of farmland, 3 = draught horses on farms per 1000 acres of farmland, 4 = Kilometres of tracks and waterways per 100 Prussian Square miles (1868), 5 = population per km2 (1864), 6 = farm horses per unit labour, 7 = farmland per agricultural labour unit (Prussian acre), 8= For the formula see the text, 9 = GRE is defined as net-income out of farming per Prussian acre agricultural land (*Grundsteuerreinertrag*, see text), 10 = GRE(nominal) weighted by the Prussian agricultural crop price index (see text), 11 = GRE(real)Province / GRE(real)Prussia , 12 = μ is an unweighted average (number of observations = 327 counties.

Table 3: Farm structure (operational units) in the Kingdom of Prussia, 1882

	Part time farming*	Small peasant farms	Medium peasant farms	Large peasant farms	Estates
	< 2 ha	2-5ha	5-20ha	20-100ha	> 100 ha
Provinces	share (%) in all farmland (100%)				
Eastprussia	2.0	3.4	14.0	40.6	40.1
Westprussia	2.3	3.0	13.9	31.6	49.2
Pomerania	2.4	3.1	12.4	21.2	60.9
Posen	2.1	3.0	17.6	18.7	58.5
Brandenburg	3.5	4.7	19.4	33.1	39.4
Silesia	4.5	9.9	25.3	21.3	39.1
Saxony	5.7	6.6	23.0	36.9	27.9
Westphalia	9.3	13.7	35.6	34.9	6.5
Rhineland	13.0	20.8	42.7	20.4	3.1
Prussia**	4.4	6.8	21.3	28.7	38.8

Source: own calculation based on Preussische Statistik, Vol. 76, Part 3, Berlin 1884ff., 2-48. *Notes*: The Prussian farm statistics of 1882 refers on operational units and not on property in land or farms. * The definition of farm classes follows the Prussian Statistic of 1882. Within these five categories the farm size classes are further differentiated. **Prussia in the borders of 1864. Reliable data on farm structure for the 1860s is not available.

Table 4: what explains agricultural productivity across Prussia?

Dep. Var.	Log(GRE/area)	Log(GRE_real/ area)	Log(GRE/area)	Log(GRE_real /area)	Log(GRE_real/are a)
Const.	0.536*** (0.028)	-3.269*** (0.027)	2.449*** (0.302)	-1.132*** (0.291)	-3.916*** (1.364)
Log(MP)	1.307*** (0.091)	1.090*** (0.081)	0.919*** (0.105)	0.817*** (0.099)	-
Log(MP<150km)	-	-	-	-	0.231*** (0.048)
Log(MP150-300km)	-	-	-	-	0.107* (0.066)
Log(MP300-450km)	-	-	-	-	0.113*** (0.047)
Log(MP>450km)	-	-	-	-	-0.139 (0.091)
Log(sharetopsoil+0.00 1)	-	-	0.046*** (0.008)	0.047*** (0.008)	0.042*** (0.007)
Log(horses/area)	-	-	0.371*** (0.066)	0.424*** (0.065)	0.466*** (0.071)
Log (transinfra/area)	-	-	0.254*** (0.064)	0.234*** (0.059)	0.259*** (0.057)
Inst_Pr_West	-	-	-0.065 (0.067)	-0.169** (0.067)	-0.229*** (0.072)
Inst_Fr	-	-	0.233** (0.079)	0.058 (0.078)	0.037 (0.077)
Inst_Sw	-	-	0.625*** (0.098)	0.619*** (0.083)	0.687*** (0.104)
No. of Obs.	338	338	338	338	338
Adj. R2	0.443	0.363	0.692	0.652	0.665
AIC	1.381	1.361	0.807	0.775	0.745

Source: own calculation, for data see appendix. Robust Standard Errors in Parentheses. Stars indicate statistical significance at the 10% (*), 5% (**) and 1%(***) level.

Table 5: exploring the mechanism

Dep. Var	Log(GRE/area)	Log(GRE/area)	Log(GRE_real/area)	Log(GRE_real/area)
constant	-0.186 (1.087)	0.027 (1.138)	-2.027*** (0.291)	-1.263*** (0.311)
Log(priceindex)	0.537** (0.272)	0.645** (0.296)	-	-
Log(cropmix1)	0.070** (0.033)	0.035 (0.028)	0.070** (0.033	0.035 (0.028)
Log(cropmix2)	-0.079*** (0.019)	-0.079*** (0.021)	-0.087*** (0.019)	-0.079*** (0.021)
Log(cropmix3)	-0.288***(0.036)	-0.187*** (0.033)	-0.286*** (0.036)	-0.189*** (0.033)
Log(milkcows/area)	0.267*** (0.126)	0.107 (0.105)	0.271** (0.128)	0.110 (0.047)
Log(pigs/area)	0.299*** (0.047)	0.205*** (0.048)	0.304*** (0.047)	0.201*** (0.048)
Log(labint)	0.119 (0.101)	0.154* (0.093)	0.078 (0.098)	0.149* (0.083)
Log(MP)	0.510*** (0.111)	0.555*** (0.099)	0.423*** (0.087)	0.513*** (0.087)
other controls (see table 4)	No	Yes	No	Yes
No. of Obs.	332	332	332	332
Adj. R2	0.740	0.805	0.694	0.772
AIC	0.642	0.371	0.647	0.369

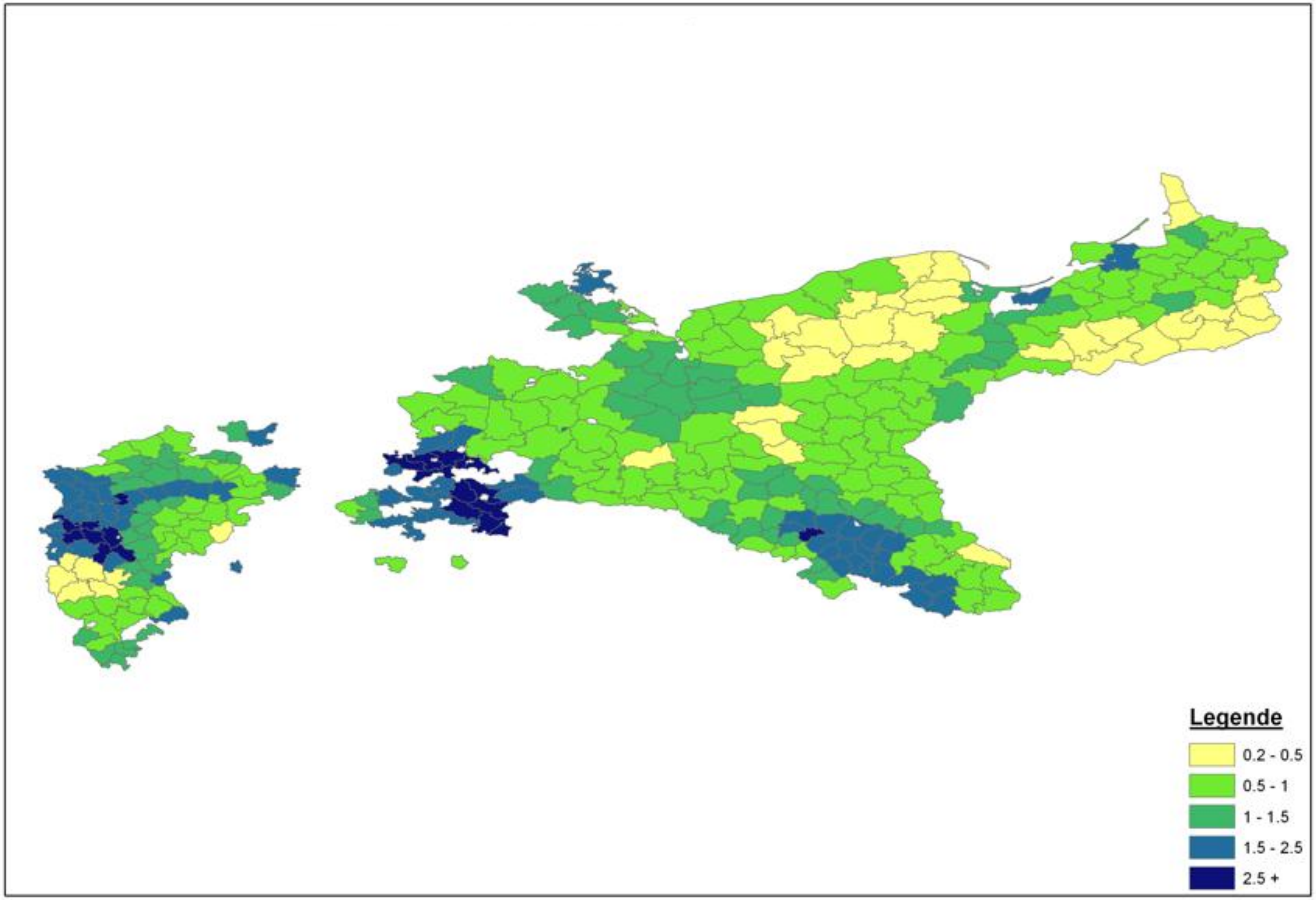
Source: own calculation, for data see appendix. Robust Standard Errors in Parentheses. Stars indicate statistical significance at the 10% (*), 5% (**) and 1%(***) level.

Table 6: is access to urban demand endogenous? IV-estimates

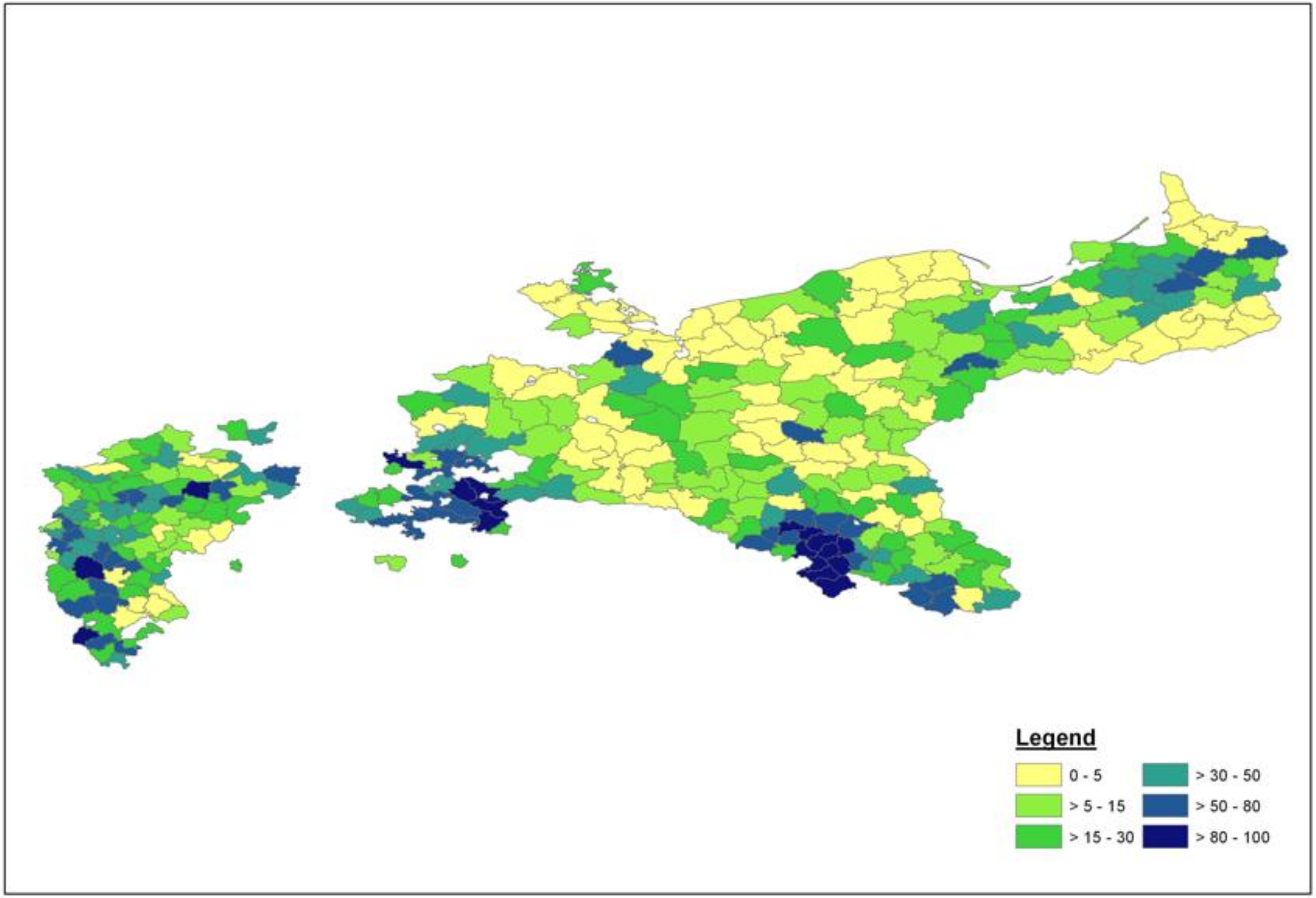
Dep. Var.	Log(GRE/area)	Log(GRE_real/area)
	MP instrumented with MP_MM	MP instrumented with MP_MM
Const.	2.449 (0.325)***	-1.121 (0.314)***
Log(MP)	1.596 (0.171)***	1.475 (0.160)***
Log(sharetopsoil +0.001)	0.043 (0.011)***	0.044 (0.010)***
Log(horses/area)	0.432 (0.068)***	0.487 (0.067)***
Log (transinfra/area)	0.095 (0.071)	0.079 (0.065)
Inst_Pr_West	-0.166 (0.068)**	-0.262 (0.074)***
Inst_Fr	0.210 (0.077)***	0.026 (0.074)
Inst_Sw	0.659 (0.066)***	0.651 (0.056)***
No. of Obs.	336	332
Adj. R2	0.622	0.575
Weak instrument diagnostic: Cragg-Donald F-statistic	221.337	218.816
Stock-Yogo critical value at 5% significance level (Wald-test size of 10%)	16.38	

Source: own calculation, for data see appendix. Robust Standard Errors in Parentheses. Stars indicate statistical significance at the 10% (*), 5% (**) and 1%(***) level.

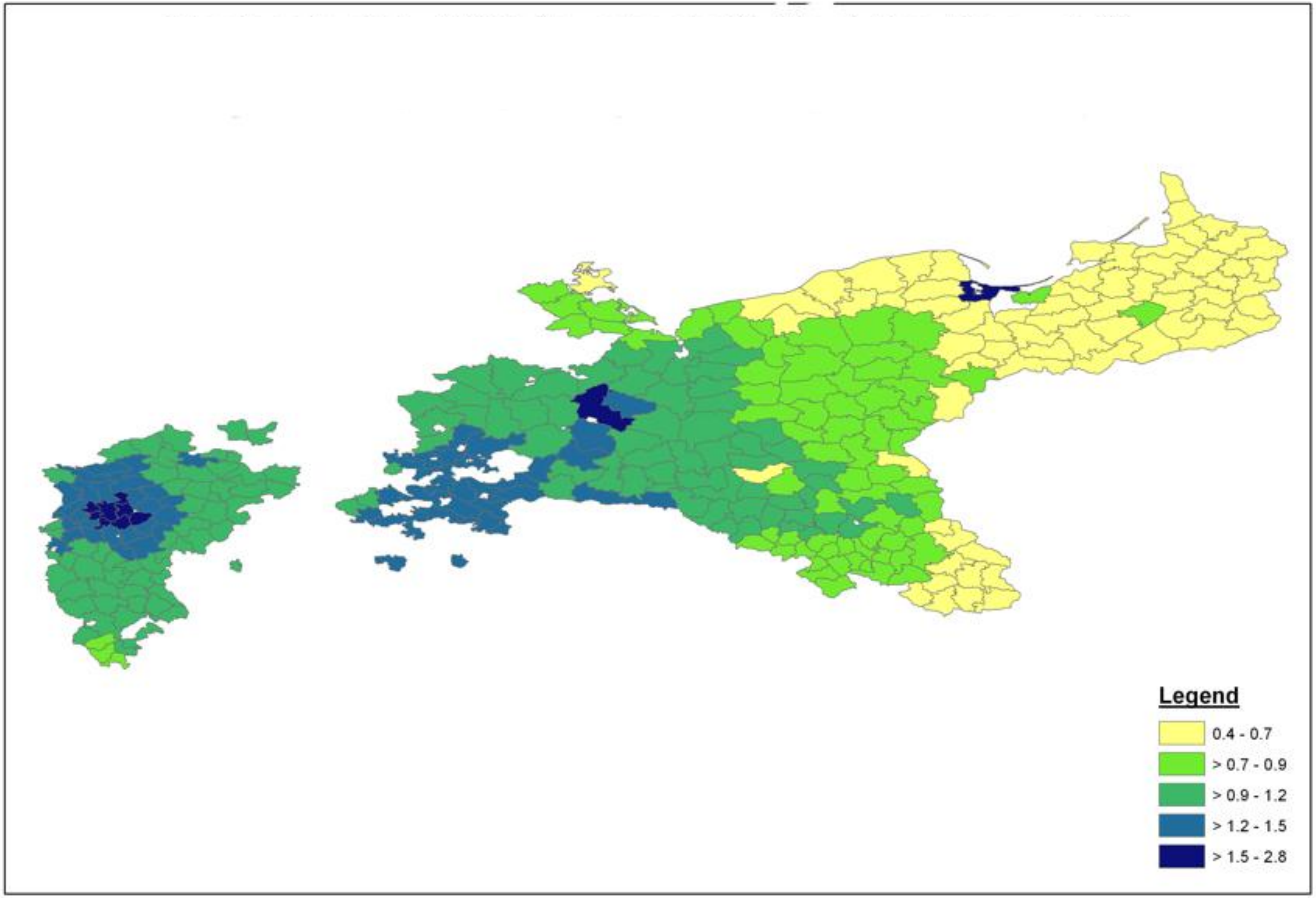
Map 1: Normalized real land rents (GRE) per Prussian Morgen farm land, 1865 (Prussian average = 1.0)



Map 2: Share of high quality soils in total area (in %), 1865



Map 3: Normalized market potential, 1865 (Prussian average = 1.0, distance weighted sum of potential urban food demand)



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