The Distributional Consequences of Trade: Evidence from the Repeal of the Corn Laws*

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Abstract

We provide new theory and evidence on the distributional consequences of trade using the 1846 Repeal of the Corn Laws. This large-scale trade liberalization opened domestic markets to the "grain invasion" from the new world that occurred as a result of late-19th century improvements in transport technology. We make use of a newly-created, spatially-disaggregated dataset on population, employment by sector, rateable values (land and property values), and poor law (welfare transfers) disbursement for around 11,000 parishes in England and Wales from 1801–1911. We show that the repeal of the Corn Laws led to rural outmigration, increased urbanization, structural transformation away from agriculture, increases in rural poverty, and sizable changes in property values. We show that a quantitative spatial model is successful in accounting for these empirical findings, with our estimates implying substantial labor mobility. We find that the aggregate welfare gains from the Repeal of the Corn Laws entailed considerable income redistribution, not only across sectors and factors, but also across geographical regions.

KEYWORDS: trade, income distribution, geography
JEL CLASSIFICATION: F14, F16, F66

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1 Introduction

> "A great and hazardous experiment is about to be made, novel in its character, and without the support of experience to guide or direct it, embracing and extending over unbounded interests, and pregnant with results that may prove fatal in their consequences." (John Gladstone, *Plain Facts Connected with the Intended Repeal of the Corn Laws*, 1846, page 30.)

One of the classic insights in international economics is that trade creates winners and losers. While research has traditionally focused on the effects of trade on the distribution of income across factors and sectors, more recent work has highlighted the uneven geographical incidence of trade shocks. In this paper, we provide new theory and evidence on the distributional consequences of trade using one of the most influential trade shocks in history following the 1846 Repeal of the Corn Laws.[1] This major trade policy reform opened British markets to international competition from the large-scale "grain invasion" from the new world that occurred in the second half of the 19th century as a result of improvements in inland and maritime transportation technologies. The key idea behind our approach is that local labor markets in Britain were unevenly affected by this trade shock, depending on the extent to which they were suitable for arable (primarily grain) farming versus pastoral (primarily sheep and cattle) farming. Using quasi-experimental empirical techniques, we first show that this trade shock led to a population redistribution from rural to urban areas, structural transformation away from agriculture, and a substantial change in the relative values of land and buildings. We next use these reduced-form moments to structurally estimate a quantitative model of the spatial distribution of economic activity across locations and sectors. We show that this estimated model is successful in accounting for the observed patterns in the data. We use it to quantify both the aggregate welfare effects from the Repeal of the Corn Laws and the distributional consequences across factors, sectors and regions.

We make use of a newly-created, spatially-disaggregated dataset on population, employment by sector, rateable values (land and property value), and poor law (welfare transfers) disbursement for around 11,000 parishes in England and Wales from 1801–1911. There are a number of advantages to this empirical setting. First, the Repeal of the Corn Laws and the opening of British markets to the "grain invasion" provides a large-scale international trade shock. Second, we have data at a fine level of spatial disaggregation over a long historical time period of a century to examine the effects of this trade shock. Third, we are able to measure regional exposure to this trade shock using exogenous agro-climatic measures of the suitability of these regions for wheat cultivation. Fourth, we have detailed data on a range of economic outcomes, which enables us to examine the distributional consequences of the trade shock across factors, sectors and locations. Fifth, 19th-century England and Wales had a largely laissez-faire economy, and hence provide a setting in which we would expect the market-based mechanisms in the model to apply.

Our paper relates to a number of strands of existing research. First, we contribute to the recent reduced-form empirical literature on the local labor market effects of international trade shocks, including Topalova (2010), Autor, Dorn, and Hanson (2013), Kovak (2013), Autor, Dorn, Hanson, and Song (2014), Pierce and Schott (2016), Kovak and Dix-Carneiro (2015), Costa, Garred, and Pessoa (2016), Kim and Vogel (2018), as reviewed in Autor, Dorn, and Hanson (2016). Most of this existing evidence on the local labor market effects of these trade shocks comes from a limited number of recent episodes, including in particular the China shock. In contrast, we provide evidence from another

[1] Throughout the paper, we use the word "corn" according to the historical British usage of all cereal grains, including wheat, oats, barley and rye, and not restricted to maize. Of all these cereal grains, wheat was by far the most important in the British market.

of the most influential trade shocks in history, which enables us to assess the generalizability of existing findings, and to explore similarities and differences. An advantage of our empirical setting is that we have an exogenous measure of the exposure to this trade shock, based on the agroclimatic suitability of locations for wheat cultivation. Whereas existing studies typically focus on overall levels of economic activity, we explore the role of this trade shock in propelling structural transformation across sectors and a reallocation of economic activity from rural to urban areas.

Our paper is also related to a recent body of research on quantitative spatial models, including Redding and Sturm (2008), Allen and Arkolakis (2014), Ahlfeldt, Redding, Sturm, and Wolf (2015), Redding (2016), Allen, Arkolakis, and Li (2017), Caliendo, Parro, Rossi-Hansberg, and Sarte (2018), Desmet, Nagy, and Rossi-Hansberg (2018), Fajgelbaum and Redding (2018), Galle, Rodríguez-Clare, and Yi (2018), Monte (2018), Monte, Redding, and Rossi-Hansberg (2018), Caliendo, Dvorkin, and Parro (2019) and Adão, Arkolakis, and Esposito (2019), as reviewed in Redding and Rossi-Hansberg (2017). While most of this literature is concerned with the spatial distribution of overall economic activity across locations, a key focus of our research is the role of the trade shock from the Repeal of the Corn Laws in explaining urbanization across locations and structural transformation across sectors, and the resulting implications for the distribution of income across factors, sectors and regions.

Third, our paper is related to a large economic history literature on the Repeal of the Corn Laws and the "grain invasion" from the new world, including Graham (1892), Nicholson (1904), Lord Ernle (1912), Barnes (1930), Olson and Harris (1959), O'Rourke, Taylor, and Williamson (1996), Howe (1998), Schonhardt-Bailey (2006), Sharp and Weisdorf (2013), Williamson (1990), O'Rourke (1997), Taylor (1999), Sharp (2009), O'Rourke and Williamson (2001), Chepeliev and Irwin (2020) and Cannadine (2019). Most of this historical research has focused on the implications of this trade shock for the distribution of income across factors (labor and the urban proletariat versus land and the rural aristocracy) and sectors (agriculture versus manufacturing and services). In contrast, our research emphasizes the uneven geographical incidence of this trade shock, and the close connection between the redistribution of population between rural and urban areas and the structural transformation of employment across sectors. Whereas most of this historical research is either qualitative or uses reduced-form empirical methods, we examine the ability of a spatial general equilibrium model to account quantitatively for the patterns in the data.

The remainder of the paper is structured as follows. Section 2 introduces the historical background to the Repeal of the Corn Laws and the "grain invasion." Section 3 summarizes the data sources and definitions. Section 4 presents reduced-form evidence on the impact of this trade shock on the distribution of economic activity across sectors and regions. Section 5 develops the spatial general equilibrium model that we use to interpret these reduced-form empirical findings. Section 6 provides evidence on that the model is successful in accounting quantitatively for the observed data. Section 7 summarizes our conclusions.

2 Historical Background

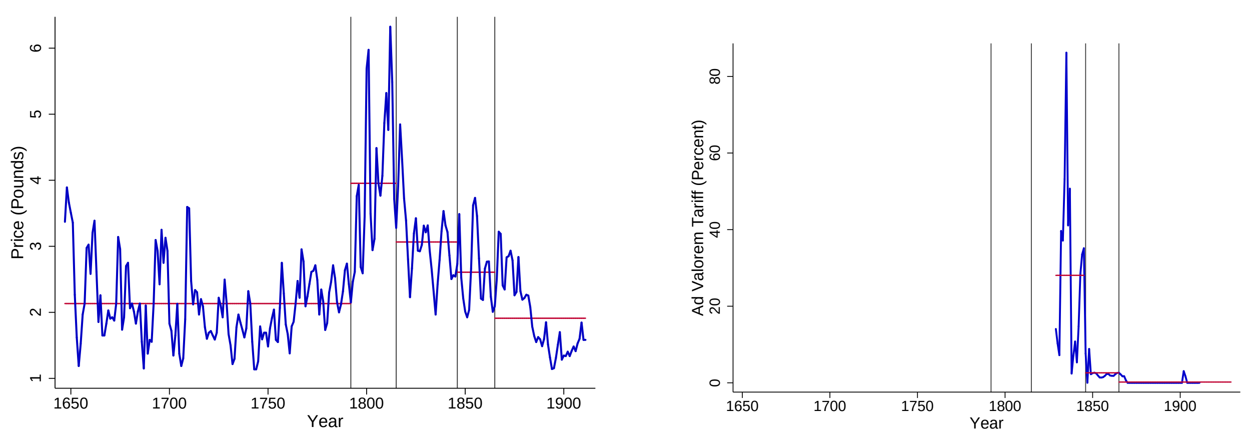
The origins of the Corn Laws date back to medieval times, as part of a broader system of regulations to control the price of bread, as the main source of sustenance for the local population.[2] After the repeal of an outdated law of 1463, there was no statutory restriction on the import of wheat until the Corn Law of 1660, which specified domestic price

[2]For historical discussions of the Corn Laws, see Nicholson (1904), Lord Ernle (1912), Barnes (1930), Fay (1932), and Sharp (2009).

bands within which different levels of import duties would apply. From 1670 until 1815, the basic format of the law stayed the same, and specified a small "nominal" duty payable when the domestic price was high, as well as a “pivot level” for the domestic price below which larger duties would be payable. In the first half of the 18th century, Britain remained largely self-sufficient in grain, and the import duties were suspended in times of scarcity, which limited their practical impact on the domestic price of wheat. However, with the onset of the industrial revolution in the 1760s and rapid population growth, the Corn Laws became of increasing relevance, as Britain developed into a growing net importer of wheat, with Prussia and Russia the traditional sources of supply.

In the aftermath of French Revolution, Britain and France were almost continuously at war during the French Revolutionary and Napoleonic Wars from 1792–1815. This widespread conflict in Europe and the inauguration of Napoleon’s continental blockage restricted Britain’s access to wheat imports from continental European countries and led to a large rise in the domestic price of wheat.[3] In Panel (a) of Figure 1, we display the mean price of wheat at Eton in England from 1646–1991. As shown by the horizontal red lines in the figure, the mean price from 1792–1815 is around double that before 1792. In response to these higher prices, marginally-productive agricultural land was brought into wheat cultivation, often involving substantial investments in land enclosure and the construction of buildings and machinery. In the aftermath of victory in 1815, the British Tory (Conservative) government of Lord Liverpool became concerned about the potential for an influx of cheap imported grains and a domestic agricultural crisis. The potential for such an agricultural crisis was of particular concern to the government, because of continuing international uncertainty about access to imports in the immediate aftermath of war, and fears of rural political unrest at a time when radical ideas had continued to circulate since the French Revolution.[4]

Figure 1: Price and *Ad valorem* Tariff on Wheat.



(a) Annual Price of Wheat (Pounds).

(b) Ad Valorem Tariff.

Panel (a): Average price of wheat in pounds sterling per imperial quarter at Eton from 1646–1911; vertical black lines show 1792 (French Revolution), 1815 (end of French Revolutionary and Napoleonic Wars), 1846 (repeal of the Corn Laws), and 1865 (end of the American Civil War); horizontal red lines show average prices in between these years; Source: Lord Ernle (1912); *Panel (b) Ad valorem* tariff on wheat from Sharp (2009).

To prevent a collapse in the domestic price of wheat, Lord Liverpool’s government passed the Corn Law of 1815, which involved a major increase in levels of protection. In particular, this law prohibited wheat imports when prices

[3]See in particular Galpin (1925). For an analysis of the impact of the continental blockade on industrial development in France, see Juhász (2018).

[4]In response to such fears of political unrest, the British government introduced a number of restrictions on individual liberty during the French Revolutionary and Napoleonic Wars (see for example Cannadine 2019). Episodes of political unrest in early-19th century Britain included Luddism from 1811–12, as well as the “Captain Swing” disturbances of 1830, as examined in Caprettini and Voth (2020).

were under 82.5 shillings per quarter, and admitted wheat free of duty above this level. As a result, with a few exceptions of some months during the years 1816–19, British ports were closed to imports of wheat until 1825. The main beneficiaries from this increased protection were rural landowners (primarily the aristocracy who were the traditional sources of support for the Tory party) through the price of land. By contrast, the main groups harmed by increased protection were workers (through a higher cost of living) and manufacturers and merchants (through a reduction in the volume of trade and upward pressure on wages to offset the higher cost of living).[5] In response to political pressure from these opponents, the provisions of this 1815 act were eventually weakened, at first through temporary acts in 1825, 1826 and 1827, which allowed some wheat to be released from bond warehouses, and later through the Duke of Wellington's 1828 act, which permanently replaced import prohibition with a sliding scale of import duties. Nevertheless, the domestic price of wheat during 1815–46 remained around 50 percent higher than before 1792 (as shown in Panel (a) of Figure 1), and the estimated average *ad valorem* equivalent of the Corn Laws over the period 1829–46 was around 30 percent according to Sharp (2009) (as shown in Panel (b) of Figure 1).

In the early 1830s, domestic harvests were plentiful and hence domestic prices remained relatively low, which ensured that discussion of the Corn Laws remained muted. In contrast, from 1837 onwards, poor domestic harvests led to a rise in the domestic price of wheat, and an increase in political protest against the Corn Laws. Supported by the growing constituency of manufacturers, and influenced by the intellectual case for free trade as espoused in Ricardo (1817), the Anti-Corn Law League developed into an influential nationwide movement led by Richard Cobden and John Bight from 1838 onwards. Around the same time, the economic recession of 1838 was the stimulus for the formation of the Chartist Movement, which campaigned for greater democratic representation of the interests of working people. In response to this growing discontent, the Tory Prime Minister Robert Peel attempted an initial set of reforms of the Corn Laws in 1842, which reduced the level of import duties. Following continuing failed harvests in Europe during the 1840s (sometimes referred to as the "Hungry Forties"), and with the beginning of the Irish Potato Famine in 1845, political pressure for further reform intensified. Finally, after thirty nights of heated parliamentary debate, and in a move that split his own Tory party and arguably kept it out of government for a generation, Robert Peel passed legislation repealing (abolishing) the Corn Laws in 1846.[6]

This repeal legislation specified a gradual reduction in import duties, which contributed towards the progressive reduction in the domestic price of wheat shown in Panel (a) of Figure 1.[7] Repeal also opened British markets to the external trade shock that occurred in the late-19th century as a result of improvements in transport technology. With increases in the speed, reliability and capacity of steam ships, international freight rates across the North Atlantic fell by around 1.5 percent per annum from around 1840 onwards, with a cumulative decline of around 70 percent points from 1840–1914 (see North 1958, Harley 1988 and Pascali 2017). Following the end of the American Civil War in 1865, the U.S. railroad network rapidly expanded into the interior, with the first transcontinental railroad completed in 1869. These reductions in internal transport costs opened up the grain-growing regions of the mid-West to international markets (see Fogel 1964 and Donaldson and Hornbeck 2016). Subsequent late-19th century expansions

[5]See for example Rogowski (1987). Land ownership in the mid-19th century was highly concentrated in the hands of the aristocracy, with around 80 percent of all land in Great Britain held by estates consisting of more than 1,000 acres as late as 1876 (Cannadine 1990).

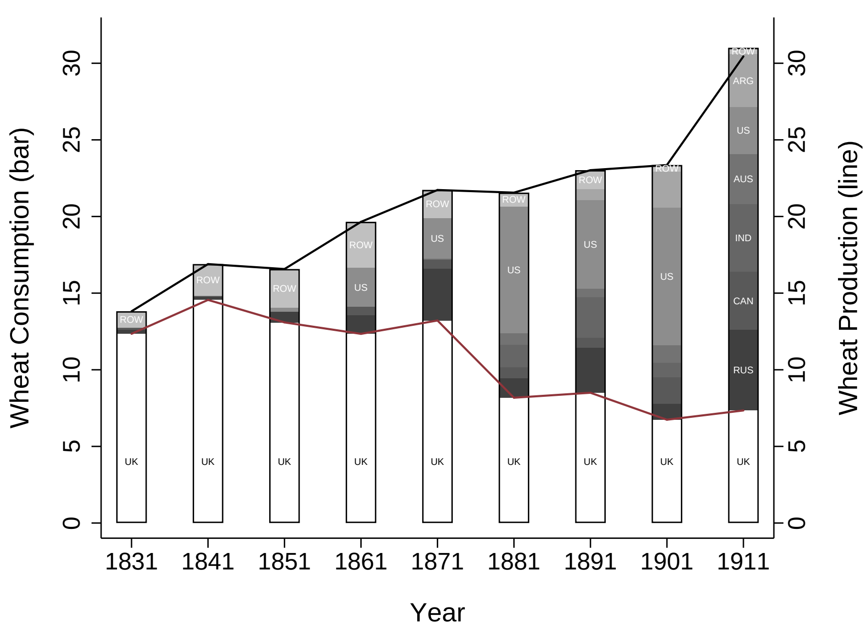
[6]Although this repeal is frequently interpreted as a political concession by an existing elite to forestall greater political change, a growing historical literature argues that Peel's decision was influenced by a threefold combination of political interests, ideologies and ideas, including in particular Irwin (1989) and Schonhardt-Bailey (1995).

[7]Following repeal, import duties were gradually reduced to 1 shilling per quarter over a three-year period until 1 February 1849. This remaining nominal duty was ultimately removed in 1869.

in the railroad network in Argentina and Canada made accessible their grain-growing interior regions (see Adelman 1994 and Fajgelbaum and Redding 2018). As a result, there was an influx of cheap new-world grain into European markets, referred to by O'Rourke (1997) as the "grain invasion," and an associated convergence in world grain prices (see Offer 1991 and O'Rourke and Williamson 2001). In contrast to a number of continental European countries, which responded to this fall in the price of wheat with increased protection, a legacy of the campaign over the Repeal of the Corn Laws in Britain was a political consensus for free trade, which ensured that British markets remained open to this grain invasion in the closing decades of the 19th century.[8]

In Figure 2, we display UK consumption, production and imports of wheat over time (quantities in millions of quarters), where consumption equals the sum of domestic production and imports. In 1831 and 1841 before the repeal of the Corn Laws, UK imports were small in magnitude, and largely originated from traditional sources of supply in Europe. Following the repeal of the Corn Laws in 1846, we observe a progressive increase in UK imports of wheat, which accelerates after the end of the American Civil War in 1865, as the American Mid-West and other New World producers become increasingly integrated into international markets. In the closing decades of our sample, Argentina, Australia, Canada, India and the United States all emerge as major new world sources of supply for wheat. In the aftermath of this grain invasion and the associated decline in the domestic price of wheat (as shown in Panel (a) of Figure 1), we observe a continuing decline in UK production of wheat until 1901, after which there is a small recovery in both the domestic price of wheat and domestic production of wheat.

Figure 2: UK Consumption, Production and Imports of Wheat 1831–1911.



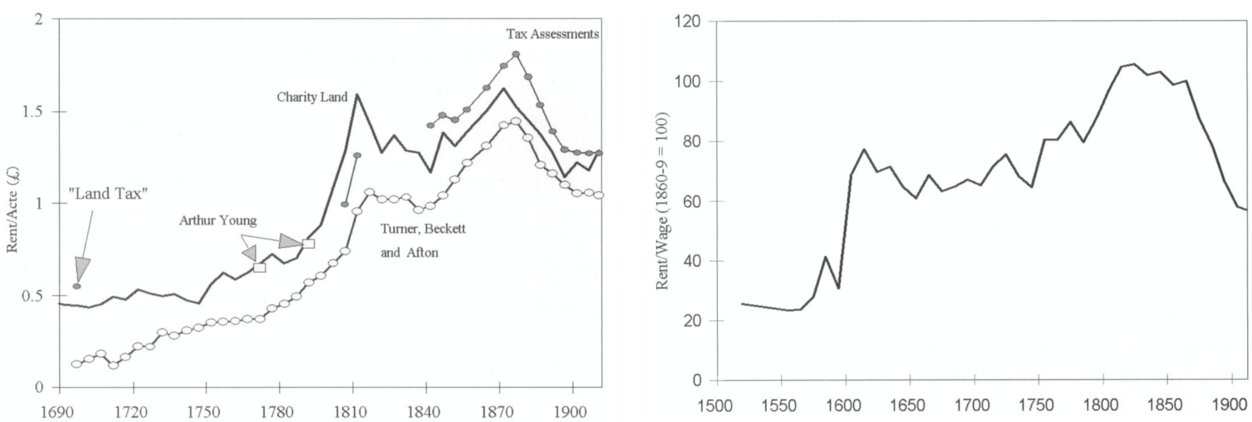
Notes: UK consumption, production and imports of wheat (quantities) in millions of quarters; consumption is the sum of domestic production and imports; imports from different source countries indicated by the gray shading and white letters: ARG (Argentina); AUS (Australia); CAN (Canada), IND (India), ROW (Rest of World), RUS (Russia), and US (United States); Source: Sharp (2009).

This "grain invasion" from the new world, and the consequent fall in domestic prices and production of wheat, led to what is referred to as the "great agricultural depression" in Britain from 1870 onwards. Land rental values fell in

[8]For further discussion of this legacy of the campaign over the Repeal of the Corn Laws, see Trentmann (2008).

nominal terms after 1870, as shown in Figure 4(a). With falling agricultural prices and rising wages as a result of the productivity gains from the industrial revolution, land rental values fell even more relative to wages than they did in nominal terms, as indicated in Figure 4(b). Large numbers of farmers either went bankrupt or switched from arable to pastoral farming (as discussed in Perry 1972). Arable land shrank over the period from 1871–1901 by 29 percent from 8.2 to 5.9 million acres, while the area of permanent pasture experienced a 36 percent increase from 11.4 to 15.4 million acres (Lord Ernle 1912). Rural depopulation became a source of contemporary debate (Longstaff 1893) and the subject of an official government report (Board of Agriculture and Fisheries 1906). As income from land land fell relative to mortgage debt and other encumbrances, many aristocratic landowners chose to divest or break up their great estates, contributing to the decline and fall of the British aristocracy: "Across the whole of the British Isles, the change between the late 1870s and the late 1930s was remarkable, as five hundred years of patrician landownership had effectively been halted and reversed in seventy" (Cannadine 1990, p. 111).

Figure 3: UK Land Rental Values and Land Rental Values Relative to Wages.



(a) Land Rental Values.

(b) Land Rental Values / Wages.

Panel (a): Land rental values in current price pounds sterling, which are the weighted average of land rental values for individual properties in Great Britain; Charity land rental values from Clark (2002); Turner, Beckett and Afton land rental values from Turner, Beckett, and Afton (1997); Arthur Young land rental values from Turner, Beckett, and Afton (1997); and tax assessments from Stamp (1920); *Panel (b):* Land rental values relative to wages from Clark (2002).

3 Data

We construct a new spatially-disaggregated dataset on population, employment by sector, rateable values (land and property value), and poor law payments (welfare transfers) for England and Wales from 1801–1911. Our main source of data is the population census, which we augment with a number of other sources of data, as summarized below, and discussed in further detail in Section B of the online Appendix.

Spatial Units: Data are available at three main levels of spatial aggregation: parishes (11,448), poor law unions (575) and counties (53). Parishes were historically the lowest level of local government in England and Wales, responsible for the provision of a variety of public goods, including poor relief (welfare payments) since the Poor Law Act of 1601. Parish boundaries are relatively stable throughout most of the 19th century, but experience substantial changes after

1911. For this reason, and to abstract from the First World War, we end our sample in 1911.[9] We construct constant parish boundary data every census decade from 1801–1911 using the classification provided by Shaw-Taylor, Davies, Kitson, Newton, Satchell, and Wrigley (2010), as discussed further in Section B1.2 of the online Appendix.

Following the Poor Law Amendment Act of 1834, these parishes were grouped into poor law unions, which became an intermediate tier of local government, responsible for the administration of poor relief for the parishes within their boundaries. These poor law unions correspond closely to registration districts in the population census and we use these two terms interchangeably. Both parishes and poor law unions aggregate to counties (e.g., Warwickshire), which were historically the upper tier of local government in England and Wales, responsible for the administration of justice, taxes, and parliamentary representation. Parishes have an average area of 13 kilometers squared and 1851 population of 1,590, which compares to an average area of 262 kilometers squared and 1851 population of 26,401 for poor law unions, and an average area of 2,553 kilometers squared and 1851 population of 404,262 for counties.

We focus on parishes as our baseline unit of analysis for two main reasons. First, poor law unions typically aggregate neighboring rural and urban parishes together, whereas we are precisely concerned with the reallocation of economic activity from rural to urban areas. Second, parishes allow us to measure variation in agroclimatic conditions at a much finer level of spatial detail, taking into account local differences in soil conditions and topography, whereas Poor Law Unions average out this variation. In some of our empirical analysis, we distinguish between rural and urban parishes, where we define using two groups using K-means clustering based on population density at the beginning of our sample in 1801, as discussed further in Section B4 of the online Appendix.

Parish Population: We construct population data from the parish-level records of the population census of England and Wales, which is enumerated every decade from 1801–1911.

Employment by industry: The population census of England and Wales reports detailed information on industry and occupation from 1851 onwards. We consider 18 one-digit industries (e.g. Agriculture, Wholesale and Retail Trade) and 797 two-digit occupations (e.g. Accountant, Agricultural Laborer). We also use this information to construct employment data for the three aggregate sectors of agriculture, manufacturing and services for each parish.

Individual-Level Data: Individual-level records from the population census of England and Wales are available digitally for 1851–1861 and 1881–1901 through the Integrated Census Microdata Project (I-CeM).[10] We use these individual-level records to track people across regions, occupations and industries over time. Building on the record-linking techniques developed for the United States in Abramitzky, Eriksson, Feigenbaum, Platt Boustan, and Perez (2020), we match individuals across the different waves of the population census. Our matching procedure uses a combination of the age, gender, county of birth and name of each individual to select a unique match across consecutive Census waves. Our use of only these matching variables ensures that the matching process s not influenced by individuals' economic decisions about occupation, sector or location after birth. We focus on men to abstract from the changes in names that historically occurred for many women upon marriage. In Section C of the online Appendix, we provide further details on the matching process, including match quality and balance statistics for the matched and

[9]As discussed further below, 1911 is also the last year for which individual-level census records are currently available for England and Wales under one hundred year confidentiality laws.

[10]The individual-level records for the 1801–1841 and 1871 population censuses are not yet available digitally.

unmatched samples. For each consecutive pair of census waves, we match around 30 percent of the population, which is consistent with match rates using U.S. population census data. We thus obtain the following matched samples of individuals between each pair of census waves: 5,323,072 (1851–61), 3,686,306 (1861–81), 7,527,280 (1881–1891), and 12,151,542 (1891–1901). Additionally, the population census for each year also reports both country and county of birth for each individual. We use this information to construct a separate measure of bilateral migration since birth between counties, which does not require name matching across census waves, and includes both men and women.

Rateable Values: We measure the value of land and buildings in England and Wales using rateable values, which correspond to the annual flow of rent for the use of land and buildings, and equals the price times the quantity of floor space in the model. In particular, these rateable values correspond to "The annual rent which a tenant might reasonably be expected, taking one year with one another, to pay for a hereditament, if the tenant undertook to pay all usual tenant's rates and taxes ... after deducting the probable annual average cost of the repairs, insurance and other expenses" (Stamp 1920). With a few minor exceptions, they cover all categories of property, including public services (such as tramways, electricity works etc.), government property (such as courts, parliaments etc.), private property (including factories, warehouses, wharves, offices, shops, theaters, music halls, clubs, and all residential dwellings), and other property (including colleges and halls in universities, hospitals and other charity properties, public schools, and almshouses). They also include all land, both agricultural and non-agricultural. All categories of properties were assessed, regardless of whether or not their owners were liable for income tax. The main exemptions include roads, canals, railways, mines, quarries, Crown property occupied by the Crown, and places of divine worship. We construct rateable values for each parish for the years for which these are available from 1815–1896 by digitizing the data reported in the publications of the Houses of Parliament (see Section B1.3 of the online Appendix).

Poor Law Transfers: The poor law corresponded to a system of welfare transfers for the poor, which dates back to the 1601 Poor Relief Act, as discussed further in Boyer (1990) and Renwick (2017). Originally, these poor law payments were administered at the parish level and consisted of disbursements of money and resources for those in need, typically referred to as "outdoor relief." Following the passage of the 1834 New Poor Law, parishes were grouped into Poor Law Unions, and there was a move towards housing recipients of poor law support in separate workhouses, typically referred to as "indoor relief." Nevertheless, substantial amounts of outdoor relief continued to be given, even after 1834. We construct poor relief payments for each parish for each census year from 1831 onwards by digitizing the data reported in the publications of the Houses of Parliament, Poor Law Commissioners, Poor Law Board, and the Annual Returns on Local Taxation.

Corn Prices, Production and Trade: We use a number of different sources of data on prices, trade policy, imports and production of corn. We construct a time-series on the price of wheat per imperial quarter at Eton from 1646 to 1911 from Lord Ernle (1912). We obtain data on total wheat imports, wheat imports from different exporting countries, the *ad valorem* equivalent of the Corn Laws, and on UK and US wheat production from Sharp (2009), Sharp (2010), and Sharp and Weisdorf (2013).

Agricultural Production: We use county-level data on agricultural land use in acres from the Agricultural Returns of the United Kingdom from 1878-1911. Agricultural acreage is reported for a number of different categories: (i) wheat,

(ii) other corn crops (e.g. barley, oats and rye), (iii) permanent pasture or grass not broken up in rotation, (iv) clover, sanfoin and grasses under rotation, (v) green crops (potatos, turnips and swedes, mangold, carrots, cabbage, kohl-rabi and rape, and vetches), and (vi) bare fallow (land remaining uncropped for a season and kept free of vegetation). We also use data on cultivated land area for a number of different crops from the 1801 crop census, as used in Caprettini and Voth (2020), and the 1836 Tithe surveys. We construct our exogenous measure of exposure to the grain invasion using data on the suitability of climate and soil conditions for the cultivation of wheat from the United Nations Food and Agricultural Organization Global Agro-Ecological Zones (GAEZ) dataset, as used in Costinot, Donaldson, and Smith (2016). Consistent with 19th-century farming practices in England and Wales, we use the measure of wheat suitability for low-input and rain-fed cultivation.

4 Reduced-Form Evidence

In this section, we present reduced-form evidence on the impact of the grain invasion following the Repeal of the Corn Laws on structural transformation, population, property values and spatial, sector and occupational mobility. In Section 4.1, we introduce our exogenous measure of location exposure to the grain invasion, based on the suitability of agroclimatic conditions for the cultivation of wheat. In Section 4.2, we provide evidence on the relationship between structural transformation and wheat suitability over time. In Section 4.4, we estimate an event-study specification for population and wheat suitability over time. In Section 4.5, we estimate a similar specification for property values. Finally, in Section 4.6, we use our individual-level data to evaluate the different margins of adjustment to this trade shock for individuals in locations with different levels of wheat suitability.

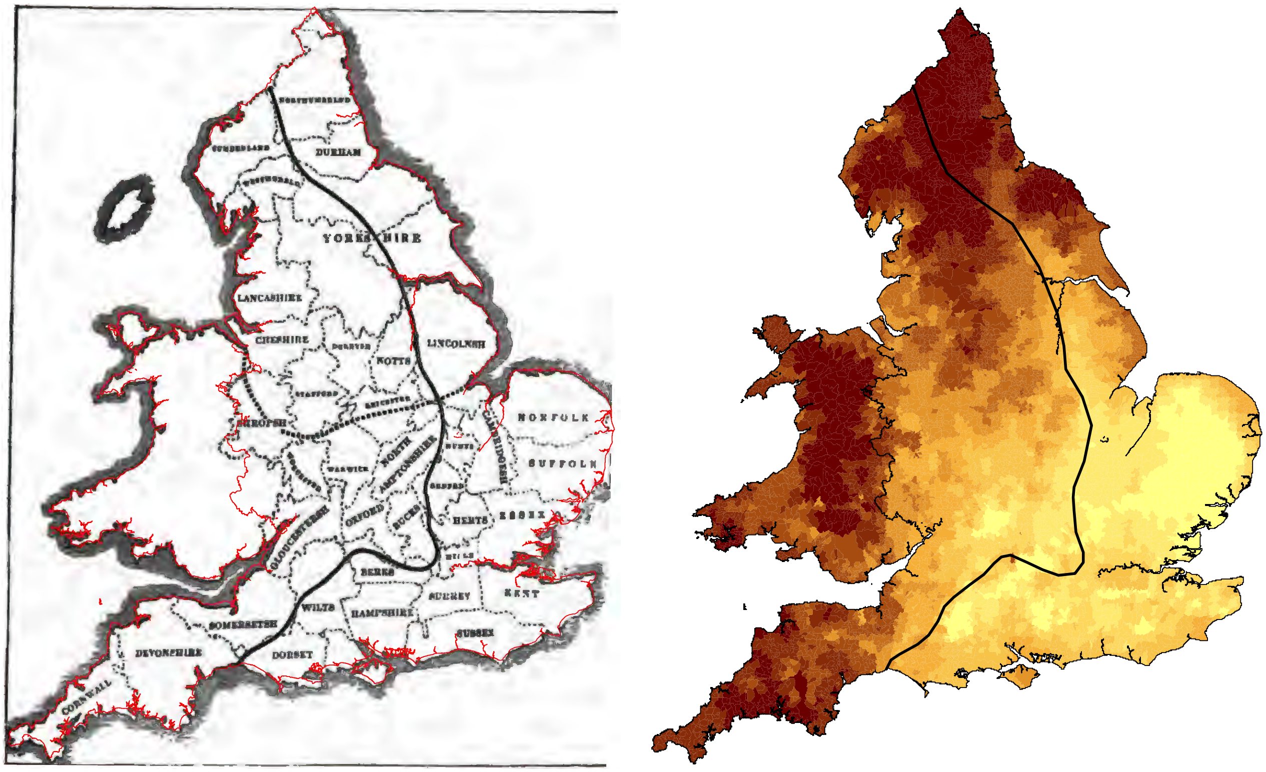
4.1 Grain and Grazing Regions

An advantage of our empirical setting is that there is a marked difference in agroclimatic conditions between the Western and Eastern parts of England and Wales.[11] In particular, the warm ocean current of the North Atlantic Drift and the prevailing winds from the South-West generate greater cloud cover, more precipitation, and lower average temperatures in Western areas. Many of the more mountainous areas of England and Wales are also concentrated in these Western areas (such as the Welsh mountains and the Lake District), with a line of hills (the Pennines) running approximately down the middle of England. As a result, these more rugged Western areas typically have thinner and more barren soils. In contrast, the Eastern parts of the country are in the rain shadow of these mountains, with lower cloud cover, less precipitation, and higher average temperatures. These Eastern areas are also more low-lying, with thicker and more fertile soils, in part because of the accumulated sediment from the water erosion of the more mountainous areas to the West. For these combined reasons of climate, terrain and soil, Western locations are more suitable for grass (and hence the grazing of cattle and sheep), while Eastern locations are more suitable for the cultivation of corn (historically mainly wheat, but also barley, maize, and rye).

This difference in agroclimatic conditions has been reflected in longstanding differences in agricultural land use between Western and Eastern regions. In his seminal mid-19th century study of the state of English agriculture, Caird (1852) drew a line approximately down the middle of England that separated the "grazing counties" of the West from the "corn counties" of the East, as shown in a reproduction of his original map in Figure 5(a). As a check on the

[11] See, for example, the classic volume on the physical geography of the British Isles by Goudie and Brunsden (1995).

Figure 4: Caird's Western-Grazing and Eastern-Corn Counties and Wheat Suitability (UN GAEZ).



(a) Reproduction of Caird's Original Map.

(b) Wheat Suitability (UN GAEZ).

Notes: Panel (a): Reproduction of Caird's (1852) original map; the thick black line shows his division between the grazing and the corn counties; the thin red line shows the outline of England and Wales used to georeference the original map; *Panel (b):* Low-Input, Rain-Fed Wheat Suitability from the United Nations Global Agro-Ecological Zones (UN GAEZ); lighter shading corresponds to greater suitability for wheat cultivation.

relevance of this distinction, we superimpose the Caird line on a map of low-input, rain-fed wheat suitability from the United Nations Global Agro-Ecological Zones (GAEZ) data in Figure 5(b).[12] Although this GAEZ measure is computed for the period 1961–1990, these differences in relative agroclimatic conditions between the Western and Eastern parts of England and Wales have been stable for centuries.[13] As shown in the figure, we find a close correspondence between the Caird line and wheat suitability as measured by UN GAEZ. Despite these clear differences between Western and Eastern areas, we also find some heterogeneity in wheat suitability within each of these parts of England and Wales, which we exploit using our spatially-disaggregated parish-level data. In particular, for each parish, we compute mean wheat suitability across 5 arc-minute pixels within its geographical boundaries.

We now use this exogenous measure of wheat suitability based on agroclimatic conditions to provide causal evidence on the impact of the grain invasion on the distribution of economic activity across sectors and regions.

4.2 Structural Transformation

In this subsection, we examine the relationship between structural transformation and wheat suitability over time. We begin by confirming that West-East location within England and Wales is accompanied by systematic differences in agricultural practices. In particular, arable farming (including corn cultivation) is substantially more intensive than

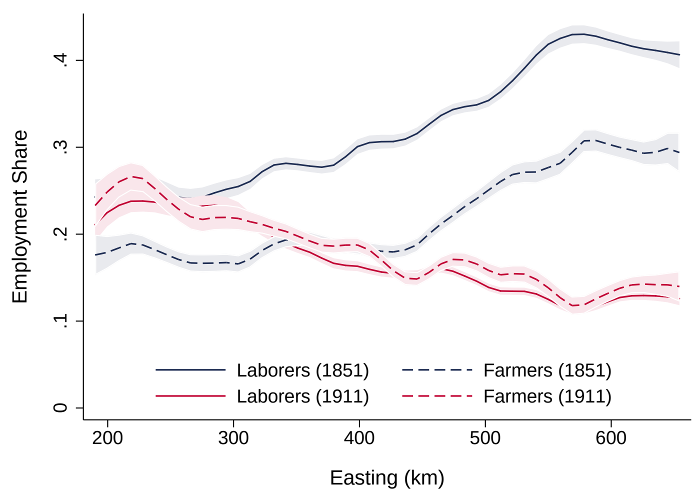
[12] We provide further direct evidence on the relationship between arable/pastoral farming and exogenous agroclimatic conditions using the 1836 Tithe maps for unenclosed land in Section B2 of the online Appendix.

[13] Despite this stability in relative agroclimatic conditions, there was an increase in overall temperature levels during the medieval warm period (900–1300 CE) and a decrease in overall temperature levels during the little ice age (1300–1850 CE), as discussed for example in Fagan (2019).

pastoral farming (including the grazing of cattle and sheep). Whereas cattle and sheep can be left to graze in fields and pastures, corn cultivation involves intensive horticultural tasks, such as ploughing, sowing, weeding, harvesting and threshing, which historically required large numbers of agricultural laborers.

In Figure 5, we display the shares of farmers (red) and agricultural laborers (blue) in employment in 1851 (solid lines) and 1911 (dashed lines) against West-East location, as measured by the Eastings of the British National Grid (BNG) of the Ordinance Survey (OS).[14] In each case, we show the fitted values from kernel (Epanechnikov) regressions (dark lines) and the 95 percent confidence intervals (light gray shading). We find that the share of farmers in employment is relatively flat and, if anything, declines as one moves further Eastwards, with the peak share of employment occurring at an Easting of just over 200 (where Swansea in Wales has an Easting of 266). In contrast, the share of agricultural laborers in employment increases progressively as one moves further Eastwards, consistent with these more Easterly locations specializing in more labor-intensive corn cultivation.

Figure 5: Employment Shares of Agricultural Laborers and Farmers in 1851 and 1911 by Easting



Notes: Kernel (Epanechnikov) regressions of employment shares on Easting across parishes in England and Wales; dark lines show fitted values and lighter shading shows 95 percent point confidence intervals; Eastings are based on the British National Grid (BNG) of the Ordinance Survey (OS) and measure East-West location, where the Guildhall in the center of the City of London has an Easting of 532 kilometers.

Between 1851 and 1911, the share of farmers in employment remains relative constant across locations with different West-East orientation. By contrast, the share of agricultural laborers in employment declines for all locations, with the greatest declines observed for locations with Easting of more than 400 (where Birmingham has an Easting of 408), with the result that the gradient of agricultural laborers in East-West orientation is much shallower at the end of our sample period than at its beginning. Therefore, we find greater structural transformation away from agriculture in Eastern-corn locations than in Western-grazing locations following the grain invasion of the late-19th century.[15]

In Figure 6, we tighten this connection between structural transformation and wheat suitability, by displaying the changes in the shares of sectors in employment from 1851–1911 against our wheat suitability measure (normalized to lie between 0 and 1). In each case, we show the fitted values from kernel (Epanechnikov) regressions (dark lines) and the 95 percent confidence intervals (light gray shading). As shown in the top-left panel, there is a much greater

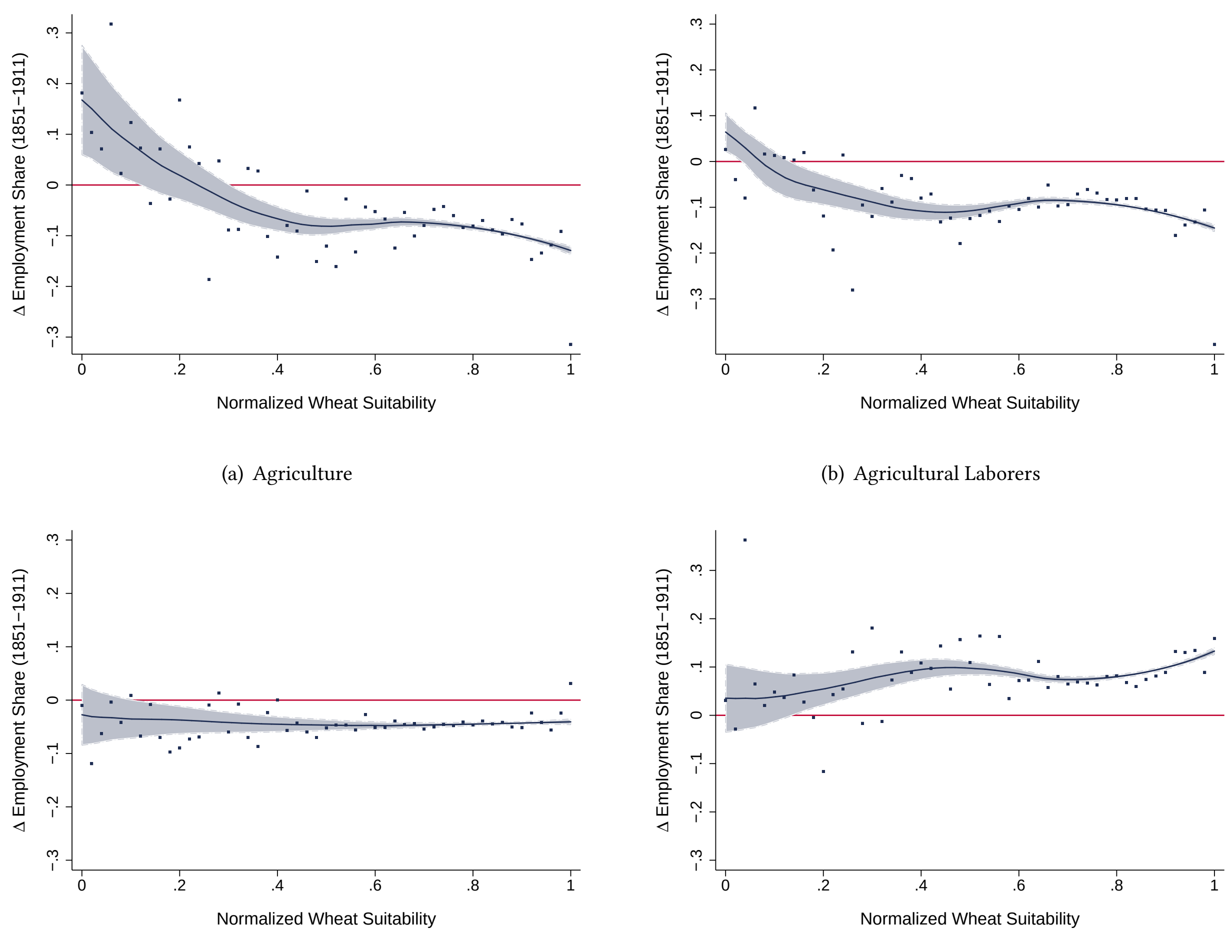
[14]The first year for which employment by industry is available in the population census is 1851. To provide a benchmark for the interpretation of the Eastings, the Guildhall in the center of the historical City of London has an Easting of 532 kilometers.

[15]For further evidence on the structural transformation of England and Wales over the 19th century, see Section B4 of the online Appendix.

overall decline in agricultural employment in high wheat suitability locations. Comparing the top-left and top-right panels, this greater decline in agricultural specialization in high wheat suitability locations is mainly driven by a larger reduction in the share of agricultural laborers in employment in those locations, consistent with a decline in corn cultivation that is intensive in the employment of these agricultural laborers.

In the bottom-left panel, we show that there is little relationship between the change in manufacturing's share of employment and wheat suitability. This finding confirms that the more rapid decline in agriculture in high wheat suitability locations is not driven by a general equilibrium "Dutch Disease"' effect from a more rapid expansion of manufacturing as part of the industrial revolution that began in the 1760s. This finding is also consistent with the fact that the expansion in manufacturing after 1760 was concentrated in the new large industrial cities of Manchester and Birmingham and in the existing urban center of London, which are located in areas with very different levels of wheat suitability (low, medium and high respectively).

Figure 6: Change in Employment Shares from 1851–1911 by Wheat Suitability.



(a) Agriculture

(b) Agricultural Laborers

(c) Manufacturing

(d) Services

Notes: Kernel (Epanechnikov) regressions of the change in sectoral employment shares on wheat suitability (normalized to lie between 0 and 1) across parishes in England and Wales; dark lines show fitted values and lighter shading shows 95 percent point confidence intervals.

Finally, as shown in the bottom-right panel, the counterpart of a more rapid decline in agricultural employment shares in high wheat suitability locations, and little systematic pattern for changes in manufacturing employment shares, is a more rapid rise in services employment shares in high wheat suitability locations. This pattern of results is in line with the idea that the reduction in employment opportunities for agricultural laborers as a result of the grain invasion increased the relative importance of local services as a source of rural employment, including in particular personal services for the gentry and aristocracy that dominated rural economic life in England and Wales until the great agricultural depression of the late-19th century.[16]

Taken together, this pattern of results is consistent with the negative trade shock from the grain invasion in the second half of the 19th century disproportionately affecting Eastern-corn locations. These findings are in line with the historical narrative on the great agricultural depression in England after 1870, which emphasizes that these Eastern-corn locations were more heavily hit, and discusses the rural depopulation as a result of agricultural laborers leaving the land, land sales by great estates in response to declining rents, and a switch from arable to pastoral farming.[17]

4.3 Reallocation Within Agriculture

In this subsection, we provide further evidence in support of our mechanism that the trade shock from the grain invasion disproportionately affected locations that were suitable for corn cultivation as opposed to the grazing of cattle and sheep. In particular, we use our county-level data on the acreage of agricultural land allocated to different uses from the Agricultural Returns of the United Kingdom. We focus on the period from 1878 (the first year for which wheat cultivated area is reported as a separate category) to 1901 (after which there is some recovery in both the price and production of wheat in Figures 1 and 2).

In Panel (a) of Figure 7, we display the change in wheat's share of agricultural land area from 1878–1901 against its initial share in 1878. Each blue dot corresponds to a county in England or Wales and we also show the regression relationship between the two variables. As shown in the figure, we observe a decline in wheat's share of agricultural land in all counties, which ranges up to 8 percentage points. Consistent with the grain invasion disproportionately affecting corn-growing regions, we find that those counties with the highest initial wheat shares (up to 25 percentage points) experience the greatest declines in wheat's share of the agricultural land. The regression relationship between two variables is negative and statistically significant at conventional critical values, with a slope coefficient of -0.331 (standard error of 0.033) and a regression R-squared of 0.77.[18]

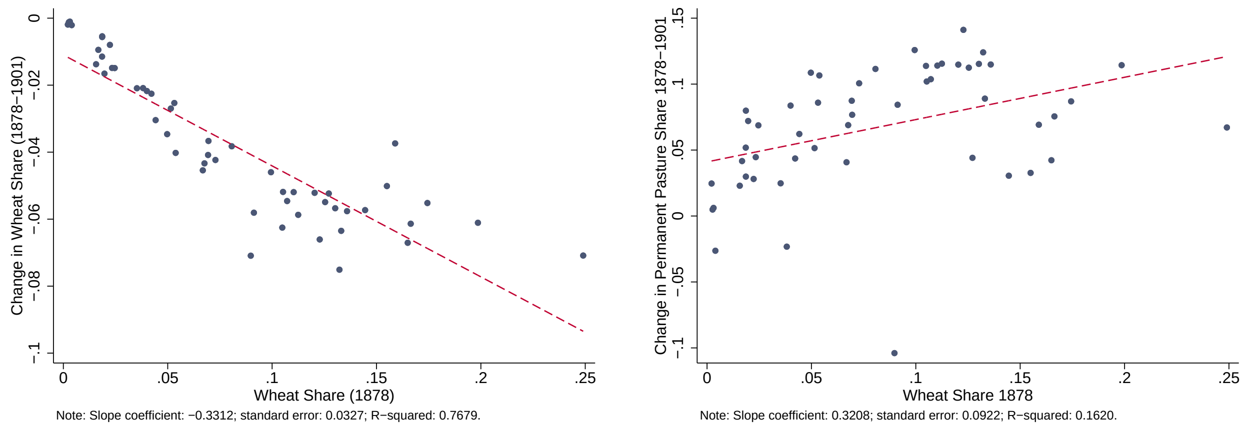
In Panel (b) of Figure 7, we display the change in permanent pasture's share of agricultural land area from 1878–1901 against the initial share of wheat in agriculture land area in 1878. For the vast majority of counties, we observe an increase in permanent pasture's share of agricultural land area. Furthermore, we find that those counties with the highest initial wheat shares experience the greatest increases in permanent pasture's share of agricultural land area. The regression relationship between two variables is positive and statistically significant at conventional critical values, with a slope coefficient of 0.321 (standard error 0.092) and a regression R-squared of 0.16.

[16] As discussed above, around 80 percent of all land in Great Britain was held by estates consisting of more than 1,000 acres as late as 1876 (see Table 1.1. in Cannadine 1990).

[17] See Fletcher (1961) and Perry (1973) on the great agricultural depression; Graham (1892), Longstaff (1893) and Board of Agriculture and Fisheries (1906) on rural depopulation; see Thompson (1963) and Cannadine (1990) on the break-up of the great estates; and Perry (1972) on the geography of agricultural bankruptcies and the switch from arable to pastoral farming.

[18] This regression relationship does not simply capture mean reversion for all agricultural goods. If we regress the change in permanent pasture's share of agricultural land from 1878–1901 against its initial share in 1878, we find a coefficient that is positive (0.031) and not statistically significantly different from zero (standard error 0.049), with a regression R-squared of 0.01.

Figure 7: Reallocation of Agricultural Land from Wheat Cultivation to Permanent Pasture.



(a) Change in Wheat Share of Agricultural Land 1878–1901

(b) Change in Permanent Pasture Share of Agricultural Land 1878–1901

Notes: Panel (a): Change in wheat share of agricultural land from 1878–1901 against initial wheat share of agricultural land in 1878; *Panel (b):* Change in permanent pasture share of agricultural land from 1878–1901 against initial wheat share of agricultural land in 1878; in addition to wheat and permanent pasture (for grazing of animals), agricultural land area also includes other corn crops (e.g., barley, oats and rye), clover, sanfoin and grasses under rotation, green crops (potatos, turnips and swedes, mangold, carrots, cabbage, kohlrabi and rape, and vetches), and bare fallow (land remaining uncropped for a season and kept free of vegetation).

Overall, these results provide further support for our mechanism, and suggest that our findings are not capturing a common decline in all agricultural activities. We find a pattern of changes in agricultural land use consistent with the idea that the grain invasion disproportionately affected corn-growing regions and led to a reallocation of economic activity within agriculture towards the grazing of cattle and sheep.

4.4 Population

In this subsection, we provide reduced-form regression evidence on the impact of the grain invasion on the spatial distribution of population in England and Wales, using our parish-level population data that are available every census decade from 1801–1911. We consider the following event-study specification for the relationship between log parish population and our measure of wheat suitability:

$$\ln L_{jt} = \sum_{\tau=-40}^{\tau=70} \beta_\tau \left(\mathbb{W}_j \times \mathbb{I}_\tau \right) + \left(X_j \times \delta_t \right) + \eta_j + d_t + u_{jt}, \tag{1}$$

where j indexes parishes; t indicates the census year; L_{jt} is parish population; $\mathbb{W}_j$ is an indicator variable that is one if a parish has above-median wheat suitability and zero otherwise; τ denotes treatment year, which equals census year minus 1841 as the last census year before the repeal of the Corn Laws; the excluded category is treatment year $\tau = 0$ (1841); recalling that our sample starts in 1801 and ends in 1911, we have 40 years before and 70 years after the treatment; $\mathbb{I}_\tau$ is an indicator variable that is one for treatment year τ; X_j are controls for observable parish characteristics that could affect population growth and δ_t are time-varying coefficients on these controls; we include among these controls (i) travel time to the nearest market town; (ii) travel time to the nearest coalfield; (iii) distance to London and distance to Manchester; (iv) Easting and Northing of the parish centroid; (v) an indicator that is one for Wales; (vi) an indicator that is one for urban parishes based on the 1801 distribution of population densities; η_j is a parish fixed effect; d_t is a census-year dummy; and u_{jt} is a stochastic error.[19] In our baseline specification, we report

[19] We describe in Appendix B4 the construction of the urban indicator and the construction of measures based on the transportation network (travel time to the nearest market town, and travel time to the nearest coalfield).

standard errors clustered by poor law union, which allows the error term to be serially correlated across parishes within poor law unions and over time.[20]

In this specification, the parish fixed effects (η_j) allow for time-invariant unobserved heterogeneity in the determinants of parish population that can be correlated with wheat suitability. The census-year dummies (d_t) control for secular changes in population across all parishes over time, as a result for example of aggregate population growth. The key coefficients of interest (β_τ) are those on the interaction terms between wheat suitability ($\mathbb{W}_j$) and the treatment year indicators ($\mathbb{I}_\tau$). These coefficients have a "difference-in-difference" interpretation, where the first difference compares parishes with above and below-median wheat suitability, and the second difference undertakes this comparison between treatment year zero (census year 1841) and each preceding or succeeding census year. The main effect of each of our controls for observable parish characteristics (X_j) is captured in the parish fixed effect. The interactions between the census-year dummies and these controls (X_j) allow for heterogeneity in population growth rates across parishes depending on latitude/longitude; proximity to urban areas; coalfields; London and Manchester; for parishes in England versus Wales; and for parishes in urban versus rural areas.

In Appendix Table D.1, we report results where we stepwise include these interactions. Figure 8 shows our preferred specification from Column 6 of this table with the full set of controls. The figure displays the estimated treatment coefficients (β_τ), where the vertical bars correspond to the 95 percent confidence intervals clustered by poor law union, and the vertical red line shows the Repeal of the Corn Laws in 1846. In the early decades of the 19th century, high and low wheat suitability locations have similar rates of population growth, with all estimated coefficients close to zero and statistically insignificant. This pattern of results is consistent with the Corn Law of 1815 limiting the fall in the domestic wheat price after the end of the Napoleonic Wars and thereby preserving the profitability of corn cultivation in the opening decades of the 19th century.

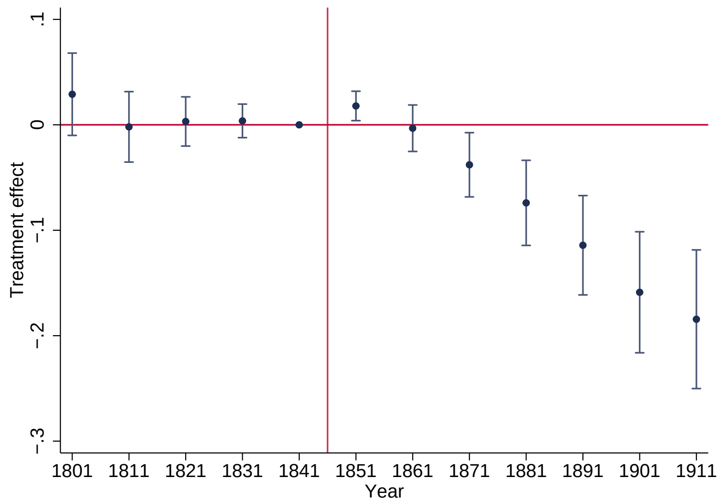
By contrast, shortly after the Repeal of the Corn Laws, we observe a sharp decline in rates of population growth in locations with high wheat suitability relative to those with low wheat suitability. This decline in rates of population growth becomes statistically significant at conventional critical values in 1871 and continues to increase in absolute magnitude through to 1911 at the end of our sample period. By this point, we find a fall in population of around 20 percent in high wheat suitability locations relative to low wheat suitability locations.[21] This timing corresponds closely to the secular decline in the price of wheat following the Repeal of the Corn Laws and the grain invasion in Figure 1 and the sharp increase in UK imports of wheat in Figure 2. This pattern of results is also consistent with the wider historical narrative discussed above, in which the decline in employment opportunities for agricultural laborers led to a population outflow that depopulated rural areas.

At first sight, this finding that the trade shock from the grain invasion induced a redistribution of population across locations stands in contrast with research for more recent trade shocks, such as the China shock, which has found muted population responses. There are a number of reasons why there could be greater population mobility in 19th-century England and Wales, including in particular the more limited welfare state. In the early-20th century

[20] As robustness checks, we report Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors following Conley (1999), and standard errors clustered two-way by 100 quantiles of wheat suitability and 560 poor law unions following a similar approach to Adão, Morales, and Kolesár (2019).

[21] While we show 95 percent confidence errors based on standard errors clustered on poor law unions in Figure 8, we find a similar pattern of results using Conley HAC standard errors with a 10km spatial lag and a two period time lag (e.g., standard error of 0.031 compared to the coefficient of -0.184 for 1911) and standard errors clustered on 100 bins for quantiles of wheat suitability (e.g., a standard error of 0.043 for 1911). In Table D.1 (Section D2 of the online appendix), we report the full set of standard errors for all years.

Figure 8: Estimated Treatment Effects for Log Population with Respect to Wheat Suitability.



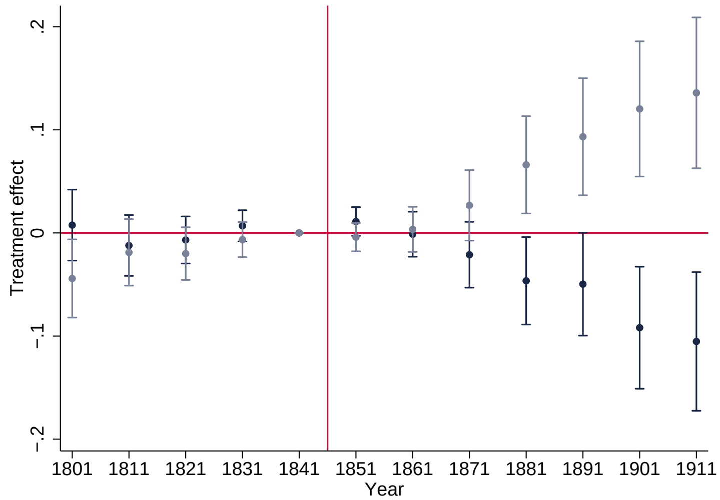
Notes: The figure shows the estimated treatment effects (β_t) from the differences-in-differences specification (1) using interactions between years and an indicator variable that is one for parishes with above-median wheat suitability and zero otherwise; vertical lines show 95 percent confidence intervals based on standard errors clustered by poor law union. The specification conditions on parish and year fixed effects, and interactions between year and (i) travel time to the nearest market town; (ii) travel time to the nearest coalfield; (iii) distance to London and distance to Manchester; (iv) Easting and Northing of the parish centroid; (v) an indicator that is one for Wales; (vi) an indicator that is one for urban parishes based on the 1801 distribution of population densities.

United States, which also featured a limited welfare state, such large-scale population movements were observed in response to changing economic and political opportunity, including for example the migration of African-Americans from the South to the North, as examined in Wilkerson (2011) and Platt Boustan (2020). Furthermore, there is recent evidence of some population response to the China shock, as for example in Greenland, Lopresti, and McHenry (2019).

As a robustness check, we re-estimate the regression specification (1) including separate treatment-year interactions with indicators for low wheat suitability (bottom tercile) and high wheat suitability (top tercile), where the excluded category is the middle tercile. As shown in Figure 9, low wheat suitability locations experience a weakly statistically significant *increase* in population relative to those with medium wheat suitability, while high wheat suitability locations experience a statistically significant *decrease* in population relative to those with medium wheat suitability. Therefore, we find a consistent pattern of results at both the top and the bottom of the distribution for wheat suitability, providing further support for the idea that our results capture a systematic trade shock from the grain invasion that unevenly affects locations with different levels of wheat suitability.

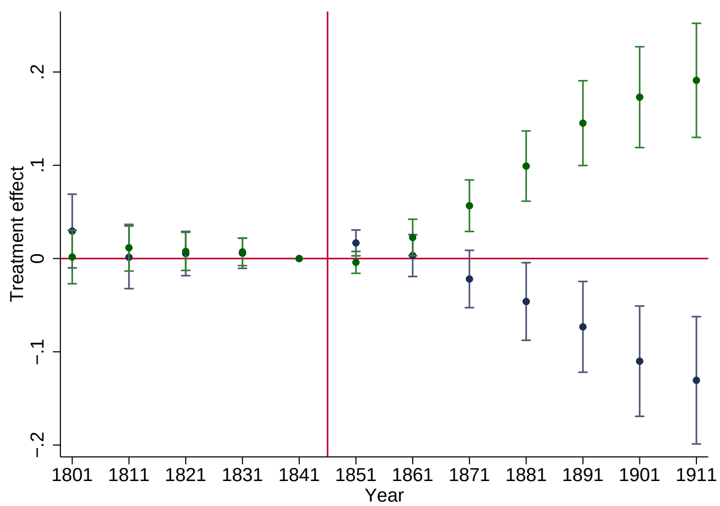
As a further specification check, we re-estimate our baseline regression specification (1), augmenting it with treatment-year interactions with an indicator for above-median grass suitability. In Figure 10, we show the estimated coefficients on both wheat suitability (in blue) and grass suitability (in green). Consistent with our results capturing the effects of the grain invasion, we find a similar pattern of estimates for wheat suitability, with negative and statistically significant treatment effects of around the same magnitude as before. The estimates for grass suitability are positive (rather than negative); this finding of positive estimated treatment effects for grass suitability is consistent with historical evidence of a reallocation from arable to pastoral farming. They are also consistent with the systematic difference in agroclimatic conditions between the Western and Eastern parts of England and Wales shown in Figure 4 above. As the grain invasion depressed the economic activity in Eastern-corn areas, this increased in relative terms the levels of economic activity in Western-grass areas.

Figure 9: Estimated Treatment Effects for Log Population with Respect to Wheat Suitability (Terciles).



Notes: The figure shows the estimated treatment effects from the differences-in-differences regression specification (1) using interactions between years and separate indicator variables for parishes with wheat suitability in the bottom and top terciles (the excluded category is the middle tercile); vertical lines show 95 percent confidence intervals based on standard errors clustered by poor law union. The specification conditions on parish and year fixed effects, and interactions between year and (i) travel time to the nearest market town; (ii) travel time to the nearest coalfield; (iii) distance to London and distance to Manchester; (iv) Easting and Northing of the parish centroid; (v) an indicator that is one for Wales; (vi) an indicator that is one for urban parishes based on the 1801 distribution of population densities.

Figure 10: Estimated Placebo Treatment Effects for Log Population with Respect to Wheat and Grass Suitability.

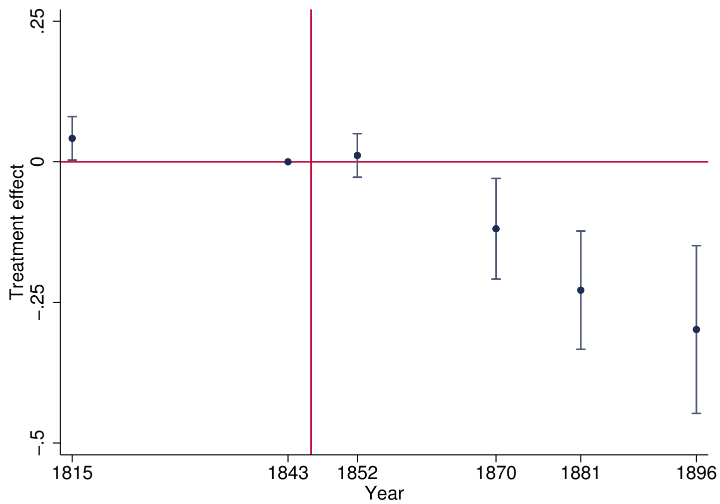


Notes: The figure shows the estimated treatment effects (β_t) from the differences-in-differences specification (1) using interactions between years and an indicator variable that is one for parishes with above-median wheat suitability; dashed black line shows estimated treatment effects from a placebo differences-in-differences specification using interactions between years and an indicator variable that is one for parishes with above-median grass suitability; vertical lines show 95 percent confidence intervals based on standard errors clustered by poor law union. The specification conditions on parish and year fixed effects, and interactions between year and (i) travel time to the nearest market town; (ii) travel time to the nearest coalfield; (iii) distance to London and distance to Manchester; (iv) Easting and Northing of the parish centroid; (v) an indicator that is one for Wales; (vi) an indicator that is one for urban parishes based on the 1801 distribution of population densities.

4.5 Property Values

In this subsection, we use a similar event-study specification to examine the differential impact of the grain invasion on the value of land and buildings across parishes of England and Wales. We use our baseline specification (1) with (log) rateable values in 1815, 1843, 1852 and 1881 as the dependent variable. As above, our key coefficients of interest are the difference-in-differences estimates (β_τ), which capture the treatment effect of wheat suitability on the growth of rateable values over time. We choose 1843, the last period before the Repeal of the Corn Laws, as the excluded category. We include parish fixed effects and year dummies, as well as interactions between our observable parish characteristics and year dummies, to control for other potential determinants of rateable values growth.

Figure 11: Estimated Treatment Effects for Log Rateable values with Respect to Wheat Suitability.



Notes: The figure shows the estimated treatment effects from the differences-in-differences specification (1) using the log of rateable values for 1815, 1843 (excluded category), 1852 and 1881 as an outcome and interactions between years and a treatment indicator that is one for parishes with above-median wheat suitability and zero otherwise; vertical lines show 95 percent confidence intervals based on standard errors clustered by poor law union. The specification conditions on parish and year fixed effects, and interactions between year and (i) travel time to the nearest market town; (ii) travel time to the nearest coalfield; (iii) distance to London and distance to Manchester; (iv) Easting and Northing of the parish centroid; (v) an indicator that is one for Wales; (vi) an indicator that is one for urban parishes based on the 1801 distribution of population densities.

Figure 11 displays the estimated treatment coefficients (β_τ), where the vertical bars correspond to the 95 percent confidence intervals clustered by poor law union, and the vertical red line shows the Repeal of the Corn Laws in 1846. We find a similar pattern of results for rateable values as for population above. In the early decades of the 19th century, areas with low and high wheat suitability have similar rates of growth of rateable values, with the estimate for 1815 close to zero and statistically insignificant. Following the Repeal of the Corn Laws and the end of the American Civil War in 1865, we find a substantial and statistically significant decline in rateable values in high wheat suitability locations relative to those in low wheat suitability locations. This treatment effect captures the effects of the grain invasion on the relative value of land and existing buildings, as well as its effects on relative rates of construction of new buildings over time. It also captures both the direct effect of the grain invasion on the value of land and buildings and its indirect or general equilibrium effects through the reallocation of population across areas with different levels of wheat suitability. Taking all of these effects together, we find a reduction in the relative value of land and buildings in areas with above-median wheat suitability of around 30 percent by the end of our sample period, which is somewhat larger than our estimate of around 20 percent for population. The values of these two treatment effects for population and land values will play a key role in the model in terms of informing the parameter determining the degree of population mobility.

4.6 Individual-level Data

Although our parish-level data are informative about net changes in population, they do not distinguish between migration versus differential birth and death rates as alternative explanations for population changes. To provide econometric evidence on the historical narrative that the grain invasion led to rural outmigration in high wheat suitability locations, we make use of our individual-level data based on linking records of the Integrated Census Microdata Project (I-CeM). We use these data to examine the different margins of adjustment through which individuals in high wheat suitability locations responded to the trade shock of the grain invasion.

We use our matched samples of individuals between each pair of consecutive census years. We treat the first pair of census years from 1851–61 as a pre-period, using the fact that the "grain invasion" does not really take off until after the end of the American Civil War in 1865. We pool the remaining pairs of census years from 1861–1881, 1881–1891, 1891–1901 and 1901–1911 as a post-period. We use the matched data between each pair of consecutive census years to compute a number of measures of individual mobility decisions: (i) an indicator that is one if an individual moves to another census registration district; (ii) indicators that are one for rural-urban or urban-urban migrations between registration districts respectively; (iii) an indicator that is one if an individual moves two-digit occupation; and (iv) an indicator that is one if an individual moves one-digit industry.

Using these measures of individual mobility, we find substantial reallocation across locations, occupations and sectors. On average, across 10-year matches between census years, we find a probability of moving parish of around 0.4; registration district of about 0.3; county of around 0.2; two-digit occupation of above 0.6; and one-digit sector of over 0.5. As a check on these results from name matching across census waves, we find an average probability on living outside the county of birth of around 0.4 in each census year, consistent with substantial mobility.[22]

We now examine the relationship between these individual mobility decisions and the grain invasion. As a first-step, we estimate kernel (Epanechnikov) regressions of each of our measures of individual mobility between an initial and subsequent census year on the wheat suitability of the individual's parish in the initial census year. In Figure 12, we display the fitted values (darker lines) and 95 percent point confidence intervals (light shading) clustered on parish from these kernel regressions. We use blue to denote the pre-period and red to denote the pooled post-periods.

As apparent from the figure, we find strong evidence in support of the historical narrative that the grain invasion led to increased outmigration from rural to urban locations. In the top-left panel, the probability of migrating to another registration district increases between the pre- and post-periods for high wheat suitability locations relative to low wheat suitability locations. In the top-right panel, this increased outmigration is not driven by movements to other rural locations. Between the pre- and post-periods, we actually find a fall in the probability of migrating to rural registration districts, which is somewhat larger for low wheat suitability regions than for high wheat suitability regions. We also see strong evidence of increased reallocation along the other adjustment margins of occupation and industry in response to the grain invasion. In the bottom-left and bottom right panels, the probabilities of moving two-digit occupation and one-digit industry both increase between the pre- and post-periods in high wheat suitability locations relative to low wheat suitability locations.

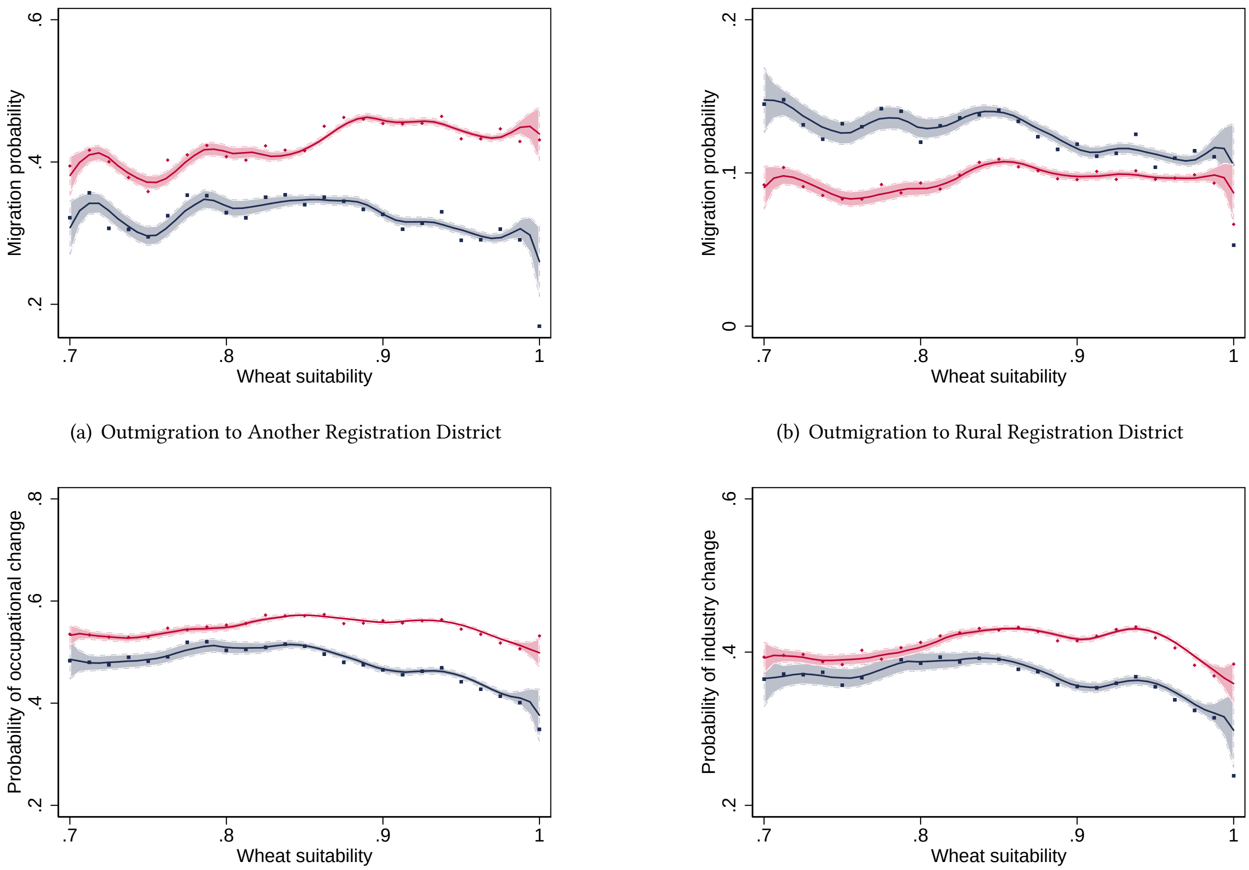
We next show that this pattern of results is robust to controlling for a wide range of other potential determinants of individual mobility decisions. In particular, we consider the following regression specification:

$$M_{ijt} = \sum_{t \in \mathbb{T}} \beta_t \left(\mathbb{W}_j \times \mathbb{I}_t \right) + \left(X_j \times \delta_t \right) + \eta_j + d_t + u_{ijt} \tag{2}$$

where the unit of observation is an individual i located in parish j in census year t; M_{ijt} is an indicator that is one

[22] Using individual-level records from the 1940 U.S. population census, which report current county and country five years previously, Hornbeck (2020) finds that 17 percent of people moved counties over that five-year period, where U.S. counties are substantially larger than those in England and Wales, which together have approximately the same total land area as the U.S. state of Georgia.

Figure 12: Probabilities of Changing Registration District, Occupation and Industry with Wheat Suitability (blue: 1851–61; red: pooled 1861–81, 81–91, 91–01)



(a) Outmigration to Another Registration District

(b) Outmigration to Rural Registration District

(c) Change in Occupation

(d) Change in Industry

Notes: sample of matched individuals from 1851–1861 (blue) and pooled sample of matched individuals from 1861–1881, 1881–1891, 1891–1901 (red); dark lines show kernel (Epanechnikov) regressions of reallocation probabilities on wheat suitability; lighter shading denotes 95 percent point confidence intervals; Panel (a) shows the probability of moving to a different registration district (poor law union); Panel (b) shows the probability of moving to a rural registration district (poor law union); Panel (c) shows the probability of moving to a different 2-digit occupation; and Panel (d) shows the probability of moving to a different 1-digit industry.

if an individual moves (either location, occupation or sector) between a pair of consecutive census years and zero otherwise; we estimate this specification pooling the pairs of consecutive census years for which the individual-level data are available: 1851–61, 1861–1881, 1881–1891, 1891–1901; the excluded category is the pre-period 1851–61, such that β_t and δ_t are estimated for each post-period relative to the pre-period; the other variables are defined above; we again controls for observable parish characteristics interacted with time-varying coefficients: (i) travel time to the nearest market town; (ii) travel time to the nearest coalfield; (iii) distance to London and distance to Manchester; (iv) Easting and Northing of the parish centroid; (v) an indicator that is one for Wales; (vi) an indicator that is one for urban parishes based on the 1801 distribution of population densities. To ensure comparability with our parish-level results above, we weight observations on individuals such that all parishes have all weights. In our baseline specification, we report standard errors clustered by poor law unions, which allows the error term to be serially correlated across individuals within unions and across census years within unions.

In this specification, the parish fixed effects (η_j) allow for time-invariant differences in mobility across parishes that can be correlated with wheat suitability. The census-year dummies (d_t) control for secular changes in mobility over time. The time-varying coefficients on the controls (δ_t) allow for differential trends of mobility across parishes with different values for these controls (e.g. parishes close to industrial centers could have larger or smaller increases in mobility over time than other parishes). The key coefficients of interest (β_t) are those on the interaction terms between wheat suitability ($\mathbb{W}_j$) and the census-year indicators ($\mathbb{I}_t$), which capture the extent to which parishes with above-median wheat suitability exhibit larger or smaller increases in mobility over time than those with below-median wheat suitability. Again, these coefficients have a "difference-in-differences" interpretation, where the first difference is between parishes with different wheat suitability, and the second difference is between later census years (1861–81, 1881–91) and the baseline census year (1851–61).

In Panel A of Table 1, we report the estimation results using four different measures of spatial mobility: (i) spatial mobility across registration districts in column 1, (ii) spatial mobility across registration counties in column 2, (iii) rural-urban migration spells in column 3, (iv) urban-urban migration spells in column 4. In line with our results above, we find a substantial and statistically significant increase in spatial mobility over time in parishes with high wheat suitability relative to those with low wheat suitability. As shown in column 1, the probability of outmigration at the parish level goes from 3 percentage points higher between 1861 and 1881 to 5 percentage points higher between 1891 and 1901. This effect is large relative to the average outmigration probability of around 0.30 at the district level discussed above. As shown in column 2, we find similar results for outmigration at the level of registration counties. From columns 3 and 4, this increase in outmigration is mostly driven by movements from rural to urban areas, consistent with the negative impact of the grain invasion largely falling on rural areas.

We find that this increase in spatial mobility is mirrored by increases in occupational and industrial mobility. More specifically, we replace the outcome of the previous specification (2) with four measures of occupational mobility: (i) occupational mobility across 2-digit occupations, but within districts, in column 1, (ii) a measure of joint mobility (changing occupations *and* districts) in column 2, (iii) a measure of mobility out of agriculture (including both farmers and agricultural laborers) in column 3,[23] (iv) mobility across 1-digit industries in column 4. We find a high incidence of occupational mobility in parishes with high wheat suitability: on average, occupational mobility across 2-digit occupations is about 3 percentage points higher between 1881–1891 and 1891–1901; this effect is however entirely driven by individuals moving across occupations *and* districts (see column 1 versus column 2). A share of this mobility across occupations and parishes can be explained by a movement out of agriculture, as shown in column 3, and more generally by movement across 1-digit industries, as shown in column 4.

Taking the results of this section together, we find strong evidence that the grain invasion led to outmigration from the areas most affected, with the largest increases in outmigration from rural to urban areas.

5 Theoretical Framework

We consider a world economy consisting of many locations by $i, n, m \in N$. These locations can be partitioned into a subset of domestic locations within England and Wales (N^E) and a subset of foreign countries (N^R), where $N = N^E \cup N^R$. The economy consists of two types of agents: workers and landlords. Landlords are geographically immobile and earn income and consume where they are born. In contrast, workers are geographically mobile across

[23] We discuss the restructuring of farming, as induced by the "grain invasion", in Section B2 of the online Appendix.

Table 1: Wheat suitability and spatial/occupational mobility.

Panel A: Spatial mobility				
	Districts	Counties	Rural-urban	Urban-urban
Wheat suitability × 1861–1881	.0147	.0235	.0133	.0001
	(.0066)	(.0064)	(.0050)	(.0029)
Wheat suitability × 1881–1891	.0214	.0093	.0118	-.0016
	(.0076)	(.0058)	(.0047)	(.0030)
Wheat suitability × 1891–1901	.0527	.0121	.0195	.0204
	(.0143)	(.0098)	(.0085)	(.0065)
Observations	9,759,420	9,759,420	9,759,420	9,759,420
Panel B: Occupational mobility				
	Occupations only	Occupations/locations	Agriculture	Industries
Wheat suitability × 1861–1881	-.0109	.0139	.0254	.0129
	(.0060)	(.0060)	(.0089)	(.0062)
Wheat suitability × 1881–1891	.0004	.0199	.0226	.0233
	(.0052)	(.0059)	(.0086)	(.0060)
Wheat suitability × 1891–1901	-.0125	.0355	.0170	.0174
	(.0077)	(.0088)	(.0088)	(.0061)
Observations	5,385,948	5,385,948	1,426,520	5,385,948

Note: Standard errors are reported between parentheses and are clustered at the union-level. The unit of observation is an individual at a given time t. All specifications condition the analysis on parish fixed effects, time fixed effects and controls for observable parish characteristics interacted with time dummies: (i) travel time to the nearest market town; (ii) travel time to the nearest coalfield; (iii) distance to London and distance to Manchester; (iv) Easting and Northing of the parish centroid; (v) an indicator that is one for Wales; (vi) an indicator that is one for urban parishes based on the 1801 distribution of population densities.

locations within the same country but immobile across countries. Each worker born in a location i can choose to migrate to another region n within the same country by incurring bilateral migration costs. Economic activity takes place in a number of sectors indexed by $k, j, \ell \in K$, including agriculture, manufacturing and services. Locations can differ from one another in terms of their amenities, productivities in each sector, and the supply of floor space, as well as in bilateral trade and migration costs. We use the model to examine the impact of an international trade shock that is concentrated in a particular sector (the grain invasion in the agricultural sector) on structural transformation across sectors and the distribution of economic activity across locations.

5.1 Preferences

Worker preferences are defined over consumption goods in each sector and residential floor space and are assumed to take the Cobb-Douglas form. A worker ψ from location i that chooses to work in sector k in location n obtains the following indirect utility:

$$u_{ni}^{k}(\psi) = \frac{b_{n}^{k}(\psi)\, w_{n}}{\kappa_{ni}\left(\prod_{j\in K}\left(P_{n}^{j}\right)^{\alpha^{j}}\right)Q_{n}^{\alpha^{H}}}, \qquad \sum_{j\in K}\alpha^{j}+\alpha^{H}=1, \tag{3}$$

where w_n is wage income in location n; $b_n^k(\psi)$ is a match-specific preference draw that determines amenities for worker ψ in sector k in location n; κ_{ni} is an iceberg migration cost that takes the form of a reduction in a worker's instantaneous utility from living in a different location n from her birth region i; P_n^j is the consumption goods price index for sector j in location n; and Q_n is the price of floor space in location n.[24] We assume that the match-specific

[24]Although we model the worker match-specific shocks as occurring to preferences, there is a closely-related formulation in terms of match-specific shocks to worker productivity. We assume for simplicity that migration costs are the same across sectors, and only vary by destination location n and birth location i, but it is straightforward to also allow them to vary across sectors.

amenities are drawn independently across individuals, locations and sectors from the following Fréchet distribution:

$$F_n^k(b) = e^{-\left(b/B_n^k\right)^{-\epsilon}}, \qquad \epsilon > 1, \tag{4}$$

where the Fréchet scale parameter (B_n^k) determines average amenities for location n and sector k.

Landlord preferences take the same form, though because landlords are geographically immobile, they have no idiosyncratic preferences for locations or migration costs. Consumption and production within each sector are modelled as in Eaton and Kortum (2002) and Costinot, Donaldson, and Komunjer (2012). In particular, each sector comprises a continuum of goods that enter the sectoral price index according to the following CES functional form:

$$P_n^k = \left[\int_0^1 p_n^k(\nu)^{1-\sigma^k} d\nu\right]^{\frac{1}{1-\sigma^k}}, \qquad \sigma^k > 1. \tag{5}$$

Total expenditure in each location n (X_n) equals the sum of the income of workers ($w_n L_n$), the income of landlords ($Q_n H_n$), and trade deficits (D_n):

$$X_n = w_n L_n + Q_n H_n + d_n w_n L_n, \qquad d_n = D_n / w_n L_n, \tag{6}$$

where L_n is the measure of workers that choose to live in location n; H_n is the supply of floor space; D_n is the trade deficit; and we allocate the entire trade deficit to labor income, such that d_n is the ratio of the trade deficit to labor income. We follow the quantitative international trade literature in treating the trade deficit as exogenous, holding constant its ratio to labor income (d_n).

5.2 Production Technology

Each good within each sector is produced using labor and commercial floor space according to a constant returns to scale Cobb-Douglas production technology. Goods can be traded between locations subject to iceberg variable trade costs, such that $\tau_{ni}^k \geq 1$ units of a good must be shipped from location i in sector k in order for one unit to arrive in location i, where $\tau_{ni}^k > 1$ for $n \neq i$ and $\tau_{nn}^k = 1$. Therefore, the cost to a consumer in location n of purchasing a unit of good ϑ in sector k from location i is given by:

$$p_{ni}^k(\vartheta) = \frac{\tau_{ni}^k w_i^{\beta^k} Q_i^{1-\beta^k}}{a_i^k(\vartheta)}, \qquad 0 < \beta^k < 1, \tag{7}$$

where sectors can differ in terms of factor intensity (β^k); and $a_i^k(\vartheta)$ is the idiosyncratic productivity draw for good ϑ in sector k in location i. We assume that these idiosyncratic productivities are drawn independently for each good, sector and location from the following Fréchet distribution:

$$G_i^k(a) = e^{-\left(a/A_i^k\right)^{-\theta}}, \qquad \theta > 1, \tag{8}$$

where the Fréchet scale parameter (A_i^k) determines average productivity for location i and sector k.

5.3 Sector Expenditure Shares

Using the Fréchet distribution of productivity, bilateral goods trade between locations within each sector exhibits a gravity equation. In particular, location n's share of expenditure on goods produced in location i within sector k is:

$$\pi_{ni}^k = \frac{X_{ni}^k}{\sum_{m \in N} X_{nm}^k} = \frac{\left(\tau_{ni}^k w_i^{\beta^k} Q_i^{1-\beta^k} / A_i^k\right)^{-\theta}}{\sum_{m \in N} \left(\tau_{nm}^k w_m^{\beta^k} Q_m^{1-\beta^k} / A_m^k\right)^{-\theta}}. \tag{9}$$

Therefore, bilateral trade in goods depends on relative production costs, as determined by wages (w_i), the price of floor space (Q_i) and productivities (A_i^k), and relative trade costs (τ_{ni}^k) between locations.

5.4 Price Indices

Using the Fréchet distribution of productivity, we can also solve for the sectoral price index:

$$P_n^k = \gamma^k \left[\sum_{m \in N} \left(\tau_{nm}^k w_m^{\beta^k} Q_m^{1-\beta^k} / A_m^k \right)^{-\theta} \right]^{-\frac{1}{\theta}}, \tag{10}$$

where

$$\gamma^k \equiv \left[\Gamma \left(\frac{\theta + 1 - \sigma^k}{\theta} \right) \right]^{\frac{1}{1-\sigma^k}},$$

and $\Gamma(\cdot)$ is the Gamma function.

Therefore, the consumption goods price index for each sector depends on a trade cost weighted average of production costs in each location, as determined by wages, the price of floor space and productivities. Using the expenditure shares (9), we can re-write this sectoral price index (10) in terms of domestic wages (w_n), the domestic price of floor space (Q_n) and the domestic trade share (π_{nn}^k):

$$P_n^k = \gamma^k \left(\pi_{nn}^k \right)^{\frac{1}{\theta}} \tau_{nn}^k w_n^{\beta^k} Q_n^{1-\beta^k} / A_m^k. \tag{11}$$

5.5 Migration Choices

Workers born in each location in England and Wales choose a sector and location within that country to maximize their utility, taking into account the bilateral structure of migration costs. Using the Fréchet distribution of amenities (4), the probability that a worker born in location i chooses sector k and location n is:

$$\lambda_{ni}^k = \frac{\left(B_n^k w_n \right)^{\epsilon} \left(\kappa_{ni} \left(\prod_{j \in K} \left(P_n^j \right)^{\alpha^j} \right) Q_n^{\alpha^H} \right)^{-\epsilon}}{\sum_{\ell \in K} \sum_{m \in N^E} \left(B_m^\ell w_m \right)^{\epsilon} \left(\kappa_{mi} \left(\prod_{j \in K} \left(P_m^j \right)^{\alpha^j} \right) Q_m^{\alpha^H} \right)^{-\epsilon}}. \tag{12}$$

Summing across sectors, and multiplying by the measure of workers born in location i ($\bar{L}_i$), an implication of our extreme value assumption for idiosyncratic amenities is that the flow of migrants from location i to location n (L_{ni}) follows a gravity equation:

$$L_{ni} = \frac{\sum_{\ell \in K} \left(B_n^\ell w_n \right)^{\epsilon} \left(\kappa_{ni} \left(\prod_{j \in K} \left(P_n^j \right)^{\alpha^j} \right) Q_n^{\alpha^H} \right)^{-\epsilon}}{\sum_{\ell \in K} \sum_{m \in N^E} \left(B_m^\ell w_m \right)^{\epsilon} \left(\kappa_{mi} \left(\prod_{j \in K} \left(P_m^j \right)^{\alpha^j} \right) Q_m^{\alpha^H} \right)^{-\epsilon}} \bar{L}_i. \tag{13}$$

Therefore, the flow of migrants from location i to location n (L_{ni}) depends on destination characteristics (such as wages (w_n), amenities (B_n^k) and the cost of living (as determined by P_n^j and Q_n)); origin characteristics (the measure of people born there ($\bar{L}_i$)), "bilateral resistance" (bilateral migration costs κ_{ni} in the numerator); and "multilateral resistance" (bilateral migration costs κ_{mi} to all other destinations m in the denominator).

Total employment in each location equals the sum across sectors and locations of the migration probabilities (12) times the measure of workers born in each location:

$$L_n = \sum_{k \in K} \sum_{i \in N^E} \lambda_{ni}^k \bar{L}_i. \tag{14}$$

Using the Fréchet distribution of amenities (4), we can also solve for expected utility for workers born in a given location i within England and Wales, which depends on a migration cost weighted average of amenities, wages and the cost of living in all locations within that country:

$$\bar{u}_i = \mathbb{E}_i \left[u\right] = \delta \left[\sum_{\ell \in K} \sum_{m \in N^E} \left(B_m^\ell w_m\right)^\epsilon \left(\kappa_{mi} \left(\prod_{j \in K} \left(P_m^j\right)^{\alpha^j} \right) Q_m^{\alpha^H} \right)^{-\epsilon} \right]^{\frac{1}{\epsilon}}. \tag{15}$$

Another implication of our extreme value assumption for idiosyncratic amenities is that expected utility conditional on choosing a sector k and location n for workers born in location i is the same across all sectors k and locations n and equal to this overall expected utility for workers born in location i (15). Intuitively, sectors and locations with attractive economic characteristics (e.g. high wages, high amenities, a low cost of living, and low migration costs) attract workers with lower idiosyncratic draws for preferences. Under the assumption of a Fréchet distribution for amenities, this composition effect exactly offsets the more attractive economic characteristics, with the result that expected utility is the same across all sectors k and locations n for a given birth location i. Nevertheless, expected utility differs across birth locations i, because of differences in the geography of migration costs.

5.6 Land Market Clearing

Land market clearing implies that the income of landlords (the price of floor space (Q_n) times the quantity of floor space (H_n)) equals the sum of payments for the use of residential and commercial floor space. Using our assumptions of Cobb-Douglas preferences and production technology, it follows that payments for residential and commercial floor space are both proportional to labor income:

$$Q_n H_n = \left(1 - \alpha^H\right) Q_n H_n + \left(1 - \alpha^H\right) \left[\sum_{k \in K} \left(1 + d_n\right) w_n L_n^k \right] + \sum_{k \in K} \frac{1 - \beta^k}{\beta^k} w_n L_n^k, \tag{16}$$

where the first term on the right-hand side captures payments for residential floor space from landlords; the second term corresponds to payments for residential floor space from workers (incorporating trade deficits); and the third term represents payments for commercial floor space.

5.7 Goods Market Clearing

Goods market clearing implies that total revenue in each sector k and location i in England and Wales (Y_i^k) equals expenditure on the goods produced by that location:

$$Y_i^k = \sum_{n \in N^E} \pi_{ni}^k \alpha^k X_n + \sum_{n \in N^R} \pi_{ni}^k \alpha^k X_n, \tag{17}$$

where total revenue in each sector and location (Y_i^k) is proportional to the wage bill ($Y_i^k = w_i L_i^k / \beta^k$) under our assumption of a Cobb-Douglas production technology.

To highlight the different ways in which international trade enters the model, we have separated out expenditure by locations within England and Wales and expenditure by foreign countries in this goods market clearing condition.

On the one hand, international trade provides a source of export demand for each sector and location, which increases income in that sector and location (though the second term on the right-hand side of equation (17)). On the other hand, international trade also provides a source of import competition for each sector and location, which reduces income in that sector and location (through lower shares of expenditure on domestic locations π_{ni}^{k} in both terms on the right-hand side of equation (17)).

5.8 General Equilibrium

The general equilibrium of the model is referenced by the wage (w_n), the price of floor space (Q_n), and the allocation of employment to each sector and location (L_n^k), given exogenous values of the measure of workers born in each location ($\bar{L}_i$), the supply of floor space (H_n) and the trade deficit (D_n). All other endogenous variables of the model can be recovered from this vector of three endogenous variables (w_n, Q_n, L_n^k). These three endogenous variables solve the following system of three equations. First, using the relationship between income and expenditure (6) and the Cobb-Douglas production technologies, the goods market clearing condition equating income and expenditure on the goods produced by a location can be re-written as follows:

$$\frac{w_i L_i^k}{\beta^k} = \sum_{n \in N} \pi_{ni}^k \alpha^k \left[\left(1 + \frac{1-\alpha^H}{\alpha^H}\right) \left(\sum_{k \in K} \left(1 + d_n\right) L_n^k \right) + \sum_{k \in K} \frac{1-\beta^k}{\alpha^H \beta^k} L_n^k \right] w_n, \tag{18}$$

where the trade shares (π_{ni}^k) depend solely on wages (w_i) and the price of floor space (Q_i) from equation (9). Second, from equation (16), the land market clearing condition is given by:

$$Q_n H_n = \left[\left(\frac{1-\alpha^H}{\alpha^H} \right) \left(\sum_{k \in K} \left(1 + d_n\right) L_n^k \right) + \sum_{k \in K} \frac{1-\beta^k}{\alpha^H \beta^k} L_n^k \right] w_n. \tag{19}$$

Third, from the migration probabilities (12), the allocation of employment to each sector and location is given by:

$$L_{ni}^k = \frac{\left(B_n^k w_n\right)^{\epsilon} \left(\kappa_{ni} \left(\prod_{j \in K} \left(P_n^j\right)^{\alpha^j} \right) Q_n^{\alpha^H} \right)^{-\epsilon}}{\sum_{\ell \in K} \sum_{m \in N^E} \left(B_m^{\ell} w_m\right)^{\epsilon} \left(\kappa_{mi} \left(\prod_{j \in K} \left(P_m^j\right)^{\alpha^j} \right) Q_m^{\alpha^H} \right)^{-\epsilon}} \bar{L}_i, \tag{20}$$

where the consumption goods price index (P_n^j) can be written solely in terms of wages (w_n), the price of floor space (Q_n), and own trade shares (π_{nn}^k), and where these own trade shares themselves depend only on wages (w_n) and the price of floor space (Q_n) from equation (9).

6 Quantitative Analysis

We now undertake our quantitative analysis of the model. We show that the model has a recursive structure, such that our quantitative analysis can be undertaken in a number of steps, where each step imposes the minimal set of additional assumptions relative to the previous step. In a first step, we solve for wages in each location (w_n) using the land market clearing condition (Section 6.1). In a second step, we separate observed rateables values ($\mathbb{Q}_{nt}$) into the price (Q_{nt}) and supply (H_{nt}) of floor space using assumptions about the floor space supply elasticity (Section 6.2). In a third step, we recover for productivity in each location using the goods market clearing condition (Section 6.3). In a fourth and final step, we obtain amenities in each location using the migration choice probabilities (Section 6.4).

6.1 Wages (Step 1)

We solve for wages using our observed data on employment in each sector (L_{nt}^{k}) and rateable values ($\mathbb{Q}_{nt}$), which correspond to the price (Q_{nt}) times the quantity (H_{nt}) of floor space in the model. In order to do so, we calibrate the model's utility and production function parameters using central values from the existing empirical literature. First, we assume a value for the share of housing in consumer expenditure of $\alpha^{H} = 0.25$, which equals the average share of rent in income across occupations in the Registrar General's survey of 30,000 workers in 1887, as reported to the House of Commons (Papers 1887). Second, we assume a share of land in building structures equal of $\beta^{A} = 0.20$ for Agriculture and $\beta^{M} = \beta^{S} = 0.10$ in manufacturing and services, which is in line with the values in Caselli and Coleman (2001). Using these assumed parameters and the observed data on employment and rateable values in the land market clearing condition (19), we obtain the following closed-form solution for wages in each location:

$$w_{nt} = \frac{\mathbb{Q}_{nt}}{\left[\frac{1-\alpha^{H}}{\alpha^{H}}\left(1+d_{nt}\right)\sum_{k\in K} L_{nt}^{k} + \sum_{k\in K}\frac{1-\beta^{k}}{\alpha^{H}\beta^{k}} L_{nt}^{k}\right]}. \tag{21}$$

Therefore, although comprehensive data on wages by parish are not available during the 19th century, we use the structure of the model to generate predictions for wages from the observed data on employment and rateable values. For some locations and years, we also have some data on wages, which we do not use to quantify the model, and hence can be used an overidentification check on its predictions.

6.2 Price of Floor Space (Step 2)

We separate rateable values into the price and quantity of floor space by making assumptions about the floor space supply elasticity. In particular, following Saiz (2010), we model the supply of floor space (H_{nt}) as depending on geographical land area (K_{n}) and a constant elasticity function of the price of floor space (Q_{nt}):

$$H_{nt} = h Q_{nt}^{\mu} K_{n}, \tag{22}$$

where h is a constant; $\mu \geq 0$ is the floor space supply elasticity; and $\mu = 0$ corresponds to the special case of a perfectly inelastic supply of floor space.

Using this assumption and the definition of rateable values ($\mathbb{Q}_{nt} = Q_{nt} H_{nt}$), we recover both the price and quantity of floor space as constant elasticity functions of rateable values per land area ($\mathbb{Q}_{nt}/K_{n}$):

$$Q_{nt} = \left(\frac{\mathbb{Q}_{nt}}{hK_{n}}\right)^{\frac{1}{1+\mu}}, \qquad H_{nt} = hK_{n}\left(\frac{\mathbb{Q}_{nt}}{hK_{n}}\right)^{\frac{\mu}{1+\mu}}. \tag{23}$$

We calibrate the floor space supply elasticity (μ) using data on the contribution of new buildings towards changes in rateable values that were compiled by London County Council for part of our time period (1871–1921) for the subset of our boroughs in the County of London. Using the overall change in rateable value and the contribution of new buildings, we compute the change in the price and supply of floor space and hence the floor space supply elasticity for each of these boroughs ($\ln \hat{H}_{nt}/\ln \hat{Q}_{nt}$). We set the floor space supply elasticity in the model to the median value of these floor space supply elasticities in the data ($\mu = 1.83$).

6.3 Productivity (Step 3)

We solve for productivity in each location using the goods market clearing condition that equates income in each location to expenditure on the goods produced in each location. We assume a standard value for the elasticity of trade flows with respect to trade costs of $\theta = 5$ following Costinot and Rodríguez-Clare (2014). Using this assumed parameter value, and separating out expenditure by domestic locations and foreign countries in equation (18), we can re-write this goods market clearing condition as follows:

$$\frac{w_i L_i^k}{\beta^k} = \sum_{n \in N^E} \left[\frac{\left(\tau_{ni}^k w_i^{\beta^k} Q_i^{1-\beta^k} / A_i^k \right)^{-\theta}}{\sum_{m \in N^E} \left(\tau_{nm}^k w_m^{\beta^k} Q_m^{1-\beta^k} / A_m^k \right)^{-\theta}} \right] \zeta_n^k \alpha^k \left[(1 + d_n) \left(1 + \frac{1 - \alpha^H}{\alpha^H} \right) L_n + \sum_{k \in K} \frac{1 - \beta^k}{\alpha^H \beta^k} L_n^k \right] w_n$$
$$+ \sum_{n \in N^R} \xi_{ni}^k M_n^k, \tag{24}$$

where ζ_n^k is the share of domestic expenditure in total expenditure within sector k for location n within England and Wales; M_n^k is foreign country n's total imports from England and Wales in sector k; and ξ_{ni}^k is the share of domestic location i in foreign country n's total imports from England and Wales in sector k.

On the right-hand side of this expression, the first line captures expenditure on domestic location i from domestic markets n, and the second line captures expenditure on domestic location i by foreign countries. In the first line, the fraction inside the first square parentheses is market n's share of domestic expenditure allocated to location i within sector k; ζ_n^k is market n's share of domestic expenditure in its total expenditure within sector k; α^k is the share of sector k in total expenditure; and the terms inside the second square parentheses correspond to the total expenditure of landlords and workers in market n. In the second line, we have written the expenditure on domestic location i by foreign country n as equal to its total imports from England and Wales within sector k (M_n^k) times the share of domestic location i in these total imports within sector k (ξ_{ni}^k).

In this goods market clearing condition (24), we observe employment for each domestic location and sector (L_n^k) and total imports from England and Wales for each foreign country by sector (M_n^k). Additionally, we have solved for wages (w_n) and the price of floor space (Q_n) from the previous steps above. Furthermore, we can compute measures of the ratio of trade deficits to income (d_n) and the domestic and foreign expenditure shares (ζ_n^k, ξ_{ni}^k) using the observed data. Given these variables and a parameterization of bilateral costs of trading goods (τ_{ni}^k), equation (24) provides a system of equations that can used to solved for unique values of the unobserved productivities (A_i^k) that exactly rationalize the observed data as an equilibrium outcome of the model.

Using these solutions for productivities (A_i^k), our solutions for wages (w_i) and the prices of floor space (Q_i), and our parameterization of the bilateral costs of trading goods (τ_{ni}^k), we immediately recover the model's predictions for unobserved bilateral trade shares between domestic locations within each sector:

$$\pi_{ni}^{k*} = \frac{\left(\tau_{ni}^k w_i^{\beta^k} Q_i^{1-\beta^k} / A_i^k \right)^{-\theta}}{\sum_{m \in N^E} \left(\tau_{nm}^k w_m^{\beta^k} Q_m^{1-\beta^k} / A_m^k \right)^{-\theta}}, \tag{25}$$

where we use the asterisk to denote that these trade shares are expressed as a share of domestic trade. Using these solutions for domestic trade shares (π_{ni}^{k*}) together with our measures of the share of domestic expenditure in total expenditure (ζ_n^k) in equation (11), we can also recover the sectoral price index:

$$P_n^k = \gamma^k \left(\zeta_n^k \pi_{nn}^{k*} \right)^{\frac{1}{\theta}} \tau_{nn}^k w_n^{\beta^k} Q_n^{1-\beta^k} / A_m^k. \tag{26}$$

6.4 Amenities (Step 4)

Finally, we solve for amenities in each sector k and location n for workers born in each location i using the migration choice probabilities. We assume a standard value of the elasticity of migration flows with respect to migration costs of $\epsilon = 3$ following Galle, Rodríguez-Clare, and Yi (2018). Given this assumed parameter value, the number of people employed in each sector k and location n equals the sum across all locations i of the migration probabilities (12) times the number of workers born in each location:

$$L_n^k = \sum_{i \in N^E} \frac{\left(B_n^k w_n\right)^{\epsilon} \left(\kappa_{ni} \left(\prod_{j \in K} \left(P_n^j\right)^{\alpha^j}\right) Q_n^{\alpha^H}\right)^{-\epsilon}}{\sum_{\ell \in K} \sum_{m \in N^E} \left(B_m^{\ell} w_m\right)^{\epsilon} \left(\kappa_{mi} \left(\prod_{j \in K} \left(P_m^j\right)^{\alpha^j}\right) Q_m^{\alpha^H}\right)^{-\epsilon}} \bar{L}_i, \tag{27}$$

In this expression, we observe employment in each sector and location (L_n^k) and the number of people born in each location ($\bar{L}_i$). We have also solved for wages (w_n), the price of floor space (Q_n) and sectoral price indexes (P_n^k) in the previous steps above. Therefore, given a parameterization of bilateral migration costs (κ_{ni}), equation (27) provides a system of equations that can be used to solve for unique values of the unobserved amenities (B_n^k) that exactly rationalize the observed data as an equilibrium outcome of the model.

[To be completed]

7 Conclusion

The distributional consequences of trade is one of the most central questions in international economics. We provide new theory and evidence on this question using the one of the most influential trade shocks in history; the 1846 Repeal of the Corn Laws and the subsequent "grain invasion" of European markets from the new world. Whereas traditional research has emphasized the distributional consequences of this trade shock across factors and industries, we highlight its uneven incidence across geographical locations.

We make use of a newly-created, spatially-disaggregated dataset on population, employment by sector, rateable values (land and property value), and poor law (welfare transfers) disbursement for around 11,000 parishes in England and Wales from 1801–1911. The key idea behind our approach is that locations were unevenly affected by this trade shock, depending on the extent to which they were suitable for arable (primarily grain) farming versus pastoral (primarily sheep and cattle) farming. We use this idea to develop an exogenous measure of exposure to this trade shock based on the suitability of agroclimatic conditions for wheat cultivation.

Using quasi-experimental reduced-form regression methods, we show that this trade shock led to a population redistribution from rural to urban areas, structural transformation away from agriculture, and a substantial change in the relative price of land and buildings. In the first half of the 19th century, rural locations with high and low wheat suitability exhibit similar population growth trajectories over time. Following the grain invasion in the second half of the 19th century, we observe a sharp decline in rates of population growth in rural locations with high wheat suitability relative to those with low suitability. By the end of our sample period in 1911, we find a cumulative reduction in the relative population of these high wheat suitability locations by around 20 percent.

We next develop a quantitative spatial model of the distribution of economic activity across sectors and locations. Given the observed data on employment, the value of land and buildings and international trade flows, we show how the model can be inverted to recover the unobserved changes in productivities and amenities that exactly rationalize the observed data as an equilibrium outcome. Undertaking counterfactuals in which we reverse the grain invasion, we use the model's predictions for changes in population and the value of land and buildings to structurally estimate the model's parameters. Our estimates imply substantial population mobility and we show that allowing for migration from rural to urban areas is central to quantitatively matching the observed moments in the data.

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