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The spatial development of Scotland in the first industrial revolution

Evidence from the Statistical Accounts

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Abstract: In 1790, Sir John Sinclair began the work which would lead to the publication of the Statistical Account of Scotland in 1796. Sinclair self-consciously sought to gather information concerning the economic and social conditions in Scotland. In this sketch, which outlines preliminary work intended to apply novel techniques of spatial econometrics to Sinclair’s data and other sources using a similar methodology from the early 19th century that have already been used extensively by social historians, we demonstrate that it is possible to extract empirical data, and to subject it to analysis in ways that allow us to make inferences about the nature of spatial relations within population data.

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1. Introduction

For the purposes of our analysis, we treat Scotland as a complex space in which a variety of development processes can be ongoing at any time. Our narrative contributes to historical analysis of social and economic developments that took place in the late eighteenth and early nineteenth century. In this preliminary exploration, we draw on data whose origins lie in the Scottish Enlightenment, the project of better understanding the world in which Adam Smith and David Hume were notable participants. We are able to comment on matters that have been of interest for many years to social historians, and, since we plan to generate outputs that will be of interest to historians in general, and not just to economic historians, we provide some general intuition for the techniques that we adopt.

2. The Statistical Accounts

In the 18th century and the first half of the 19th century, attempts to understand the economic activity and social development of Scotland depended on survey data. Webster, 1755, conducted the first private census. The respondents to his survey were ministers of the Church of Scotland. For this paper, we will treat the Church as being established: it was organised on territorial lines, with the whole of Scotland partitioned into parishes, which were the primary unit both of religious organisation and civil government, so that Church ministers in effect formed a religious magistracy. Within their parishes, they had responsibility for the provision of (primary) education and poor

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1 It appears to be Webster’s work to which Adam Smith refers when he notes the frugality of the Scottish church, and its efficiency as a vehicle for religious instruction.
relief. They also took responsibility for catechising the inhabitants of their parishes, although there was substantial variation in their diligence in this matter.

There are two other important private surveys that we can use. In 1790, the MP, financial reformer and agricultural improver, John Sinclair of Ulbster, began the undertaking which led to the eventual publication of the *Statistical Account of Scotland* (1790–96). This was a natural outworking both of the Enlightenment project to measure and understand the world, and more specifically of Smith’s political economy: the first systematic attempt to assess the state of social development and economic activity across a country. Sinclair followed Webster in circulating a questionnaire to Church ministers, again ensuring that there could be universal geographical coverage. The questionnaire was very general, effectively inviting respondents to answer his enquiries as they saw fit, with questions inviting lengthy answers; and this was a time when knowledge often reflected minute and careful observation.

Given the method of data collection, it should be no surprise that the *Statistical Account* has long been an important data source. With over 700 entries, typically essays of 5,000–10,000 words, arranged geographically by county, its wide and diverse coverage includes agriculture and manufacturing activities, trade, education, migration, patterns of religious observance and many

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2 We also note here that this conception of religious activity is very different from what is assumed in much of the economics of religion (Iannaccone, 1988, 1998), in which religious activity is a voluntary response to the provision of public goods. It is notable that throughout the period that we are discussing, the state’s interest in the funding of religious activity in Scotland was in its *instructional* role: hence the Royal Commission on Religious Instruction in Scotland, 1837–39 investigated the need for additional public funding of religious functions on the basis that religious institutions would provide what are now seen largely as secular services.

3 This allowed church ministers considerable freedom to develop policy interventions. Possibly the most important of these was Henry Duncan, minister of Ruthwell (1799–1843), who developed the savings bank concept to encourage thrift among his parishioners, and then led a 10 year campaign that culminated in the passage of the Savings Bank Act (Scotland), 1819, to ensure adequate regulation.

4 We may compare this with the Cassini maps of France (1750–1815), the massive project to produce a complete cartographic account of a country.

5 As with other parochial duties, not every minister was assiduous in the discharge of this duty. Sinclair was on occasion compelled to draw on other informants, including anonymous ‘Friends of the Statistical Accounts.’ This, in part, explains why the project took seven years to complete.
social activities (Morris et al, 2009). This structure presents substantial challenges for economic analysis. As a narrative ‘collection of information about the economic and social activities of the natural resources of Scotland,’ rather than a collection of statistics in modern usage, it has been impossible to extract data suitable for any form of cliometric analysis. With digitisation of the accounts, and the development of optical character recognition technology, it is now possible (in principle) to harvest numerical data from the narrative accounts. This will be a particularly challenging task because Sinclair’s project was so massively innovative. The enquiries were so general and the responses so varied precisely because of the absence of prior attempts to understand the social and economic state of an entire country.

While the Statistical Account is the most important single source of data for this research, we can augment it with several other reports. The decennial population censuses of Great Britain, initiated in 1801, used questionnaires circulated to parish ministers from 1801 – 1831. It was only with the 5th census, of 1841, that inquiries extended to households. Information from these records has often been incorporated into the New Statistical Account of Scotland (1832 – 1845). This was a conscious attempt to replicate Sinclair’s original enquiry, but undertaken by the Society of Sons and Daughters of the Scottish Clergy. We note below some of the historical circumstances that led to this work being undertaken.

3. Economic and social change in Scotland as the context for data generation

In the period that we are considering, we consider it appropriate to restrict our attention to Scotland, rather than to Great Britain. We treat Scotland as an early follower of England in processes of industrialisation: it is easy to confirm that the road and canal network did not extend smoothly from England into Scotland. Beyond the central belt, connecting the Forth and Clyde valleys, there were no canals or turnpike roads built in the 18th century. The same is true of railways
in 1840, with the national railway network connecting London to Edinburgh and Glasgow for the first time in 1848. For the period that we are considering, shipping provided the easiest means of travel between England and Scotland.

We also consider that this period saw substantial reorientation of economic activity between the East and West of Scotland. Traditionally, Scotland relied on trade links with the Baltic, with trade in agricultural and other commodities and manufactured goods passing through ports along the East coast of the country. This is reflected in the distribution of burghs, towns with charters allowing them to hold regular markets. With industrialisation, the central belt becomes more prominent, partly because of the location of coal and iron ore deposits, but also because of access through the Clyde estuary to the Atlantic trade: it is no happy accident that there is a Mount Vernon in Glasgow, but rather a reflection of the importance of the tobacco trade in the 18th century.

Allied to this, we see substantial population growth: Webster estimated the total population of Scotland to be 1.27m; rising to 1.61m in the first census of Great Britain in 1801; but reaching 2.62m in 1841. Nonetheless, we have evidence, especially from the New Statistical Account, of parishes in which populations declined substantially during this time. The agricultural improvement that Sinclair championed displaced people from rural locations. Small scale industrialisation led to the relatively rapid growth of burghs. The more rapid industrialisation of the early nineteenth century required the replacement of water power with steam power, and led to a further wave of urbanisation, with rather greater concentration of population in a cities and large towns, especially around Glasgow. As well as rapid population growth, there was migration, both within the country and beyond.

All of this posed substantial challenges to traditional Scottish institutions. Simplifying political history rather boldly, we postulate that the Scottish Parliament, through a six-year campaign aimed at ensuring Scottish institutions retained their identity, prevented the Treaty of Union, 1707, from
being an incorporating union. Scotland remained a separate nation from England. It retained its own judicial system, which placed more emphasis on principles of jurisprudence derived from Roman law than English common law; it retained its own education system, which is widely supposed to have raised literacy levels above those of England during this period; it retained Presbyterian church governance, with the Church of Scotland effectively being granted a monopoly over the supply of the ordinances of religion; and that fed directly into the continuation of a voluntary poor relief system, administered within parishes.

In this setting, the creation of new parishes was strongly desirable in a time of steadily increasing population, especially given the reluctance of the Church to ordain several ministers to a single charge. Since a parish was the primary unit of civil government as well as the primary unit of religious organisation, new parishes (and division of existing ones) required not just the approval of the Church of Scotland, but an Act of Parliament. Almost inevitably, given the complexity of the process, parish formation lagged behind urban growth, and so the traditional arrangements, not just for the provision of the ordinances, but also social services, came under substantial stress. Again, simplifying substantially, we argue that the lack of responsiveness of public authorities to the needs of migrant populations fed into the emergence of dissenting churches which emphasised a particularly austere Gospel, and a rather more radical evangelical theology.

The surge of data collection in the 1830s can be explained through the public policy arguments associated with these stresses. The Catholic Emancipation Act, 1829, removed many of the civil penalties that Catholics faced. In Scotland, the almost immediate response to increasing religious tolerance was the Voluntary Controversy, a campaign led by the clergy of the United Secession Church, which sought changes to the appropriation of teinds – the heritable burdens on land that were the main source of income of the Church of Scotland.
Again, simplifying grossly, for example by ignoring completely the subtleties of theological debate among supporters of the Establishment and voluntaryism, between what are now often called the evangelical and moderate parties in the Church of Scotland, and the complex relation of the Church of Scotland and the British state, which led to litigation, civil disobedience, and, ultimately schism in the Church, we simply note that the *New Statistical Account* was motivated by the need for better data during the Voluntary Controversy. Although not commissioned by the Church of Scotland, the General Assembly of the Church of Scotland (its supreme decision making body) approved its preparation in 1834, with the final text also being presented to the General Assembly in 1845.

We can see in this – as in so much else in public life in Scotland in the 1830s and 1840s – the organisational genius of Thomas Chalmers, theologian, church minister, social reformer, economist and a master of corporate finance. For Chalmers, the problem facing the Church of Scotland was a lack of endowments – capital assets that would give it secure access to the funds needed to develop its operations. To overcome this obstacle, Chalmers believed that the Church needed capital funding from the government; and he realised that as a first step, the Church had to demonstrate that there were areas of the country in which it did not have the resources to provide an effective ministry (remembering that in this context, ministry encompassed not merely the ordinances of religion, but also education and poor relief, and the supply of services that might otherwise be funded directly from the public purse). The (Old) Statistical Account could not be relied upon for this purpose, and so a replacement was required.

Perhaps foolishly, the Church allowed Chalmers to lead negotiations on the question of with the British government. These effectively broke down in 1836, but still generated the final source of

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6 Fry, 1987, argues that by the end of this process, Scotland had acquired a new set of political institutions, which have largely endured to the present time (although now modified very substantially by the creation of a Scottish Parliament).

7 Even listing Chalmers’ many achievement is a lengthy business. See Brown, 1982, for the best recent biography, and the first not to be written in the long shadow that Chalmers cast over the Scottish churches.
potentially usable data. The government, seeking to defer making a decision that would disappoint the Church, established the Royal Commission on Religion Instruction, which published nine reports between 1837 and 1839. However, the Commission’s deliberations were effectively undercut by the continued deterioration relationship between the Church and the government, with the Prime Minister, Viscount Melbourne effectively pre-judging its findings by announcing in 1838 that the only support that the government would give the Church would be some liberalisation of the regulation of the teinds. The Royal Commission nonetheless continued its work, collecting a substantial volume of evidence. It adopted the method of addressing questions to ministers of all Christian denominations, and this may allow some verification of the estimates of Church of Scotland minister. In Edinburgh, for example, the Commissioners received two substantial reports, one from the Church of Scotland and the other from representatives of the dissenting churches.

4. An initial review of data

We report on a preliminary review of the data contained within the Statistical Accounts for Forfarshire. This county, located in eastern Scotland, to the North of the Firth of Tay, extends through the rich farmland of Strathmore, famous for the production of soft fruit, into the Angus Glens, in which the pattern of settlement is rather sparser, and agricultural activity is limited to hill farming. There were five royal burghs: Forfar and Brechin in Strathmore; Dundee on the Firth of Tay in the South of the county, and Arbroath and Montrose on the East coast of the county. Forfar, Montrose and Dundee obtained burghal charters from David I in the 12th century, while Brechin and Arbroath were recognised as burghs in the 16 and 17th centuries. During the period that we are studying, all except Dundee were consolidated into a single Parliamentary Burgh. In addition, Kirriemuir obtained baronial burgh status in the fifteenth century.
By 1755, Dundee was a relatively large settlement with a population of 12,500. None of the other burghs had populations in excess of 5,000, even if Arbroath and the neighbouring parish of St Vigeans are counted as a single settlement. With a population of 3,400, Kirriemuir, on the Southern edge of the Angus Glens had the second highest population among the burghs. We concentrate on the burghs because those parishes, and in the case of Dundee and Arbroath, certain adjoining parishes, were the ones to experience substantial population growth, typically of the order of 1.5 – 2.0% per year between 1755 and 1835. In contrast, parishes in the Angus glens generally experienced static or declining populations.

It appears that even within Forfarshire, there were quite complex processes of population growth and migration taking place. We note that through much of the period of our study, growth rates were higher in the burghs that were initially smaller. Dundee, although the fourth largest settlement in Scotland, only seems to grow more rapidly than the other burghs after 1830. These observations are consistent with the reports from the New Statistical Account of the migration of skilled workers from rural parishes to larger settlements, while the growth of Dundee reflects substantial expansion of its port in the 1830s, which allowed it to develop an orientation towards international trade that was not copied by the other burghs. We therefore believe that this study will examine only the early stages of the industrial revolution in which agglomeration was primarily a local process.

Population data is the most systematically recorded in the Accounts. The narrative structure conceals much that is interesting, but we have found enough to confirm that it should be possible to retrieve useful data on prices of many basic commodities and goods – of grain, meat and cloth, for example – in both sets of Accounts. We have not completed this work for the parishes in Forfar, but we are confident of being able to create wage and price indices at parish level, and so to use such data relating to market conditions to understand better drivers of the population distribution across the country.
5. A spatial econometric perspective

Despite the fact that theoretical mechanisms such as technology diffusion, factor mobility (particularly migration, but also potentially capital), trade and transfer payments, all of which are argued to drive regional convergence, exhibit explicit spatial spillovers, the role of spatial effects in regional studies has been somewhat understudied. Barro and Sala-i-Martin (1992) studied convergence in the U.S. over the period 1963 to 1986 using data on per capita gross state product for 48 U.S. states using the cross-section regression model

\[ y_i = \alpha + \beta x_i + \epsilon_i, \quad i = 1, \ldots, 48 \]

where \( y_i \) denotes the average growth rate in per capita income in region (state) \( i \) over the 23 years, \( x \) denotes the log of per capita income in 1963, and an estimate, \( \hat{\beta} < 0 \), measures the strength of convergence, with growth of income per capita negatively correlated with starting incomes. This has been labelled \( \beta \)-convergence (Baumol, 1986). In a study of convergence clubs among regions in the U.K. using data for the period 1977 to 1991, Chatterji and Dewhurst (1996) made a call for more explicit spatial econometric treatment in regional studies. Rey and Montori (1999) estimate similar regression equations across different time periods, including explicit models of spatial spillovers. They consider the following three models:

\[ y = \alpha + \beta x + \pi (W x) + \epsilon; \quad (1) \]

\[ y = \alpha + \beta x + \epsilon, \quad \epsilon = \theta (W \epsilon) + u; \quad \text{and} \quad (2) \]

\[ y = \alpha + \rho (W y) + \beta x + \epsilon; \quad (3) \]

where \( y \) is a \((k \times 1)\) vector of outcomes across the \( k \) regions, and with the regressor \( x \) and random spatial or idiosyncratic errors \( \epsilon \) and \( u \) defined likewise, and \( W \) a \((k \times k)\) spatial weights matrix. The spatial weights matrix \( W_{(k \times k)} = ([w_{ij}; i, j = 1, \ldots, k]) \) is a square matrix with zero diagonal elements and with off-diagonal elements that capture spatial spillovers between regions or spatial units; for
example, the spatial weight $w_{ij}$ represents the strength and direction (sign) of spillover from region $j$ into region $i$. The standard literature in spatial econometrics has taken the elements of $W$ as exogenous and given *a priori*, typically measured by binary adjacency or contiguity indicators or as decreasing functions of geographic (or in some cases, economic) distances.

The structural interpretations of the three models are very different (LeSage and Pace, 2009). Model (1) is a variant of the spatial Durbin model where the spatial effects arise exogenously from spillovers in $x$. In model (2), the spatial error model, the spatial effects are exogenous as well, arising from spillovers in the exogenous regional income shocks $\varepsilon$. By contrast, the spatial lag model (3) has endogenous spatial spillovers in the response variable $y$.

Rey and Montouri (1999) construct a spatial weights matrix $W$ based on contiguity of the 48 states and find substantial spatial autocorrelation which can be explained by each of the three above models. However, the empirical implications of the three models turn out to be very similar. This is not unexpected, since it is not very easy to distinguish between different spatial models based on the data, particularly when the elements of the weights matrix are small. In turn, spatial weights are typically small by design and are required to be small relative to the identity matrix, $I$, in order to ensure spatial stationarity and identification of the reduced form. In particular, the spatial lag and spatial error models are not very well identified separately, not least because their reduced forms are identical up to first order Taylor approximation; see, for example, Bhattacharjee et al. (2014).

A recent branch of the literature has focussed on estimated, rather than *a priori* assumed, spatial weights matrices. Bhattacharjee and Jensen-Butler (2013) show that, with panel data for several regions, $W$ is not fully identified without making additional assumptions. The assumption of symmetric spatial weights ensures identification, and symmetry is also implied by spatial effects modelled through contiguity or geographic distances. Based on the above application, Bhattacharjee and Jensen-Butler (2013) show how such a symmetric weights matrix can be estimated. In some applications, symmetric spatial weights may not be desirable as an identifying assumption. For
example, with potential core-periphery relationships, where the periphery may not affect the core
to the same extent as the core affects the periphery, imposing symmetry could easily appropriate.

Alternate identifying assumptions have therefore been considered in the literature. Bhattacharjee
and Holly (2013) propose estimation of an unrestricted spatial weights matrix, identified under
moment assumptions that can be validated from the data. Bailey et al. (2014) identify \( W \) under the
assumption of sparsity and estimate spatial weights based on testing cross-region spatial
autocorrelations. Ahrens and Bhattacharjee (2014) make an approximate sparsity assumption to
estimate \( W \) using the LASSO (least absolute shrinkage and selection operator) proposed by
Tibshirani (1996). Finally, Bhattacharjee and Eibich (2014) show that a triangular structure in the
spatial weights matrix can be identified from the data, and once the structure is identified, such a
triangular spatial weights matrix can be estimated by simple OLS regressions.

As compared with the above literature, our current context is to understand the growth of Scottish
towns and burghs in the 19th century, both in absolute terms and in relation to each other. At the
global level, the reality in the 19th century was the so-called Great Divergence, rather than one of
convergence between countries. As our simply review of the data for

The linkages between the towns themselves would likely have played a major role in this process. In
Forfarshire, Dundee could provide a port for much of Perthshire and Fife as well as the interior of
Forfarshire, but Montrose was the obvious port for much of Strathmore. Geographical distances
might then have played a relatively minor role in characterising cross-town spillovers. In general, the
challenging terrain of Scotland led to substantial dependence on sea routes, especially with the
limited development of turnpike roads and canals. Recent literature also points to the importance of
trade and migration of skilled labour in determining the forces of convergence or divergence
between regions and countries, as well as technology spillovers (Ditzen and Bhattacharjee, 2014).
Again, our initial survey suggests that were important migration effects in Scotland.
As a first attempt towards understanding the endogenous evolution of the spatial structure of the Scottish economic geography in the 19th century, we present analysis of the decennial population growth in the 9 principal towns/cities and royal burghs of Scotland. These are, in decreasing order of population in 1801: Glasgow, Edinburgh & Leith, Dundee, Aberdeen, Paisley, Perth, Kilmarnock, Dumfries and Inverness. Following Rey and Montouri (1999), we assume a spatial error model and estimate the following model of decennial population growth:

\[ y_t = \alpha + \beta x_t + \epsilon_t, \quad \epsilon_t = \theta(W \epsilon_t) + u_t, \quad t = 1811, 1821, \ldots, 1891, \]

where \( y_t \) denotes decennial population growth, \( \ln(n_{it}/n_{i(t-10)}) \), the exogenous regressor is logarithm of initial population, \( x_{it} = x_i = \ln(n_{i,1801}) \), and \( n_t \) denotes the population of town \( i \) in census year \( t \). The source of population data are the decennial censuses for the years 1801 through 1891. Initially, we measure \( W \) by inverse road distances between the towns, which may be treated as purely exogenous. As an alternative, we also consider a matrix of in-migration over the decade 1841-51, drawn from a Table titled “Birthplaces of the Inhabitants of Principal Towns” in Hansard Papers (1954). Since migration is likely endogenous to the process of population change, we also follow Kelejian and Piras (2014) in estimating the model by an instrumental variables approach using as instruments geographic (road) distances between the towns.

However, the spatial effects turn out to be non-significant in all the above cases. This underscores the idea that spatial spillovers are complex and difficult to accurately describe using ad-hoc a priori fixed distance measures or spatial weights. Ultimately, we plan to conduct narrative analysis or text mining on the Statistical Accounts to construct different alternative spatial weights measures, potentially using gravity models on the frequency of key words used in these documents. To obtain an initial assessment as to whether such efforts are likely to bear fruit, we consider \( W \) as unknown and estimate the same under the assumptions of symmetry (Bhattacharjee and Jensen-Butler, 2013) and triangular structure (Bhattacharjee and Eibich, 2014); these estimates are reported in Tables 1 and 2 below respectively.
Several interesting observations follow from Table 1. First, unlike the inference based on \textit{a priori} assumed spatial weights based on distances or migration, there are some statistically significant estimated spatial weights. This reflects strong spatial spillovers between some towns, but also the indication that neither geographic distances nor migration provide universally strong explanations for spatial spillovers. Second, there are strong positive externalities between some towns: Glasgow and both Kilmarnock and Dumfries; and similarly Paisley and both Kilmarnock and Dumfries; and likewise Perth and both Kilmarnock and Dumfries; Edinburgh and both Aberdeen and Inverness; and similarly Dundee and both Aberdeen and Inverness. Such positive externalities make good sense in the context of the period.

Third and perhaps most importantly, there are some negative spatial interactions reflecting strong competition between some towns. Prominent examples are Glasgow with Paisley, Perth and Inverness, Aberdeen and Inverness and Dumfries and Kilmarnock. Spatial weights measured using positive values distances or contiguity assume the absence of such spatial competition.
Fierce spatial competition is also evident from Table 2, with negative spatial spillovers from Edinburgh to Dundee, Aberdeen to Edinburgh and Inverness, and Inverness to Paisley. At the same time, there is substantial evidence of positive externalities as well. Positive spillover effects are observed from Perth to Dumfries, Dumfries to Edinburgh, and Edinburgh to Paisley, Paisley to Aberdeen, and Kilmarnock to Glasgow and Paisley. This reflects a reasonably dense inter-town network that generates a rich pattern to positive and negative spillovers.

Of course, results in Tables 1 and 2 are conditioned on the identifying assumptions that we have made – symmetry and triangular structure respectively. Careful narrative analysis of the Statistical Accounts based on text mining would provide additional rich insights into the process of endogenous transformation of the spatial structure of Scotland in the 19th century.

Finally, the lack of temporal variation in the regressor in model (4) may be somewhat limiting. One can modify the definition of $x$ slightly as: $x_{it} = ln(n_{i,t-10})$. This modification may allow for more efficient estimates of the spatial models above.

<table>
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Table 2: Estimated triangular spatial weights matrix, W
(Bold/ Italics: significant at 5 per cent/ 10 per cent level)
6. Conclusion

When Sir John Sinclair planned his comprehensive inquiries into the state of Scotland, he was conscious of its being the first attempt to assemble in such minute detail the social and economic data associated with a complex space. It created a methodology for measurement – reliance on reports from parish ministers – that was entirely sensible in Scotland given the state of its public institutions up until the schism of 1843, after which it was impossible for church ministers to claim to be representative of the whole country. The research that we have started will therefore allow us to extend the econometric history of Scotland to the Age of Enlightenment and the first phase of the industrial revolution.

We have confirmed that there is substantial quantitative data contained with the *Statistical Accounts*, and while we have only started to explore how this might be used, we note that the technique that we have identified as most likely to be useful – with endogenous spatial weights – is likely to add substantially to our understanding of the spatial development of Scotland precisely because it does not impose any structure on the data, but instead allows us to identify and estimate relations that exist within the data. In particular, we note that this allows us to admit the existence of multiple causal relationships across space, of the sort that social historians have inferred for many years from close reading of their sources.
References