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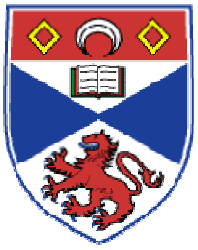

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Infrastructure Finance and Industrial Takeoff in England*

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ABSTRACT

That financial matters did not constrain industrial takeoff in the UK is generally accepted in the historical literature; in contrast, contemporary empirical analyses have found evidence that financial development can be a causal determinant of economic growth. We look to reconcile these findings by concentrating on a particular aspect of industrialising UK where inefficiencies in finance could have had bite: The finance of physical infrastructures. We document the historical record and develop the importance of spatial disaggregation and spillovers in both technological and financial development. We develop a simple model that captures the nature of infrastructure finance within a theory of endogenous growth where financial costs are endogenous. We argue that the conception of the finance-growth nexus as a largely static, aggregative phenomenon misses out a good deal of complexity and we relate that complexity to a number of implications for regulation of both financial systems and the emergence of infrastructures.

JEL Classification: O11, O16, O40, N23
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1 Introduction

The sustained period of high economic growth in the UK from the mid-eighteenth century was accompanied by a massive increase in the supply of physical transport infrastructure, from turnpikes to waterways to railroads. While innovation in industrial technologies was critical in expanding production possibilities, the supply of such infrastructure defined the scope of markets by determining the cost of obtaining raw goods and of shipping products to market. We know a good deal about the impact of infrastructure on industrial development, but we know less about the financial underpinnings of that expansion of infrastructure and the affect of that finance on wider economic and financial development. The development of infrastructure in the UK, particularly the financing arrangements that supported its projection, and the connection of this to wider economic and financial development is the focus of this paper.

In addition, the interdependence between infrastructural finance and the expansion of industrial output means that we can, to a limited extent, draw parallels with the more general contemporary literature on the nexus between finance and growth. In order to demonstrate this link further, we develop a theory that captures the nature of infrastructural finance we uncover in the context of simple model of finance and growth.

In Section 2, we look to understand the historical perspective that finance was not a constraint on industrial takeoff in the UK; that is, the central financial markets or large and efficient banks we see today are not thought to have been a *causal* factor in explaining the occurrence of industrial revolution. We document the nature of infrastructure finance and show that it too did not rely on central money markets in its early stages. Instead, formal coalitions of local investors were formed in order to finance the construction, moving toward the use of centralized financial systems as the economy developed. We also consider the existence of spillovers

from these early coalitions onto the efficiency of wider financial intermediation. The importance of such spillovers to the later emergence of sophisticated, centralised financial structures suggests a new channel for understanding the potential for financial matters to determine growth.

In Section 3 we develop a simple theory of finance and endogenous growth that can account for some of the dynamic, disaggregated elements found in our historical analysis. The theory captures low-growth equilibria and sheds light on the implications of accounting for such disaggregation in models of finance and growth. In particular, we find that encouraging the emergence of a *national* financial system can have negative consequences for growth. In Section 4 we consider the contemporary finance and growth literature in the light of the historical evidence, and argue that the factors identified in the UK case are relevant to, but omitted from, our current understanding of the finance-growth nexus. Section 5 concludes the paper with a summary of our main findings.

The general reader might wonder what all this has to do with modern economies that are integrated with global financial systems and in which large infrastructure projects are managed and financed through sophisticated public-private partnerships. The present extent of international capital flows can mask a detachment from financial services of large parts of an emerging nation's population. Beck and Demirgüç-Kunt (2008) summarizes the recent research agenda that addresses the lack of access to finance by many in poor countries. The historical episode and the theory presented in this paper emphasises the importance of local information in identifying emerging hotspots of economic activity before they are more widely seen at the aggregate level. The lack of access to finance noted in Beck and Demirgüç-Kunt has relevance for the ability of local investors today to take advantage of their informational advantages in the way that investors did during the industrial revolution in England. Those informational advantages could also mean that, in emerging economies, the decentralised development of an infrastructure more sen-

sitive to differences in local demand might be preferable to the grand ambitions of state-sponsored infrastructure networks intended to integrate an otherwise geographically separated national economy.[1] The historical evidence presented here raises questions that are potentially highly relevant to the modern context.

2 The Industrial Revolution and Finance

The historical consensus is that finance did not constrain the industrial growth of the UK. Subsection 2.1 goes through historical evidence on the role of finance in entrepreneurship and industry. Subsection 2.2 introduces evidence on the financial arrangements that emerged to fund physical infrastructure projects through the industrial revolution. Subsection 2.3 begins to draw-out some of the findings from our historical analysis.

2.1 Industrial Finance

Among the major financial innovations of the industrial revolution in Britain was the expansion of access to the incorporation of limited liability joint-stock company in the middle of the nineteenth century.[2] Robinson (1952) puts this invention on a par with that of the steam-engine. The belated emergence of widely used joint-stock finance was mirrored by the relatively late growth of formal stock markets that grew out of the early capital markets described in Neal (1990).

This apparent delay in the development of more specialized financial services did not, however, prevent the emergence over the course of the eighteenth and early nineteenth century of alternative methods of industrial finance. Cottrell (1980)

[1] Consider China's current investment in infrastructure to connect remote parts of that country or the capital expenditure on the Trans-Amazon Highway in the 1970s. Smith (1990) argues that a centralised approach in France retarded that country's industrial takeoff.

[2] Specifically, the Joint Stock Companies Acts of 1844 and 1856, and the Limited Liability Act of 1855, greatly expanded the access to the establishment of a limited liability joint stock company and formalized the procedure of incorporation via a Registrar of Companies.

argues that it is generally accepted that savings were adequate to support industrialization and that the most commonly cited institutional impediments to finance, the Usury Act of 1660 and the Bubble Act of 1720, constituted no real barrier to industrialization.[3] Hudson (2002) reiterates this: Internal self-finance was the dominant facilitator of industrial expansion. Prominent macroeconomic histories of the industrial revolution, such as Landes (1969) and Mokyr (1990), barely consider that institutional constraints on finance might have caused differences in industrial take-off. Neal (1994) details the growing connections between financial innovations and industrial development, but our question is one of causality. Financial development was most surely a necessary component of industrial takeoff, but not clearly a sufficient one.

The general argument runs that an individual entrepreneur, especially a good one, could find the start-up capital required or use reinvested profits to expand as and when conditions allowed. Further demands for finance were met by the growth in the number of country banks (often set up by industrialists) and, later, by the gradual take-up of joint-stock banking and the growth of a central stock market into the nineteenth century. The late emergence of banking and stock markets described in Neal (1994), in this view, reflected not the release of some legislative or institutional constraint but an acceleration of demand for them along the pecking order of finance. The absence of bank finance, of central stock markets, and of accessible joint-stock operations was not a *direct* impediment to industrial takeoff. As Robinson (1952, p.86) put it, "where enterprise leads, finance follows."

This argument runs against the large body of empirical evidence, surveyed in Levine (2005), that suggests that financial development is strongly correlated with, and perhaps leads, the level of economic growth. As we describe in Section 4, part of reconciling these findings is in recognising we do not have a good understanding

[3]The former Act restricted the rate of interest that could be charged on bills and advances; the latter necessitated that consent to establish joint stock companies must come from Parliament.

of precisely *where* constraints of finance might bind. In order to see this, we need to make a distinction between the types of activity requiring finance.

Problems in raising finance for investment largely occur where there is a significant element of fixed costs. As Pollard (1964) argued, most investments in early industry could be small – at least contained within the easy reach of an individual firm's finances – so the industry-leads-finance story is perhaps not so surprising.[4] Physical transport infrastructures are a class of investments characterized by large fixed costs and are strongly correlated with industrial development.[5] Physical infrastructures needed some forms of financial organization in order to emerge, therefore. Section 2.2 goes through evidence on the nature of infrastructural finance through the period of industrial revolution in the UK.

2.2 Finance, Industrial Growth and Infrastructure in the UK

The production of significant pieces of infrastructure required a greater financial outlay than was feasible for most firms alone. As such, in the absence of public investments, the emergence of financial intermediation of some form – through informal coalitions of firms, bank finance, or the creation of joint stock companies – was thus inevitable. Such intermediation was, of course, itself not costless: Mapping the path of infrastructure required coordination among firms; legal specialists needed to be hired in order to obtain Parliamentary assent; potential wider investors needed to be sought out; banks needed to be negotiated with; and so on. On top of this, at the onset of the industrial revolution many new infrastructural technologies had yet to be proven and the industrial centers had yet to emerge. The costs of relaying information about the virtues of any given project, especially dur-

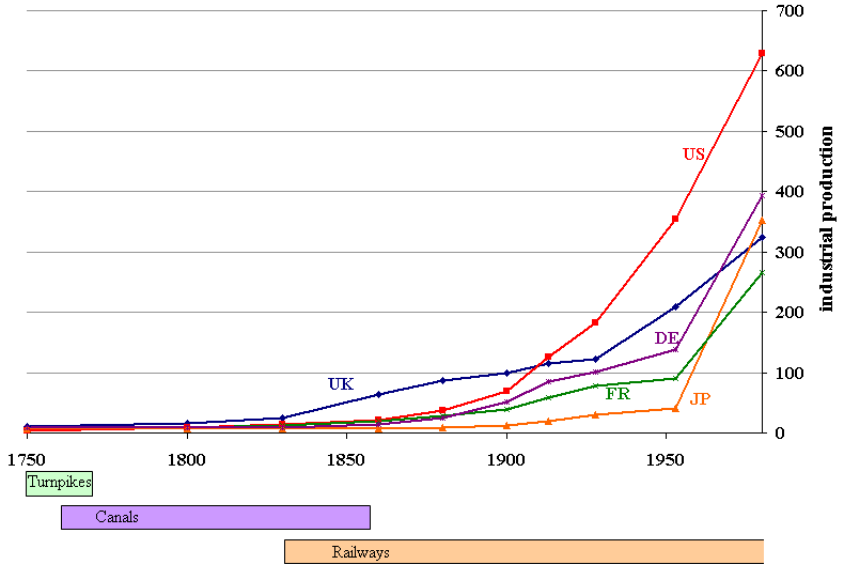
[4]Even what we might think of to be a large fixed cost in manufacturing, the factory premises constructed to house workers and machines, were often rented in arrears from more wealthy individuals, with multiple tenancy, subletting and power-sharing prevalent (see Hudson, 2002).

[5]See Hulten (1996), Calderón and Servén (2004), Keller and Shiue (2008) and Atack et al. (2008).

ing times of speculation, were crucial determinants of the intermediary structures that resulted.

For reference, Figure 1 depicts the phases of each of the main forms of transport infrastructure in the UK next to data for the per capita volume of industrial production, using the data in Bairoch (1982).

Figure 1: Per Capita Industrial Production and UK Infrastructure, 1750–1980



The industrial revolution saw a gradual standardization of the way in which infrastructure finance was regulated through Parliament. The Bubble Act of 1720 necessitated that joint-stock companies be authorized by royal charter. Thus, the construction of any piece of infrastructure required a Bill to be passed in Parliament. Further, from 1794, requirements for an infrastructure Bill included the need to deposit a map of landholdings in the vicinity of the project, reference books (linked to the map of landholdings) of landowners and occupiers as well as their support or opposition to the plan, and a list of proposed financial supporters. Most of the evidence cited in this Section is based on analysis of these deposits. We can interpret these data with confidence, therefore.

2.2.1 The Emergence of Turnpikes in the UK

A surprising amount is know about the turnpikes of the mid-eighteenth century. Buchanan (1986, p.227) notes that most turnpike companies "were run by men representative of the economic life of the area." Regional capital markets funneled some investments and investors were large in number and from a wide range of social strata. Bogart (2006) finds that turnpike trusts were typically spatially concentrated in the vicinity of major economic centers. Regional and network effects in the diffusion of turnpikes were significant.

2.2.2 Financing the UK Canal Network

The development of the UK's waterway network during the late eighteenth century was achieved without the use of central money markets. Ward (1974) describes the typical process of projecting a canal: A group of industrial and merchant leaders would see the potential benefit to their business of installing a canal in their vicinity. The promoters would either call upon a financier, or become financiers themselves, to sell scrip and shares in a prospective joint-stock canal company. The canals were mostly financed by those local to the route of the canal. Those who invested were by no means uniformly wealthy. Ward classifies investors by occupation and social status, and documents that the majority of investments came from local landowners, merchants, tradesmen, manufacturers and professionals – people whose wealth was not only relatively limited but also mostly tied up in their primary employment.

This pattern is seen across the country and throughout the century. Ward notes, however, that through the eighteenth and into the nineteenth century, centralized stock markets became more willing to support canal projects. Turnbull (1987) finds not only this pattern of local finance of canals but also a localized pattern in the *construction* of canals. The importance of an integrated, national system of waterways gave way to local and regional demands for routes unconnected to trunk lines. Canals were built as local enterprizes first, and formed part of a national

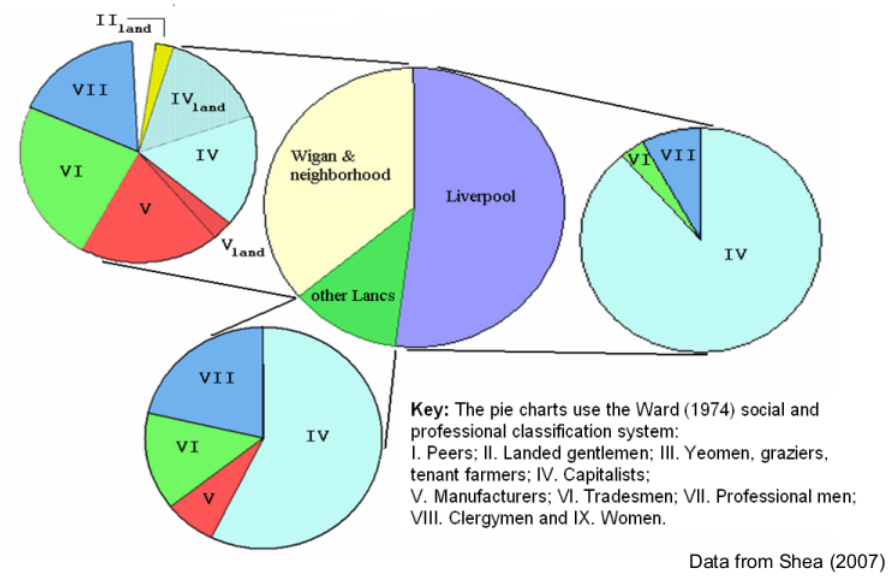
network only later.

2.2.3 The Finance of Railways in the UK

We have the most data about the financial development of the UK railway system. Mitchell (1964) documents the scale of investment: Capital expenditure on railways peaked at over 6% of national income in the 1840s before falling off after then. Hunt (1935) first showed that the early railways were, like the canal system, established without the use of the London stock exchange. Again, the provincial nature of finance is also clear.[6]

We can draw upon some specific evidence from late industrial Lancashire in Shea (2007), a new dataset of corporate finance history; in particular the capital history of the Wigan Branch Railway. There was nothing special about this railway, it was one of another 6 or 7 small railways built in Lancashire from the late 1820's and it was typical of how many other early British railways, canals and gas and water supply were built. Figure 2 gives a breakdown of initial investors in the railway.

Figure 2: Wigan Branch Railway: Investors



[6]According to Pollins (1954), this is a pattern repeated across the country in the finance of tunnels and docks.

As can be seen, shares in the railway were not purchased by a small number of very wealthy distant individuals, but by a large number of relatively modest local capitalists, manufacturers, tradesmen and professionals. The investors were highly spatially concentrated around the location of the railway. This pattern of spatially-concentration financial coalitions is observed in the Shea (2007) dataset across different railways of the same period.

We also see most clearly with railways an element of learning in the emergence of financial coalitions: Before a new form of transport has been tried and tested, and before industrial hotspots have been identified, potential investors took more convincing that buying shares was worthwhile (see Pollins, 1954). Following the successful projection of early railways by local investors, so finance from a wider sphere could be sought. Broadbridge (1955) finds similar results on the spatially concentrated nature of early railway capital. That paper, and Ward (1974), also points to the later emergence of regional centers of finance. Broadbridge tracks a gradual movement in the second half of the nineteenth century away from local subscription toward London. This did not happen just because the stock market was there, but because conditions and capital requirements changed: His evidence supports the "conventional view that railways were drawing their capital from ever-widening sources in the early 1840's, as compared with previous decades." (ibid., p.206). Mitchell (1964) also documents this progress and specifically notes the positive spillovers from railway finance *onto* the later efficiency of the centralized stock markets which provided finance for the wider economy: "Then again, it was the railways which brought about the very rapid growth in provincial stock exchanges in the 1840's..." (ibid. p. 330). By popularising the limited liability form, by expanding the range of individuals trading in shares, the emergence of the large railway companies facilitated the emergence of a centralized stock market that began to direct surplus savings into profitable industry.

2.3 Local Investments, Regional Growth and Dynamic Features

The most striking aspect of this history is that banks and central stock markets were missing in the initial projection of each form of physical infrastructure.[7] In the early stages of development, obtaining finance for infrastructure projects from central markets was dominated by raising it from scratch from among a relatively modest local populace. Lesser information problems at the local level and the spillovers onto the local economy meant that intermediation among local investors was the preferred course.[8]

As infrastructures became larger, as industrial centers became more evident and as industrial development itself began to require more sophisticated external financing, the central financial systems evolved into markets more capable of evaluating distant (and, increasingly, larger) infrastructure projects. The examples of spillovers from railway finance onto the late development of stock markets are specific to that case, but one might view the whole history of infrastructure finance as a process of learning in financial technologies; the development of the efficient financial structures that could then be tapped into by industry more widely. The informational problems at the national level began to wane as the institutional framework for centralized finance developed. Over time, central financial markets became the dominant form of infrastructure – and industry – finance.

The pattern in provincial infrastructure development is mirrored by the provincial nature of the industrial revolution. For Cottrell (1980, p.19), the "industrial revolution... was essentially a process of regional growth." Landes (1994) writes of

[7]Buchinsky and Polak (1993) find evidence that regional financial markets more generally were detached from the London markets up until the end of the eighteenth century. The focus of this paper is specifically on the finance of infrastructure projects but, clearly, the interactions between these processes of learning at different points of the industrial takeoff and across different types of industrial activity deserve further study.

[8]Work such as Petersen and Rajan (2002) has established the importance of distance to the relationship between banks and those to whom they lend. Here, distance is important in the emergence of the financial coalitions that predated the wider use of banking.

the 'precocity' of regional specialization in England compared with Continental Europe. Recent work, such as O'Brien (2006), continues a growing literature on the industrial revolution as a provincial phenomenon.[9] Disjointed local and regional infrastructures supported a local and regional industrial growth that itself comprized, on the national level, a disjointed patchwork of regional economies.[10] As the national economy emerged, so, in parallel, did both the national infrastructure and the national financial markets to finance it and the rest of the economy.

Obviously this is a simplified version of the historical detail. The spatially concentrated coalitions of investors in the early stages are observed consistently, however, across different forms of infrastructure. The disjointedness of regional development is also a clear conclusion of recent research. The implications of these dynamic, disaggregated elements for industrial development and aggregate growth are easiest spelled out in a simple theory of finance and growth that encapsulates them.

3 A Model of Growth, Finance and Infrastructure

In the manner of the most influential simple models following King and Levine (1993), we assume that financial intermediation is to some extent costly. Those costs are intended to reflect the frictions associated with information asymmetries between agents of different types.[11] The structure of those costs, in the model of this paper, is motivated by the historical record of infrastructure finance in the UK.

We assume that firms have no trouble raising capital for production. In con-

[9]Keller and Shiue (2008) and Atack et al. (2008) also relate regional market expansion with regional infrastructural development.

[10]In the context of developed economies, the connection between local financial systems and local economic performance is underlined in Dehajia and Lleras-Muney (2003) and Guiso et al. (2004).

[11]A number of finance and growth models are surveyed in Levine (2005). A model of growth that establishes microeconomic foundations for financial intermediation is Prescott and Boyd (1986).

trast, infrastructure, an input to production, cannot be funded by individual firms or individual agents alone. Agents who see the demand for infrastructure become 'entrepreneurs' and contract with intermediaries to organize capital funding. Entrepreneurs then construct and lease infrastructure to firms. The efficiency of that intermediation determines the costliness of raising capital for infrastructure. Firm output is affected by the level of infrastructure that the firm is willing to pay for, given the costs of raising capital for that infrastructure.

3.1 Productivity and Economic Integration

Assume that there are two regions in the economy. Funds can be raised at the regional level, via regional financial intermediaries, or at the national level, using national financial intermediaries. We make two assumptions: 1) A regional financial intermediary can only finance a regional infrastructure; and, 2) a firm can only operate at the scale of the infrastructure that it employs. We are, of course, abstracting greatly here in our conception of 'regional' and 'national' infrastructures. Small pieces of infrastructure sometimes connected up to larger trunk lines which mapped out a national network. The timing of such investments is not always obvious, either. We simply wish to capture the idea that different investments in infrastructure can cohere markets of different scale; and that early small-market infrastructures fed into the emergence of later large-market infrastructures.

Part of the incentive for firms to operate at the national level arises from extensive scale effects in technology, after Rivera-Batiz and Romer (1991) and McDermott (2002). Extensive scale also has a role in financial intermediary conditions. The historical analysis above has indicated that both firms and investors can have a preference for local funding in the early stages of growth. For reasons of trust, knowledge of local market demand, ease of monitoring, etc., it is relatively less costly to convince a local investor that a project is worth investing in when the prospects of that project are hard to identify.

There is also an intensive scale effect; we have seen that a transition from spatially concentrated finance and markets to economy-wide finance and markets can occur endogenously, because of complementarities between the local coalitions and the later stock markets. We account for, in addition to the fixed information cost effect of extensive scale, a learning effect in financial intermediation. This might be a demonstration effect, or learning in the *technology* of financial intermediation. It might also be that the return on national infrastructure projects are only sufficiently high once regional projects have been developed. This learning process is similar to the model in Lee (1996) where as the economy grows, intermediaries accumulate information which in turn makes financial intermediation more efficient.

3.2 The Model

We have two regions, A and B, in the same closed economy. In each region there is a unit mass of firms and a unit mass of consumer-agents. Agents can become either intermediaries or entrepreneurs; entrepreneurs raise capital via intermediaries in order to construct the infrastructure demanded by firms.[12] One region cannot trade capital with another without financial intermediation and infrastructure on a *national* level. At a given point in time the economy operates as either i) non-integrated regions with no national trade in capital; or, ii) an integrated national economy with full factor mobility and equalized rates of return.

Agents are given an initial capital endowment and can allocate that between production and funding infrastructure. Firms demand capital and infrastructure. Agents can sell capital direct to firms but infrastructure is supplied via financial intermediaries who 'raise' the funding from agents. The costliness of intermediation drives a wedge between savings and investments that impacts upon what both firms and agents receive. Consumption optimization by agents, combined with a specific

[12]Perfect competition will ensure every agent has identical consumption. We are not specific about occupational choice in the model, except to rule out the possibility that agents become entrepreneurs *and* intermediaries

production function for firms, generates endogenous growth based on externalities in the manner of Rebelo (1991).

3.2.1 Regional Growth

Two factors enter the production function: Capital, k_t, and infrastructure, I_t.[13] Assume both regions are specified identically and that initial values for capital and infrastructure, k_0 and I_0, are the same in both regions. Consider region A, in which firms produce a single good,

$$Y_t^A = A(k_t^A)^\alpha (I_t^A)^{1-\alpha}, \tag{1}$$

where $0 < \alpha < 1$. Each firm maximizes profits,

$$\pi_t^A = Y_t^A - rk_t^A - iI_t^A, \tag{2}$$

subject to $\pi^A \geq 0$, and where each takes the rate of return on capital, r, and infrastructure, i, as given,

$$r = \alpha \frac{Y_t^A}{k_t^A}; \tag{3}$$

$$i = (1-\alpha)\frac{Y_t^A}{I_t^A}. \tag{4}$$

There is a market for the construction of infrastructure. Agent-entrepreneurs can recognize the demand for infrastructure by firms but cannot fund it themselves, they must obtain the services of intermediaries to raise the necessary capital. Investment in infrastructure is different because it *requires* the services of an intermediary. The entrepreneurs' incentive is the rent she can charge for firms' use of the infrastructure.

Suppose that there are no costs to *becoming* an entrepreneur. Where m is

[13] Infrastructure is not subject to congestion.

the rate on capital supplied by the intermediary, M_t^A is the infrastructure capital supplied by an intermediary in region A and $I_t = f(.)$ is the production function for infrastructure, each entrepreneur maximizes profits,

$$iI_t - mM_t \geq 0. \tag{5}$$

We specify the simplest form for infrastructure production, specifically $f(M_t) = M_t$, so the marginal return from capital allocated to infrastructure is constant and perfect competition implies $i = m$.

The financial intermediary raises capital from agents and sells it to entrepreneurs. Any agent who sees the demand for financial intermediation can become an intermediary. The profit to an agent from financial intermediation at the *regional* level is,

$$\mathcal{F}^A = (1 - \psi)mM_t^A - (1 + \phi)sM_t^A, \tag{6}$$

where s is the private return that agents obtain from selling infrastructure capital to intermediaries.

Two costs are incurred by the intermediary. First, a cost $\phi > 0$ of collecting capital from agents reflects the costs of communicating the worthiness of investment in terms of expected risk and return. We have seen from the historical analysis that this cost can be significant. Second, a cost $\psi > 0$ of distributing that infrastructure capital to entrepreneurs reflects the cost of evaluating and monitoring potential entrepreneurs. For the purposes of this analysis, and following much the literature (see Levine, 2005), we do not specify the sources of these costs analytically. We simply take the view, following the historical analysis above, that these costs exist and can be significant.

The market for intermediation is also perfectly competitive: Given a large number of firms, agents and entrepreneurs, and given no fixed costs to becoming an intermediary, any profits from intermediation are competed away. From equation

(6), with $\mathcal{F}^{\mathcal{A}} = 0$, we have the following relationship between the rates of return on infrastructure capital,

$$m = \frac{(1+\phi)}{(1-\psi)}s. \tag{7}$$

Equation (7) reflects the *wedge* between saving and investment, as in Pagano (1993): The more efficient the intermediation, the lower are the costs of collecting and disseminating finance, and the closer are the rates of return on saving and investment.

Substituting the demand for infrastructure, equation (4), into the production function, and given $i = m$, we have,

$$Y_t^A = \left[A \left(\frac{(1-\alpha)(1-\psi)}{(1+\phi)s} \right)^{1-\alpha} \right]^{\frac{1}{\alpha}} k_t^A, \tag{8}$$

which, where s is constant, is a simple form of Ak production which we know will generate endogenous growth.

To close the model we specify conditions of consumer optimisation. Infinitely-lived consumers maximize their expected discounted income stream,

$$U = \int_0^\infty e^{-\rho t} u(c_t) dt, \tag{9}$$

where we define instantaneous utility as have constant elasticity of substitution,

$$u(c_t) = \frac{c_t^{1-\theta} - 1}{1-\theta}. \tag{10}$$

Agents chooses how much capital to sell to firms, how much to sell to intermediaries (taking s as given for the moment) and how much to consume given $\dot{k}_t + c_t = (r - \delta)k_t + sM_t$ where δ is the rate of capital depreciation.[14]

[14]Implicitly, we are assuming that the I/k ratio is constant, so infrastructure grows at the same rate as capital.

The Euler equation in consumption is,

$$\frac{\dot{c}_t^A}{c_t^A} = \frac{1}{\theta}(r - \delta - \rho), \tag{11}$$

which is equal to the balanced growth rate of the economy, γ. From the production function, equation (8), we can derive r,

$$r = \left[A \left(\frac{(1-\alpha)(1-\psi)}{(1+\phi)s} \right)^{1-\alpha} \right]^{\frac{1}{\alpha}}. \tag{12}$$

If the return on providing infrastructure funding is greater than the return on capital for production all finance will be sold to the intermediary. If the return to agents from selling capital to intermediaries is less than the return on that sold to firms, all capital goes to firms as capital. Competitive intermediation thus ensures also that $s = r$ and so, from equation (12),

$$s = r = A \left(\frac{(1-\alpha)(1-\psi)}{(1+\phi)} \right)^{1-\alpha}. \tag{13}$$

As such, from the Euler equation and this expression for the interest rate we have in both regions the growth rate,

$$\gamma^A = \gamma^B = \frac{1}{\theta} \left[A \left(\frac{(1-\alpha)(1-\psi)}{(1+\phi)} \right)^{1-\alpha} - \delta - \rho \right]. \tag{14}$$

3.2.2 National Growth

In the light of the historical evidence discussed above, we allow for the possibility that there are significant scale-effects in the costs of financial intermediation. We define the national intermediary conditions to be,

$$\mathcal{F}_t^* = 2(1-\psi^*)i^* M_t - 2(1+\phi^*)s^* M_t, \tag{15}$$

where $\psi^* = \Psi + \frac{2\omega}{I_t}$ and $\phi^* = \Phi + \frac{2\nu}{I_t}$, $\omega, \nu \geq 0$. So the costliness of intermediation is related to the *level* of infrastructure. The parameters Ψ and Φ are exogenous fixed scale factors, that could reflect the institutional environment. At early stages of development, or if fixed costs are always high, an intermediary incurs additional costs to operate at the national level, and to maintain zero-profit requires a higher return on infrastructure capital sold to entrepreneurs. The fixed cost premia, $\Psi - \psi$ and $\Phi - \phi$, reflect the difference in underlying efficiency of the regional cf. the national intermediary given the institutional environment. The non-fixed costs, parameterized by ω and ν, reflect the 'learning' costs of establishing an infrastructure in order to operate an economy at the larger level. Proxying for the size of regional markets by the level of local infrastructure demand, $I_t^A = I_t^B = \frac{1}{2} I_t$, we have that the cost raising finance to build a national infrastructure is decreasing in the size of regional markets. In the long-run, these costs are zero but, in the early stages of growth, they may be a significant determinant of the scale of intermediation.

An extensive scale effect in productivity, motivated above, means that the the coefficient of technological progress at a national level is higher than that at the regional level. The national production function is thus,

$$Y_t^* = \bar{A} k_t^{\alpha} I_t^{1-\alpha}, \tag{16}$$

where $\bar{A} > A$. The incentive for agents to want to fund projects at a national level is the higher productivity of their capital, tempered by the costs of funding intermediation to facilitate that production. As in the case of the regions, we can find an analogous expression for the rates of interest on capital in the case of integration,

$$r^* = \bar{A} \left(\frac{(1-\alpha)(1-\psi^*)}{(1+\phi^*)} \right)^{1-\alpha}. \tag{17}$$

It should be clear that r^* will not be constant so long as $\nu, \omega > 0$. We will still obtain a balanced growth path in the long run, but we approach it from below as

$I_t \to \infty$. The long-run growth rate of the national economy is,

$$\gamma^*_{LR} = \frac{1}{\theta}\left[\bar{A}\left(\frac{(1-\alpha)(1-\Psi)}{(1+\Phi)}\right)^{1-\alpha} - \delta - \rho\right]. \tag{18}$$

The transition to this asymptotic growth rate follows,

$$\gamma^*_{SR} = \frac{1}{\theta}\left[\bar{A}\left(\frac{(1-\alpha)(1-\Psi-\frac{2\omega}{I_t})}{(1+\Phi+\frac{2\nu}{I_t})}\right)^{1-\alpha} - \delta - \rho\right]. \tag{19}$$

We will need to re-formulate this expression for any numerical simulation but, for the moment, the transitional growth dynamics should be clear: The rate of growth of consumption and infrastructure is related to the *level* of infrastructure. The rate of change of economic growth is at first positive and reduces to zero as time goes to infinity: For an integrated national economy, $\lim_{t\to\infty} \gamma^*_{SR} = \gamma^*_{LR}$.

This growth rate will only be realized if the regional economies integrate. The rate of interest at the national level, equation (17), reflects the combination of increased productivity and increased cost of integrating the two regional economies. Integration thus takes place if $r^* > r$, where r is the rate of interest in the regional economies. This condition is satisfied where,

$$\frac{\bar{A}}{A} > \left(\frac{(1-\psi)(1+\Phi+\frac{2\nu}{I_t})}{(1-\Psi-\frac{2\omega}{I_t})(1+\phi)}\right)^{1-\alpha}. \tag{20}$$

Once this occurs, there is capital mobility and we have the national production function of equation (16) and no separate regional output, i.e. no agent would prefer to operate regionally when national output is possible. At the point where $r^* = r$ the growth rate at the national level is equal to that at the level of the regions. By equation (20), the feasibility of integrating is decreasing in both the relative additional costs of intermediating at a national level and the ratio of coefficients of technological progress. So the timing of and transition to national integration here

is endogenous to the model.

3.2.3 Equilibria

There are three possible equilibria for the economy, dependent on both parameter values and the initial demand for infrastructure, I_0. We either have regional separation, national integration, or a transition from the former to the latter.

The only thing that will prevent integration in the long-run are high fixed information costs relative to the productivity improvement, i.e. if,

$$\frac{\bar{A}}{A} \leq \left(\frac{(1-\psi)(1+\Phi)}{(1-\Psi)(1+\phi)} \right)^{1-\alpha}. \tag{21}$$

So it is possible that in the presence of either a low effect of integration on productivity ($\frac{\bar{A}}{A}$ is close to unity) or persistent high premia of pooling and coordinating savings over the larger economy (Φ and Ψ are significantly higher than ϕ and ψ) then we can be caught in a low growth trap. As such, there is, in this case, room for exogenous intervention to make integration feasible. There is not, however, room for a 'big push' story to reach a higher growth path.

A second equilibrium will occur where initial infrastructure supply, I_0, is such that we begin with an integrated economy in the first instance, if,

$$\frac{\bar{A}}{A} > \left(\frac{(1-\psi)(1+\Phi+\frac{2\nu}{I_0})}{(1-\Psi-\frac{2\omega}{I_0})(1+\phi)} \right)^{1-\alpha}. \tag{22}$$

In this case, either a high productivity increase from integration or low fixed information cost can mean that a low initial infrastructure supply and low learning cost effects (low ν and ω) could create conditions such that the economy is always integrated.

The intermediate case, where the economy begins in its non-integrated form

and endogenously integrates when conditions become right. This requires,

$$\left(\frac{(1-\psi)(1+\Phi)}{(1-\Psi)(1+\phi)}\right)^{1-\alpha} < \frac{\bar{A}}{A} \leq \left(\frac{(1-\psi)(1+\Phi+\frac{2\nu}{I_0})}{(1-\Psi-\frac{2\omega}{I_0})(1+\phi)}\right)^{1-\alpha}. \tag{23}$$

In time zero, scale costs mean that it is optimal for financial intermediaries operate on a small scale, using local finance to fund the construction of a regional infrastructure. In this initial phase, growth is low. Over time, regional markets grow and a local infrastructure is constructed to support local output. This also lessens the cost of raising finance to build infrastructure and integrate at a national level. At a critical value of local market size we have national integration and a smooth take-off in growth, approaching γ^* over time as the economy matures. We thus have an acceleration in industrial output growth as determined by endogenously improving conditions for financial intermediation. In this case there is room for exogenous action bring forward the take-off point. The critical value of infrastructure, at which we integrate, is the positive root of,

$$(1-\Psi)(1+\Phi)I_t^2+\left[\left(\frac{\bar{A}}{A}\right)^{\frac{1}{1-\alpha}}\frac{(1+\phi)}{(1-\psi)}2\omega(1-\Psi)-(1+\Phi)2\omega-(1-\Psi)2\nu\right]I_t-4\omega\nu=0. \tag{24}$$

So there is a potential role for accelerating development by reducing the costs of information problems, as in the non-integrated equilibrium, but also here an institution can either bring forward or put back the point at which integration occurs; we present such results numerically.

3.3 Numerical Implications

Consumption, capital and infrastructure all grow, in continuous time, at the rate $\gamma = \max\{\gamma^A, \gamma^*_{SR}\}$. For the purposes of a numerical extension we need to consider the growth rate of the economy in a discrete-time form, so $\gamma_h = (x_t - x_{t-h})/hx_{t-h}$ for all growth variables x in the economy where h is the length of each discrete

time increment. In the limit as $h \to 0$ we have that $\gamma_h \to \gamma$. In the regional economy, and in the long-run integrated economy, the growth rate is constant. The transitional growth rate, equation (19), is dependent on the stock of infrastructure at time t, however. We can re-write the transitional growth rate as,

$$\frac{I_t - I_{t-h}}{hI_{t-h}} = \frac{1}{\theta}\left[\bar{A}\left(\frac{(1-\alpha)(1-\Psi-\frac{2\omega}{I_t})}{(1+\Phi+\frac{2\nu}{I_t})}\right)^{1-\alpha} - \delta - \rho\right]. \tag{25}$$

We can solve for I_t in terms of I_{t-h} and obtain a solution for the growth rate of the economy that can be solved numerically. Let $I_t = \mathcal{I}(I_{t-h})$ be the solution to,

$$\left(1+\Phi+\frac{2\nu}{I_t}\right)\left\{\bar{A}^{-1}\left[\rho+\delta+\theta\left(\frac{I_t - I_{t-h}}{hI_{t-h}}\right)\right]\right\}^{\frac{1}{1-\alpha}} = (1-\alpha)\left(1-\Psi-\frac{2\omega}{I_t}\right). \tag{26}$$

Of course, we need to check first that, given a particular calibration, there is only one finite and real solution to equation (26). Then we can write equation (19) as,

$$\gamma^*_{hSR} = \frac{1}{\theta}\left[\bar{A}\left(\frac{(1-\alpha)(1-\Psi-\frac{2\omega}{\mathcal{I}(I_{t-h})})}{(1+\Phi+\frac{2\nu}{\mathcal{I}(I_{t-h})})}\right)^{1-\alpha} - \delta - \rho\right]. \tag{27}$$

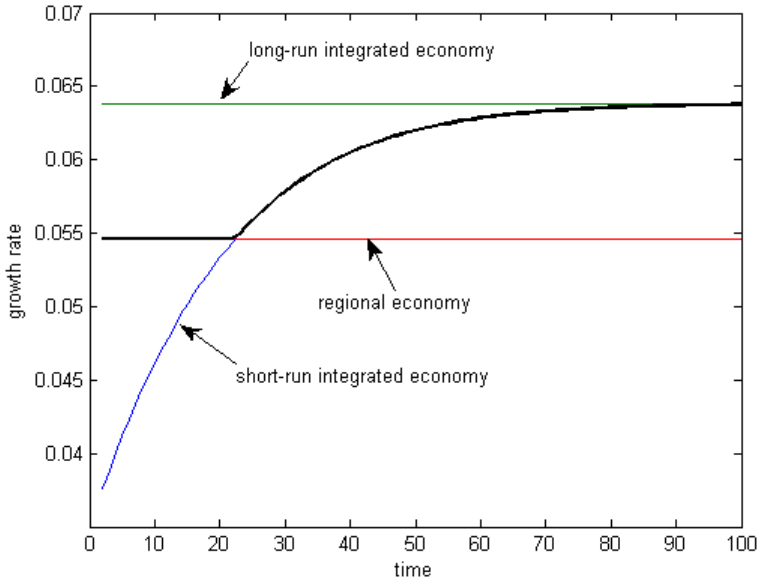
Table 1 gives a benchmark calibration with which we can demonstrate some of the growth dynamics. Figure 3 plots the course of growth. This economy is one which begins regionally separated and integrates as endogenous financial intermediation costs drop over time. As can be seen, the rate of growth of the regional economy is constant at around $\gamma^A = 0.054$. That of the integrated economy begins low and climbs to a long-run rate of around $\gamma^* = 0.064$. The thick black line indicates the equilibrium growth rate at any point in time, with national integration occurring at $t = 23$ and a smooth transition towards the long-run growth rate of the integrated economy.

Takeoff in industrial growth is endogenous to the costliness of raising finance for fixed-cost investments, such as physical transport infrastructure. Institutions

Table 1: Baseline Calibration

initial capital	k_0	40
capital share	α	2/3
subjective discount rate	ρ	0.02
elasticity of substitution	θ	5
regional coefficient of technological progress	A	0.5
national coefficient of technological progress	$\bar{A}$	0.6
fixed cost parameter on regional intermediation	ψ	0.25
fixed cost parameter on regional intermediation	ϕ	0.25
fixed cost parameter on national intermediation	Ψ	0.3
fixed cost parameter on national intermediation	Φ	0.3
scale cost parameter on national intermediation	ν	5
scale cost parameter on national intermediation	ω	5

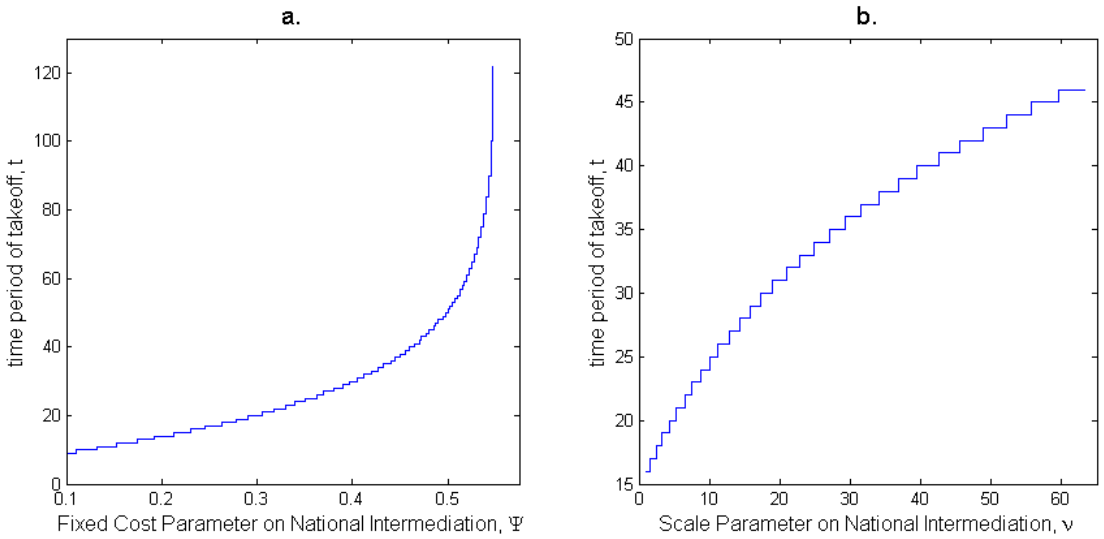
Figure 3: Example Growth Path



that affect the costs of such intermediation will, then, indirectly affect industrial development, even though industrial finance is itself not directly constrained. We can see this by exogenously varying the finance parameters; Figure 4 reports the time period, t^* of takeoff under the parameterization of Table 1 but separately varying Ψ (panel a.) and ν (panel b.).

At the same time as increasing the time until takeoff, a higher Ψ can lower long-

Figure 4: Takeoff and Financial Costs

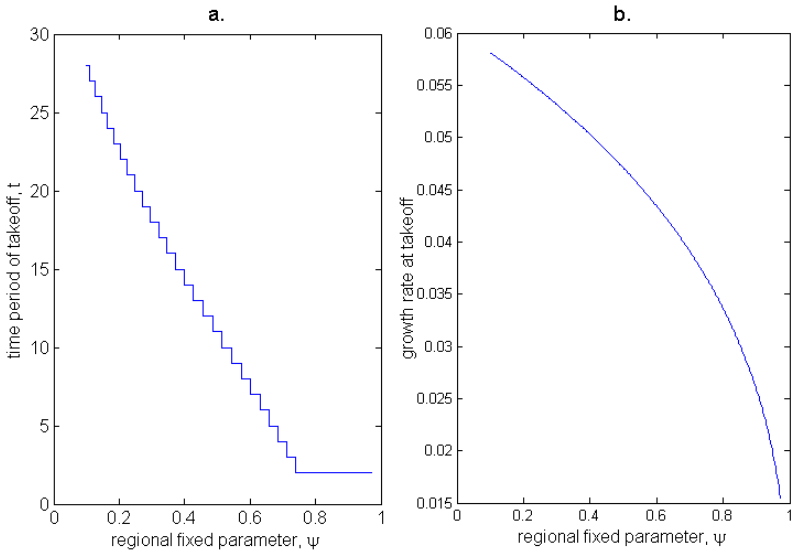


run growth rate until the point where the long-run non-integrated equilibrium is preferred to the national equilibrium even as $t \to \infty$; as Ψ goes approaches 0.55 in the Figure, so the point of takeoff approaches infinity. Varying ν, however, does not affect the long-run growth rate, so does determine *whether* the economy integrates, only when. That is, increasing the learning costs, other things equal, delays the point of integration and the speed with which we approach the long-run growth rate. There are substantial gains to reducing fixed costs in intermediation, then, when they are very large. The gains from reducing ν apply only once Ψ is relatively low.

The effect of decreasing the cost parameter on regional intermediation is to *delay* the point of integration. In a normal model of finance and growth, this might have deleterious welfare consequences. In this model, however, lower regional intermediation costs make the regional growth rates higher and, with national financial costs constant, delays takeoff. When national takeoff does occur, it benefits from the lower learning costs resulting from the additional scale achieved at the local level. The spillover from regional intermediation to the initial rate of growth of a later integrated economy can be significant. Figure 5 contrasts the simple effect

of increasing ψ on bringing forward the integration point (panel a.) against the national rate of growth at that point of integration (panel b.).[15]

Figure 5: Regional Costs, Takeoff and Growth



In other words, a non-integrated financial system can be a *preferred* method of obtaining high average growth. In a model with an institution that must allocate resources to reducing either national or regional financial costs, the optimal approach is not unambiguous. Institutions designed to *delay* the emergence of a integrated financial system by encouraging regional solutions to financing problems might be preferred to institutions aimed at directly increasing the efficiency of the national financial sector.

We have concentrated on an environment in which both regions are identical but we can think the implications of some types of asymmetry between regions in this simple model.[16] Where initial capital stocks are different but the cost parameters are the same the regions will grow at the same rate while not integrated and then integrate at point where the *aggregate* stock of infrastructure reaches the critical level defined by equation (24). The integrated economy then grows at the rate

[15]These simulations assume that at $t = 1$, the economy is not integrated; the earliest point of integration is $t = 2$.

[16]I thank an anonymous referee for prompting this discussion.

defined by equation (19). Suppose instead that initial capital is identical, but that region A that has a lower value for ψ or ϕ. In this case, region A, the region with *better* financial conditions, determines a point of takeoff that will be later than that which region B would prefer.[17] There are historical examples in which the pool of investors in a piece of infrastructure were purposefully restricted to those who has close connections with the locality.[18] This slightly counter-intuitive theoretical implication has some merit, therefore.

Of course, we cannot generalize too far based on a specific study of one country. But the importance of spatially concentrated coalitions of infrastructure financiers during the industrial revolution in the UK does suggest that the finance and growth mechanism might not be best understood as a purely aggregate phenomenon. Recognising this might allow us to reconcile the historical account of the UK with contemporary empirical evidence on the relation between finance and growth.

4 Finance and Growth in Context

A range of studies, starting with King and Levine (1993), Demetriades and Hussein (1996), have established that there is a relationship between financial development (principally measured as aggregate financial depth) and the long run level of economic growth; in some studies a causal channel is identified running $from$ finance to growth.[19] Levine et al. (2000) used panel data and identification strategies to demonstrate a positive correlation, while industry- and firm-level estimates, such

[17] We are assuming that the national economy integrates only when it becomes mutually beneficial. Imagine two levels of regional growth in Figure 3; the growth rate in region A would be lower if it integrated at the point when region B preferred integration. The simple model we present in this paper is not capable of considering more complex interactions that might occur in the presence of such asymmetry.

[18] Ward (1974) notes that investments in some waterways were restricted to those local to the project in order to limit the effects of speculative investments by those who had capital but little knowledge of the specific projects.

[19] As Beck and de la Torre (2006, p.1) notes, the "causal link running from finance to growth has been rather convincingly established."

as Demirgüç-Kunt and Maksimovic (1998), also support the view that financial depth is related to industrial growth. More recently, Brunt and Cannon (2009) have provided microeconomic evidence for the connection between banking depth and capital investment in the context of the industrial revolution in England.[20]

Arestis and Demetriades (1997) demonstrate how different countries can be characterized by different relationships between finance and growth. As such, the implications of our UK study for the finance-growth nexus more generally is somewhat limited. But the causal findings in studies following King and Levine (1993) do stand in contrast to the historical consensus that, in the UK during the industrial revolution, financial matters did not constrain the takeoff of industry. We have argued, however, that the ability to form spatially concentrated financial coalitions was an important factor in the development of physical infrastructure. National banking and stock markets did not matter until later in the development process, and may have benefited from spillovers resulting from the development of those earlier financial structures. In the finance and growth literature, there has been relatively less stress placed on how such dynamic, spatially disaggregated mechanisms interact with economic growth during a period of industrial takeoff.

We know from the theory that positive transaction costs, asymmetric information and uncertainty can connect steady state endogenous growth to the level of financial sector inefficiencies.[21] Where those inefficiencies can be related to the design of prevailing institutions, our understandable inference is for policies to be formed in order to encourage the development of efficient national banking systems, or to maximize the size of the financial sector on aggregate.[22]

But the costliness of transacting, the degree of information asymmetry, and

[20]Empirical work on historical data, such as Rousseau (1998) and Rousseau and Sylla (2005), has also found that financial depth is related to, and perhaps leads, economic growth. See Levine (2005) and Beck (2008) for surveys.

[21]Levine (2005) surveys a number of theories that rationalize the links between finance, entrepreneurship and growth.

[22]See Demirgüç-Kunt and Levine (2008) for examples of the policy implications.

so on, is different between different economic agents, depending at least in part upon geographic distance. Understanding of this is not new in the banking and finance literature.[23] The marked sectoral and geographical distinctions observed through the industrialising UK suggest that these frictions can indeed be at work in the context of an economy experiencing a significant takeoff in growth. A fuller understanding of the affects of policy on finance and growth might need to take into account the interaction with such disaggregated and dynamic mechanisms in addition to the the affects on aggregate financial development.

These findings also draw attention to the parts of the finance and growth literature which point toward a more complicated relationship between financial development on economic growth. For example, Arestis et al. (2001) use time-series data to show that stock market development is not uniformly a growth-promoter. In particular, they find no causal relationship between the size of the stock market and economic growth in the US, a country with an historically fragmented state banking system. Additionally, Rioja and Valev (2004a,b) have found that the relationship between financial development and growth can depend on the level of economic development. Rousseau and Wachtel (2010) have shown that the finance and growth connection appears to have largely disappeared in more recent data. The additional complexity explored in this paper could go some way to explaining why some countries exhibit a link between finance and growth whereas others do not. These issues clearly deserve additional research.

5 Concluding Remarks

In thinking about the objective of policy in the context of finance and growth, there is a temptation to emulate the highly specialized, interconnected and centralized financial systems of contemporary developed economies. By looking at evidence from

[23]See, among others, Petersen and Rajan (2002), Dehajia and Lleras-Muney (2003) and Guiso et al. (2004).

UK history, we have been able to identify a greater complexity in the transmission between finance and growth.

We have argued that economic growth and financial development can interact in ways that an aggregative, static understanding omits. The understanding of constraints on finance then differs by consequence. The importance of non-centralized, non-specialized intermediaries in the financial history of the UK suggest that policy be framed to accommodate the emergence of potentially more efficient decentralized solutions to financing problems.

There are implications particular to the regulation of infrastructure construction and finance. Institutions which impose detailed restrictions on the quality or location of infrastructure, or which require that only highly qualified engineers be involved might restrict the feasibility of locally organized, relatively less-specialized solutions.[24] While *industrial* finance might be relatively unconstrained, industrial development is dampened because decentralized infrastructural finance is made more costly.

The UK institutional environment through industrial revolution did necessitate that the financial coalitions which fund infrastructures obtain assent. This imposed significant costs on coalition formation but it also facilitated the coordination of infrastructures, provided a forum for resolution of local property disputes and helped gradually to formalize a best practice in finance and construction. Such regulation would seem to allow those entrepreneurs with the best information about local economic conditions to have the greatest chance of efficient finance of their projects.

There are other, more general implications for financial regulation. The role of the government in the early phase of industrialization would seem to be the support of private enterprize by forming institutions that make it easier to write enforceable contracts, cutting the costs of forming private financial arrangements so that the

[24]The case of France in the early industrial period is a good example of this case (see Smith, 1990).

early financial structures can emerge endogenously. This has come out of both our historical analysis and the theoretical model we constructed to match our stylized facts. Similar messages come out of the work of Demirgüç-Kunt and Levine (2001).

There are a number of potential extensions to the simple model we have used to capture the relation between infrastructure finance and growth. Exploring the role of institutions in this set-up also seems interesting, both in terms of the mix of public and private finance in infrastructure development and also in terms of the pursuit of large-scale specialized financial systems that may not be appropriate to the prevailing degree of under-development in the rest of an economy.

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