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Endogenous Financial Development and Industrial Takeoff*

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ABSTRACT

There is a large and growing literature on the relationship between financial development and economic growth. It suggests a positive causal link running from finance to growth. We consider, in broad terms, the existing historical evidence on this connection. We demonstrate that constraints on investment finance occur primarily in the presence of fixed costs. Investments in physical transport infrastructures are prime examples of projects in which financial constraints can retard industrial growth. Furthermore, an appreciation of spatial and dynamic elements is central: Infrastructure development was privately financed by spatially concentrated coalitions of modest investors. We contrast the institutional environment in Britain with that in continental Europe. We develop a theory of finance and growth that can account for the disaggregated and dynamic nature of the finance and development of infrastructure.

JEL Classification: O11, O16, O40, N23.
Keywords: Finance and growth, endogenous growth, economic integration, economic history.

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1 Introduction

A plethora of supportive empirical studies and a more sparse but equally supportive theoretical literature has engendered confidence in the belief that there is a causal relationship between financial development and the long run level of economic growth. We suggested in Trew (2006), however, that there are good reasons for not proclaiming an end to the debate. First, we have argued that empirical cross-section results are strongly biased toward accepting the finance-causes-growth hypothesis. Second, much of theory and econometrics considers the question in only its comparative sense; an understanding of transitional issues is commonly omitted. This must have implications for policy in regard to the implementation of any finance-led growth strategy within a country. Third, the connection between theoretical mechanisms and empirical results in finance and growth has, largely, been neglected. Specifically, the former typically looks at financial efficiency; the latter at financial depth. How are efficiency and depth related, and what might a theory calibrated to data tell us about the quantitative effect of finance on growth? Fourth, the theoretical microfoundations of finance and growth have not been fully explored, leaving a large gap in our *understanding* of any causal link, however convincing it is established in an empirical sense. Fifth, we have found indications that aggregation issues play a highly significant role in the relationship between transitional growth paths and financial matters. Where does the literature on endogenous financial coalitions and growth impact on contemporary finance and growth theory? Sixth, we have seen that a dynamic financial intermediation story can be relevant. Omitting dynamic elements means that the finance-causes-growth hypothesis is poorly-conceived as a policy tool when applied across heterogenous economies.

At the heart of this critique is an uncertainty regarding the mapping between cross-sectional results and the ability to explain time-series growth patterns. Further, there is no clear theoretical understanding of the mechanisms by which this mapping can be accounted for. How then can we view the relationship between

financial depth, financial efficiency and industrial take-off *within* a country? The remainder of this thesis will strive to address these questions.

Recent cliometric research has begun to consider the long-run time-series relationships between measures of aggregate financial depth and long-run growth. Additional research on firm-level data has also been conducted. The findings from these studies suggest to us that the positive relationship between finance and growth is not entirely driven by selection bias. There *is* a positive correlation between financial development and economic growth. But still, aggregative cliometrics and richer cross-sectional econometrics do not help us to address the more fundamental, theoretical, issues regarding aggregation and the evolution of financial conditions. Understanding the dynamic interplay between finance and growth in an economy as it goes through a period of transition from low to high growth will shed a great deal of light on the remaining questions.

We intend to do two things in this paper: First, given the remaining questions raised by our critique of empirical results and the paucity of any proper longitudinal understanding, we delve into an examination of the finance-growth relation based on historical evidence. This entails an analysis of historical accounts of the finance-growth nexus, develops a number of key distinctions to be made in our understanding of finance and growth, and introduces a new dataset of financial coalitions through the industrial revolution in the UK. Restricting our attention to this evidence means that our findings have a particular implication for countries going through industrialisation. The role of financial markets in industrially developed economies going through transition from non-capitalism to capitalism has been considered elsewhere, e.g., Colombo and Driffill (2003). Second, taking this historical analysis as a guide, we develop a new theory of finance and growth that can account for some of the dynamic, disaggregated elements found in our historical analysis.

This paper is organised as follows: Section 2 presents our historical analysis. Section 3 then constructs an endogenous growth model to account for the stylised facts on finance and growth from the historical analysis. We then calibrate the

model to data for industrial growth paths and then interpret these results. Section 4 concludes the paper with a summary of our main findings.

2 An Historical Context for Finance and Growth

Economic historians have long considered the industrial revolution from a macroeconomic perspective. The prime example is Landes (1969). More recently, Mokyr (1990) has stressed many of the same issues. Such studies place the technological progress at the heart of the growth mechanic, in concurrence with endogenous growth theory (though the latter also places emphasis on the accumulation and technology of human capital). The importance of financial matters in determining the rate of economic growth has, not least in the economic history literature, taken a back-seat. The proposition that financial constraints do not matter has commonly been regarded as a truism: In this view, political and economic incentives are such that impediments to the finance of entrepreneurship are at worst transitory. There is, however, a great deal of evidence that this proposition is very far from a truism and that, in fact, financial constraints can have a significant, if indirect, effect on industrial development. Reconciling these views requires us to take a more detailed look at the financial history, and this in turn requires more disaggregated and richer data.

The analysis of the historical evidence below will, no doubt, paint too many broad brush strokes for the liking of an economic historian. In looking to the historical record for answers on any topic of debate a multitude of conflicting pieces of evidence will always be found. Furthermore, we must, to some extent, generalise away from historical detail in favour of telling a more cogent macroeconomic story. This is necessary if we are to begin to place extant theories of finance and growth into a more realistic setting. It is hoped that in making these compromises between generality and specifics we do not move too far away from reflecting what actually happened.

Subsection 2.1 considers some commonly-cited historical perspectives. Subsec-

tion 2.2 goes through some historical evidence on the role of finance in entrepreneurship and industry. In doing this, we develop the central distinction to be made between types of finance and the effect of constraints on industrial development. Subsection 2.3 develops this distinction by drawing on the historical record of industrial revolution in Europe. Subsection 2.4 introduces part of the new *Handbook* of 18th and early 19th century British corporate finance. This *Handbook* sheds further light on our historical analysis and enables us to draw some firmer conclusions. Subsection 2.5 begins to draw-out some of the lessons from our historical analysis. Subsection 2.6 then looks at these findings in the light of alternative policy environments, specifically the European experience.

2.1 Historical Perspectives

The motivation of finance and growth as a subject for debate is often lent weight via the views of various prominent figures in political economy. Naturally, these views have played a part in shaping the way in which modern economists think about the nexus.

Chief among the oft-cited critics of the view that finance leads growth is Robinson (1952, p.86), who famously wrote, "...where enterprise leads, finance follows." The impression given by this phrase belies a deeper, more qualified statement on the importance of financial constraints. Robinson (p. 87) distinguishes between finance as a determinant of enterprise-led growth and as a determinant of finance-led growth; she advocates the view that finance can constrain but only enterprise can cause growth:

> . . . the supply of finance cannot be regarded as a rigid bottleneck limiting the rate of investment, but must be treated rather as an element in the general atmosphere encouraging or retarding accumulation.

Lucas (1988) is also frequently cited as a contemporary critic of the view that financial constraints play any role. But his concern that the part played by financial matters in determining economic growth might be "over-stressed" does not preclude

the importance of financial 'institutions' *per se*. There is a distinction between money-neutrality and financial services that might reduce transactions costs. He writes (ibid., p.6),

> ... insofar as the development of financial institutions is a limiting factor in development more generally conceived I will be falsifying the picture, and I have no clear idea as to how badly.

The inadequacy of innovation in creating wealth, and the additional need for efficient financial systems, was observed by Bagehot (1873). His *Lombard Street* was among the first to suggest that a scarcity of finance, "no spare money for new and great undertakings" (ibid. para. I.6), can be an element in keeping poor countries poor. Further, it is argued that an ineffectual institutional environment can mean that in rich countries "the money is too scattered, and clings too close to the hands of the owners, to be often obtainable in large quantities for new purposes." He lauds the London money market of Lombard Street as an "efficient and instantly-ready organisation," (ibid. para. I.12). The perceived importance of efficient financial markets is in allowing those that require it to obtain capital from disparate sources at reasonable rates.

There are, for Schumpeter (1934), two agents of economic growth: The first, and better known, depicts innovation as a search for monopoly, or entrepreneurial, profit; the second stresses the importance of finance in *determining* the rate of economic growth, not in simply emerging as an albeit necessary sideshow to technologically-driven growth. The first channel has been adapted into growth theory generally, such as in Aghion and Howitt (1998). The second channel has latterly come to support proponents of the finance-causes-growth school. Schumpeter (1934, p. 74) wrote,

> He [the banker] stands between those who wish to form new combinations and the possessors of productive means. He is essentially a phenomenon of development... He makes possible the carrying out of new combinations, authorises people, in the name of society as it were, to form them.

He is the ephor of the exchange economy.

The role of financial intermediaries, according to Schumpeter, is in allowing entrepreneurs to *be* entrepreneurs by mobilising scarce savings, evaluating research projects, managing risk, evaluating future cashflow and facilitating transactions. This is the familiar list of properties attributed by finance and growth researchers, such as Levine (2005). For Schumpeter (*op. cit.*, p. 77), an intermediary exists to mitigate the entanglement of the "entrepreneur's essential function... with other kinds of activity, which as a rule must be much more conspicuous than the essential one."

The idea that finance impacts on growth via inhibiting entrepreneurship, and so technological progress, has taken hold. Of course, finance is central for a healthy entrepreneurship and so constraints on finance can have an impact. But what would cause the banker to *not* stand as a conduit between savers and investors? In other words, why does finance not follow enterprise? Schumpeter does not help us on this: For him, the banker is a phenomenon of development. Robinson and Lucas, among others, are only suspicious of arguments based on the exogenous existence, exogenous persistence, and exogenous impact on entrepreneurship of imperfections in financial markets. How can we reconcile these views? We must consider why such constraints arise in the context of economic development, how they persist and in which economic arenas they act to dampen entrepreneurial spirit.

2.2 Historical Evidence

Among the major financial innovations of the industrial revolution in Britain was the creation of the limited liability joint-stock company in the middle of the nineteenth century. Before the Joint Stock Companies Act of 1844, those wishing to establish a joint stock company had to obtain consent from the crown or through Parliament. The Limited Liability Act of 1855 then allowed companies to be incorporated under the protection of limited liability for its investors. Robinson (1952) puts the invention of the joint-stock company on a par with that of the

steam-engine. Its formal emergence in England was, according to Hunt (1935a), the outcome of economic necessity in the face of substantial legislative and judicial opposition. This resistance was born partly out of lingering memories of the 1720 South Sea Bubble. As *The Times* of 1833 had it: "if, as a *sleeping partner*, [an investor] chooses to be robbed, the public ought not to be robbed because he chooses to *sleep*."[1]

The belated emergence of joint-stock finance was mirrored by the relatively late growth of formal stock markets. But this apparent delay in the development of financial services did not prevent the emergence over the course of the eighteenth and early nineteenth century alternative, and efficient, methods of industrial finance. As Pollins (1954, p.230) succinctly puts it,

> One of the commonplaces of English economic history is the fact that manufacturing industry has seldom made use of the [London] capital market machinery for the raising of its capital. In the early period of industrialization small manufacturers were able to make use of their own resources, or loans from friends or from banks; later they ploughed back their profits.

This view is one widely supported in the historical literature. Take Hudson (2002, p.267): "It has long been accepted that internal self-finance was *the* dominant form of industrial finance during the industrial revolution in England."

Critical of this perspective, Harris (2000, p.289) argues that while Britain was enjoying the world's first industrial revolution, the "formal legal framework of business organization remained in its preindustrial state." He argues that this relative backwardness retarded entrepreneurial growth. He notes also, however, how the business corporation evolved from its origination in the sixteenth century to legal acceptance in the first half of the nineteenth. Further, this development "*paralleled* the rise of capitalism, in its mercantilist and industrializing phases." (p. 290, my emphasis). He also points (p.127) to the number of alternative sources of finance in

[1] Quoted in Hunt (1935b), p. 342.

eighteenth century England: Short-term credit and long-term personal borrowing from "banks, merchants and kin" was commonplace. The movement towards the use of stock issue as a method of finance occurred only gradually towards the end of the century.

For Landes (1994, p. 641), "Once they [Europeans] caught the whiff of wealth in their sails, no change in government policy, no want of official support, was going to stop them." Cottrell (1980) writes that it is more generally accepted, that "savings within the economy were not inadequate to support industrialization." (p.5). He also argues that profit-ploughback was the principal method of financing early growth in manufacturing. Some cotton firms even began to borrow money from their employees before looking to banks for finance. A reliance on bank finance for long-term investments only occurred later, when profit margins fell. In other words, firms chose the method of finance to suit their current situation. Further, he argues that the Bubble Act and Usury laws did not constitute an institutional barrier to industrialisation. The later emergence of banking and stock markets reflected not the release of some legislative or institutional constraint but an acceleration of demand for them.

The order of financing method also fits in with the 'pecking-order theory' following Myers (1984). The pecking-order of finance runs as follows: Internal financing is always preferable, followed, if external finance is unavoidable, by debt then equity. So, agents were not constrained to use profit ploughback or limited local credit in the early stages of the industrial revolution: This was their *preference*.

These sources depict an historical record in which financial constraints did not have a direct negative effect on the pace of industrialisation. The oft-cited example of such constraints, the creation of the joint-stock company as an accessible legal entity, was not central to the finance of the early part of the industrial revolution. Further, the resistance to its entrance into legislation did not substantially inhibit the pace of industrial growth. From this standpoint, the pattern of industrial finance through Britain's history is the outcome of relatively unconstrained optimal financing behaviour by firms in response to their desire for expansion under varying

economic conditions.

This we take as the story of the finance of industry, in general. Proponents of the enterprise-leads-finance school rightly say that inefficiencies in the finance of industry, *per se*, have not constrained the economic development of the UK. The same was true for continental Europe: Milward and Saul (1973) and Mathias and Postan (1978) tell broadly similar stories in regard to the finance of European industry. Earlier case studies of banking through industrialisation, such as Cameron (1967, 1972) also support these conclusions.

If we consider that most investments in early industry could be small and/or non-lumpy, then this consistent historical story is perhaps not so surprising: An individual entrepreneur, especially a good one, could find the little start-up capital required or use reinvested profits to expand as and when conditions allowed. 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).

In order to see where constraints on finance can have a real effect, we need to make a distinction between the types of activity requiring finance, based on the proportion of the investment which is fixed. Problems in raising finance for investment largely occur where there is a large fixed cost element. Large-scale infrastructure projects are thus prime examples of the class of investments in which financial conditions can have a large effect on economic growth. Among contemporary analyses, Hulten (1996) and Calderón and Servén (2004) indicate what we would expect: An effective supply (i.e., one that works efficiently) of infrastructure can have a large effect on the economic development of an industry that surrounds it. So while finance does not directly constrain industry, it might inhibit the expansion of markets along both supply and demand lines via its impact on the growth of fixed-cost investments such as infrastructure.

In short, it is with regard to investments where fixed costs are high that the financial system has to work harder. Without either wealthy backers or efficient

financial market from which to obtain funds, an individual entrepreneur must either obtain finance from a wide range of sources or forsake the opportunity. Often even a serious backer could not provide all the start-up capital required, and joint-stock operations became necessary. Take, for example, Milward and Saul (1973, pp. 347–8) on the power of French joint-stock companies in comparison with the wealth of even the deepest of individual pockets,

> No matter how large the private fortune of even a family like the Rothschilds it could not hope to bear comparison with a capital fund which was to be built up by selling shares to the public in relatively small denominations and thereby mobilising the collected savings of France.

For investments with a large fixed cost component, all those aspects of the policy, legislative and institutional environment which, we hypothesise, might have an impact on growth via finance come into sharper relief. We need to explore these issues in greater depth.

2.3 Finance, Industrial Growth and Infrastructure

We have argued that financial constraints did not directly inhibit the pace of industrial growth. We suspect, however, that limitations on the availability of finance can have an effect on growth via their impact on projects where fixed costs are a large proportion of the investment.

For Bagehot (1873, para. I.6.), the absence of adequate financial institutions is directly related to difficulties in infrastructure development,

> A citizen of London in Queen Elizabeth's time could not have imagined our state of mind. He would have thought that it was of no use inventing railways (if he could have understood what a railway meant), for you would not have been able to collect the capital with which to make them.

How would we characterise an 'efficient' market for the finance of infrastructure? It must be one in which information flows freely between large numbers of savers and

investors. Financial constraints deriving from imperfections in financial markets are, in part, a product of both information asymmetry and the politico-institutional environment. In theory, it has been shown that deviations from the complete financial markets of Arrow-Debreu can arise as a result of information problems. For Grossman and Stiglitz (1980), costs to the acquisition of information mean that information-efficient markets are impossible. We might add to the costs of obtaining information the (related) costs of forming comprehensively complete contracts.

The purpose of this section is to investigate the realities of those information problems, which costs exist to cause them, and the ways in which they impacted upon optimal financial systems. We also look at the part played by the institutional and legislative environment in this context. We are able to see the effect that fixed costs have on the nature of the financial systems that emerge to cope. We characterise in detail, using both secondary and primary sources, the nature of the financial coalitions that emerged to supply infrastructure and how these typically evolved over time. In Section 3 we develop a model that can capture a number of the macroeconomic implications for finance and growth, leaving to Nolan and Trew (ming) a deeper theoretical investigation into some of the microeconomic roots of our findings.

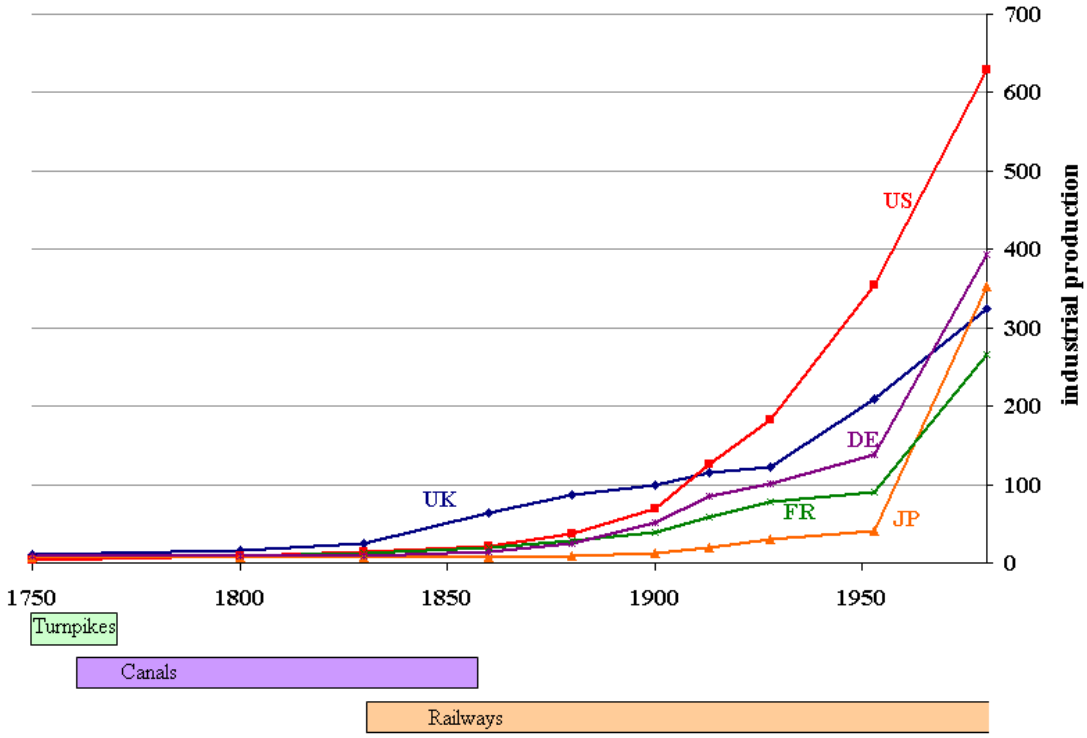
We focus on the finance of physical transport infrastructure for four reasons: They are a classic example of investment projects in which fixed costs are a large element; the development of an effective infrastructure is strongly correlated with industrial development; infrastructures are constructed using both public finance and private enterprise under public regulations; and, perhaps most importantly, there is a great deal of historical and cliometric evidence covering the finance of infrastructure through the period of industrial revolution.

We can broadly date the phases of each of the main forms of transport infrastructure in the UK: In the 1750s and 1760s, there was a boom in the number of turnpike trusts; from the 1760s to the 1850s canals dominated, with a boom in 1792–3; and from the 1830s the 'Railway Age' commenced. The first railway 'mania', of 1843–47, saw capital expenditures on railways increase tenfold in the space

of five years (see Kenwood, 1965).

For reference, we replicate in Figure 1 these phases of infrastructure development against time paths for the per capita volume of industrial production, using the data in Bairoch (1982). The data (reproduced in Appendix Table **??**) are normalised relative to 100 in the UK for the year 1900. We can see that the UK had an early lead in industrial take-off which was sustained for over a century and a half.

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



The recent dispute between Landes (1994, 1995) and Crafts (1995a,b) demonstrates that there are no simple answers to the question 'Why Was England First?' Additionally, we have argued above that underlying shifts in technological progress, those which are subject to entrepreneurship, have not been significantly dampened by financial constraints. We are not suggesting a new 'single-cause' explanation. What we wish to understand, however, is whether financial constraints might have played a part in limiting the growth rate through their effect on the development of infrastructure.

The early history of the development of physical infrastructure in England was

one of private enterprise and local finance. Government practiced its regulatory role with a light-touch, enforcing only some standards on construction and maintenance. Except for major disputes over land use, Parliament did not meddle with the layout of infrastructure.

Along with the standardisation in the construction of infrastructure, the industrial revolution saw a gradual standardisation of the way in which infrastructure finance was regulated through Parliament. The Bubble Act of 1720 necessitated that joint-stock companies be authorised by royal charter. Thus, the construction of any piece of infrastructure required a Bill to be passed in Parliament. Further, from 1794, after the canal mania, requirements for an infrastructure Bill included the need to deposit three things: 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 subscription list of proposed financial supporters. These deposits enabled Parliament to judge not only the likely success of the proposed project, but also to consider conflicting local interests before securing private property rights to a corporation.

Most of the evidence cited on the finance of infrastructure is based on analysis of these records. As such, it is an excellent source and we can read a great deal into them with confidence. Using these sources also means, however, that they often cover only the initial period of any piece of infrastructure and not its performance over time after its construction. We pay attention to dynamic analyses of infrastructure finance wherever possible.

2.3.1 The Emergence of Turnpikes in the UK

A surprising amount of evidence can be drawn upon to characterise the emergence of turnpike trusts in the early and middle parts of the eighteenth century. Prior to the enactment of legislation allowing the establishment of turnpike trusts, road maintenance was carried out by local parishes, funded by levying local taxes. From the beginning eighteenth century, however, Parliament could approve the establishment of individual turnpike trusts. The trusts could raise finance through issuing

debt and levying tolls on road users. Bogart (2005) suggests that this institutional innovation brought forth a wider road transport revolution. It is beyond question that the construction of canals and railways aided industry by reducing the cost of transporting goods. Bogart shows that, in addition to waterways and railways, the levying of tolls by turnpikes did not increase freight charges, and may have even reduced them.

Buchanan (1986, p.227) notes that most turnpike companies "were run by men representative of the economic life of the area." His analysis sheds light on the existence of a significant regional capital market and demonstrates, using the Ward (1974) classification scheme, that investors were large in number and from a wide range of social strata. Further to this, Bogart (2006a) finds regional and network effects in the diffusion of turnpikes. Turnpike trusts were typically spatially concentrated in the vicinity of major economic centres.

2.3.2 Financing the UK Canal Network

Ward (1974) develops a highly detailed analysis of the finance of canal companies in England through the eighteenth century. A group of industrial and merchant leaders would see the 'economic' motive, in terms of the direct benefit to their business, of installing a canal in their vicinity. These promoters would then either call upon a financier, or become financiers themselves, to sell scrip and shares in a joint-stock canal company under a 'financial' motive of potential future returns on holding the issue. Ward shows that canals were generally financed by those local to the route of the canal. The financiers would tour local public houses, hold town meetings, coax relatives and friends, to convince local individuals to invest in the scheme. Those who invested were by no means uniformly wealthy. Ward classifies investors by occupation and social status, showing 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.

The spatial concentration was, particularly during and after investment booms,

sometimes a restriction ordered by financiers wishing to avoid speculative investment. More often, however, the parochial nature of finance was a result of informational asymmetries: A local familiarity with market conditions, with local industry and an affinity with the canal promoters made it more easy to raise finance locally than on the London market. Ward puts the spatial concentration down to inequalities in the social and geographic distribution of capital. He notes (ibid., p.171–2) an unwillingness of London creditors to invest in regional infrastructure projects because "appropriate capital markets did not exist and the scale of investment was insufficient to support them." We prefer to interpret this observation in the following way: The costs of forming spatially concentrated coalitions of small investors was, under the institutional environs, less than the costs of inducing interest from those with more investment experience and deeper pockets. We come on to the possible reasons for this below. This pattern is seen across the country and throughout the century. Ward notes, however, that through the eighteenth and into the nineteenth century, centralised stock markets became more willing to support infrastructure projects; in the process, the problems of finance were gradually relaxed.

Turnbull (1987) finds not only a similar pattern of regional finance of canals but also a localised 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 enterprises first, and formed part of a national network only later. This was the outcome of market forces, and reflects the idea that the industrial revolution was regional. For Cottrell (1980, p.19), the "industrial revolution... was essentially a process of regional growth." Recent work, such as O'Brien (2006), continues a growing literature on the industrial revolution as a provincial phenomenon.

2.3.3 The Finance of Railways in the UK

There is a great deal of evidence that railways were financed using methods similar to those employed in turnpikes and canals, namely spatially concentrated coalitions of local, relatively modest investors. Hunt (1935b) suggests that the English railway

network was established without the use of the London stock exchange. Pollins (1954, pp.230–1) describes the establishment of a typical railway during the first half of the nineteenth century:

> Some public-spirited men... would recognize the need for improved communication in their locality. They would subscribe among themselves to finance a survey, or would call public meetings in the locality to arouse support and obtain subscriptions. Later a definite route would be decided upon, public meetings held to sell scrip, and the committee of the company would appoint local agents to obtain subscriptions and take deposits. Those who took scrip would be asked to sign the subscription contract (or parliamentary undertaking) required by parliamentary Standing Orders, and an application would be made to parliament for an Act of incorporation.

Pollins suggests this process is repeated across the country in the finance of canals, tunnels, docks and railways. Again, it is observed that companies often reserved shareholdings for local landowners and occupants of towns along the route of the railway. He suggests there was also some element of learning to the emergence of financial coalitions: Before a new form of transport has been tried and tested, potential investors took more convincing that buying shares was worthwhile. Even once technologically proven, during boom-periods a proximity to the route of a proposed railway aided potential investors in deciding over which railway companies to support. Only after a few years of local finance did companies float on the stock exchange.

Broadbridge (1955) also finds similar results on the spatially concentrated nature of early railway capital. That paper also points to the later emergence of regional centres of finance, particularly in the North of England. A good deal of even Scottish railway stock was held in Lancashire. He 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).

To firm-up our understanding of the financial coalitions formed to finance infrastructure projects during the industrial revolution we can draw upon a new dataset of corporate finance built by Gary Shea. We summarise current findings from Shea (2007) in the next section, and give a concrete example of how these sorts of findings can be drawn.

2.4 The Shea *Handbook*

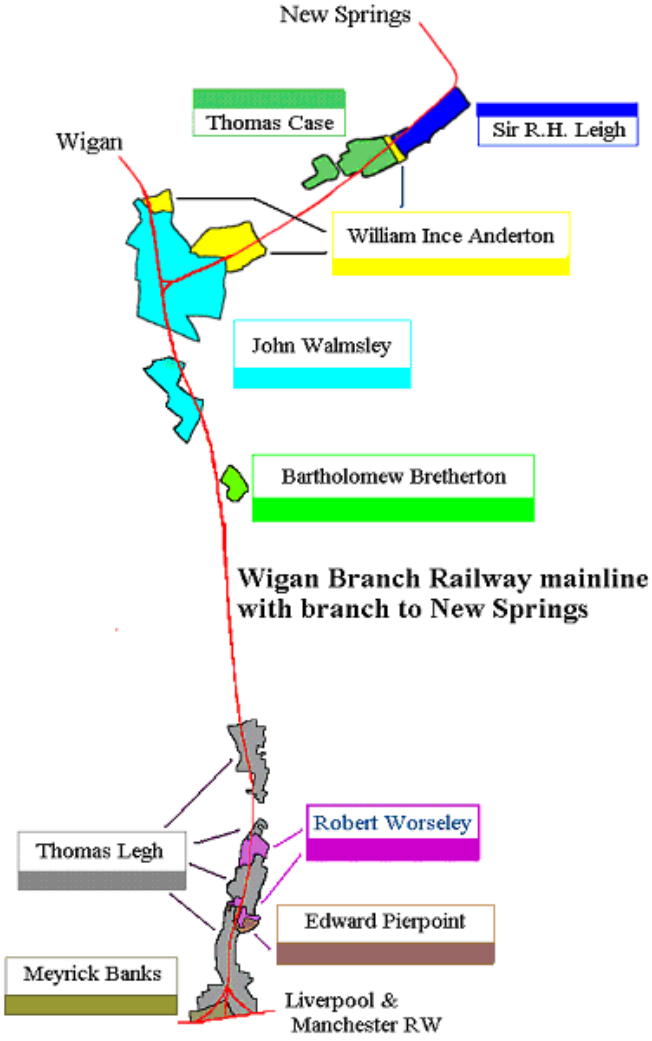
We intend to give an indication of the sorts of data that can be drawn upon to make inferences about the finance of infrastructure. To do so, we present a case study from Shea (2007). The full *Handbook*, once completed, will cover a number of case studies, for around 20 railways, 80 canals, 20 energy companies, and 40 others over the period 1760-1834.

We include here an example of how such records, along with other materials, can be used to illustrate the successful projection of a local infrastructure project. There is nothing special about the Wigan Branch Railway. It was minor railway, but it was typical of about 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 maps the route of the railway, as well as noting those landowners along the route who also invested in the railway company. These landowners comprised almost 10% of total capital investment. Figure 3 gives a breakdown of investors under the Ward (1974) classification scheme.

We can see clearly from these Figures how investment in the Wigan Branch Railway was heavily financed by share issue, not debt acquisition. It suggests that shares were not purchased by a small number of very wealthy individuals, but by a large number of relatively modest local capitalists, manufacturers, tradesmen and

Figure 2: Wigan Branch Railway: Geography

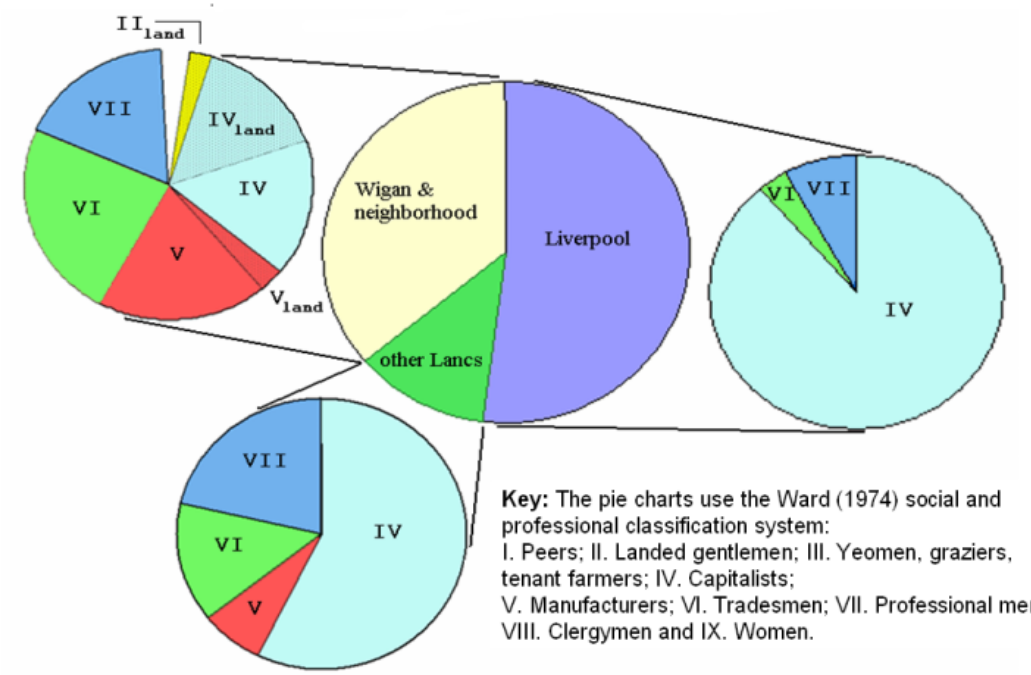


professionals. It also clearly demonstrates how these investors were spatially concentrated around the location of the railway, and suggests a pattern for landowners along the path of a railway to also invest in it.

2.5 Regional Growth, Spatial Concentrations and Dynamic Aspects

We can summarise a few stylised facts from the above analysis in relatively short order. The finance of early infrastructures in Britain generally took the form of spatially concentrated coalitions of large numbers of relatively modest individuals.

Figure 3: Wigan Branch Railway: Investors



In the early stages, infrastructure development was also nationally disjointed. A national network emerged later, as the industrial revolution took hold. At the same time, centralised financial markets became the primary method of raising finance, and infrastructure projects could raise finance from the stock exchange or large banks.

How should we interpret both the nature of coalitions and their change over time? The scale and form of financial intermediation was the key decision in any entrepreneurs' attempt to finance an infrastructure project. We need to consider how the costs of intermediation are related to its scale; the role played by information asymmetries must be central.

In the early stages of development, the cost of obtaining external finance from central financial markets was greater than the cost of raising it from scratch from among a relatively modest local populace. Even though the process of raising local finance in this way was time-consuming and expensive, lesser information problems at the local level made local markets preferable to seeking finance in more

distant ones. This must have something to do with the cost of forming effective contracts. For financial coalitions to form, members must be contracted into it: Payoffs, responsibilities, and other actions must be specified in an environment where there may be a great deal of uncertainty about the future. The costs of forming these contracts cannot always be considered to be negligible. And there is a consequent decision to be made about the *quality* of that contract (i.e., how well it specifies party behaviour, how many loopholes are left, how enforceable it is), given its cost. We might think of an inverse relationship between the quality of a contract and its cost. Moreover, there will be a degree of heterogeneity: Some agents are better informed, or better educated than others while the level of trust between agents can also vary. In addition, the institutional environment can affect the costs of forming contracts (and so the choice of contract quality) by, among other things, establishing industry standards, supporting property rights, easing the gathering of information and enforcing written contracts. We come on to these issues in Nolan and Trew (ming).

The very existence of spatially concentrated financial coalitions suggests that the national financial market was not efficient in informational and contractual terms. In the absence of information and contracting problems at the national level, and given a conducive institutional environment, a national financial market would have been first-best efficient in terms of the supply of finance. Without such an efficient national financial market, financiers' only alternative was to build financial coalitions of local investors.

We cannot draw from this that the financial arrangements which emerged to finance infrastructure were not themselves *optimal*: Given the costs and benefits of obtaining information, and the costs and benefits of forming contracts, the financial structures observed through the industrial revolution might simply have equated marginal conditions in information gathering and contract writing. But this is not just a problem of private arrangements. It should be clear that the costs of obtaining information and forming contracts can be subject to further institutional and legislative constraints. Further, the capacity of the public purse to mitigate

information problems is itself not limitless: Optimal levels of public expenditure, and so optimal levels of taxation, follow. There is then, in theory at least, an optimal combination of private and public behaviour that combines to support the optimal, private, financial arrangement. We develop a theoretical framework for understanding these trade-offs in Trew (2007). For the purposes of the current paper, we abstract from formalising the existence of optimal information extraction and optimal contract formation. Our focus is, then, on the institutional environment as the source of inefficiencies (sub-optimal outcomes) in the finance of infrastructure. Even where the institutional and legislative environment deviates from that which was optimal, we consider that rational private arrangements to mitigate information problems were optimal responses to *both* the present institutional conditions and the private costs and benefits of obtaining information and writing contracts.

Despite the spatial concentration that characterised the early industrial period, there was an institutional and economic learning process. Over time, as infrastructures became larger, as industrial centres became more evident and as industrial development began to require more sophisticated external financing, the financial systems of London evolved into markets more capable of evaluating distant (and, increasingly, larger) infrastructure projects. Institutional and legislative changes played a part in this evolution. It has been argued that the government played a role in advancing property rights and encouraging the private provision of public goods. Bogart and Richardson (2006) introduce a large database on the passage of Acts of Parliament and show that the passage of Acts pertaining to enforcing property rights and encouraging public good provision were positively correlated with (and sometimes led) the provision of infrastructure and the rate of economic growth in the run-up to industrial revolution. That papers also draws attention to the unique position that Parliament held in acting as a forum for transforming the structure of landholding into its modern, capitalist form. As they note, in most other nations this transformation was delayed and, in France and Russia, sowed the seeds of revolution.

Through the middle of the nineteenth century, centralised and specialised finan-

cial services gained precedence and began to cater for the greater demands of larger infrastructure projects. The informational problems at the national level began to wane as the institutional framework for centralised finance developed, and as the returns on infrastructure investment became more reliable. Eventually, central financial markets were such that constructing local and regional coalitions of finance was the less efficient method of finance.

The pattern in provincial infrastructure development is mirrored by the provincial nature of the industrial revolution. Disjointed local and regional infrastructures supported a local and regional industrial growth that itself comprised, on the national level, a disjointed patchwork of regional economies. As the national economy emerged, so, in parallel, did both the national infrastructure and the national financial markets to finance it.

So there are three effects here: First, a learning process in national financial markets made them gradually more amenable to the finance of distant infrastructure projects; second, the development of political and institutional environment had an impact on the efficiency of centralised financial markets; and third, economic development and the growth of the stock of infrastructure made economic integration and market expansion an additional incentive to build and finance infrastructure nationally.

We develop in Section 3 a model of finance and growth that can capture a number of the stylised facts we have outlined here. Before that, we look in Subsection 2.6 at whether alternative policy environments, such as a bias toward public finance and public planning, had an effect on the development and finance of infrastructure in other countries going through industrial revolution.

2.6 Alternative Policy Environments

To appreciate properly the experience of British infrastructural development we must look at it in the light of a wider context. France is a good example of a very different approach to that in Britain. We might also look to the emerging

body of cliometric research on the US and Canada to widen the application of our hypotheses: Wright (2002) draws attention to the importance of information problems in the emergence of the US financial system over the period 1780–1850; and, Sylla et al. (2006) track the integration of transatlantic capital markets through the first half of the nineteenth century. We focus on the Anglo-French contrast here, since it serves to motivate an understanding of the finance of infrastructure in what were, at the outset of the industrial revolution in Britain, otherwise relatively similar economies.

Broadly, the development of British infrastructure was one based on market forces; that of France was the outcome of public planning and a great deal public finance. The French industrial revolution occurred much later than in Britain, some argue that it began properly as late as the 1850s; this is affirmed by inspection of Figure 1.

Milward and Saul (1973) are among those that put the delay in French economic development down, in part, to the way in which infrastructure policy was formed. French governments of the late eighteenth and early nineteenth century initiated a publicly financed, centrally planned and tightly regulated system of canals that, it was intended, would serve all citizens at no charge. The Becquet plan of 1822 envisioned a public-private partnership: A rational (i.e., centrally planned) waterway system paid for by private capital. A group of civil engineers, the Corps des Ponts et Chaussées, was charged with setting and enforcing the regulations for a waterway network of sufficient quality. The plans did not come to full fruition. The routes which did get built quickly were those where local economic demands most greatly necessitated them.

Lévy-Leboyer (1978) notes that the centralised nature of infrastructural development in France extended beyond canals and covered also railways. There was, in addition, a great deal of overlap in the plans. The Corps, at first, viewed railroads as 'dry canals'. Smith (1990, p.665) writes that Becquey and the Corps were remembered for "committing their country to waterways on the eve of the railroad age."

Many of the new railway schemes were in direct competition to the previously planned canal networks. A solution based on complementarity between railways and waterways was found: Canals, it was thought, served best the transport of heavy goods while railways carried light goods and passengers. Indeed, plans for some stretches of infrastructure specified parallel lines of canal and railway (see Figure 2 in Smith, 1990).

The Legrand plan of 1838 began to map the national plan for canals to one for railways. A system of trunk lines emanating from Paris to each of the largest cities was envisaged, a so-called Legrand Star. Private companies were restricted from constructing major routes for fear that it would interfere with the greater plan. Up till 1837, only three private bids to construct railways were accepted. From 1865, smaller lines could, at the discretion of local authorities, be appended to the trunk lines as and when local economic conditions demanded.

By the middle of the nineteenth century, Napoleon III began to promote the private finance of a dominant railway infrastructure. Private infrastructure developments were still subject to the layout, location and specifications dictated by the Corps. Milward and Saul (1973, p. 336) note that government "beset railway building with so many safeguards as to delay its flourishing by a full decade." Again, those railway lines that were taken up were those in greatest demand by local industry.

The French experience of public planning can be contrasted with the experience of Germany. There, it is argued, the country was able to construct a railway infrastructure much more quickly because of less stringent requirements on standards and a more liberal approach to the granting of private enterprises. Further, the political fragmentation of mid-nineteenth century Germany allowed separate regions to go ahead with railway developments in opposition to more central directives: Regional political units could better coordinate infrastructural development.

In our discussions of previous sections we viewed the finance of infrastructure in Britain as somewhat inefficient. The experience of France suggests at least that the encouragement of private finance and a relatively laissez-faire approach to regula-

tion was the right policy approach in terms of the development of infrastructures. We do not wish to imply (though it is by some) that the retardation of infrastructural development was the root of the delayed entrance of France into high growth paths, of course there can be many other reasons.

There is, however, further evidence on the relations between infrastructure development, policy issues and economic growth. Hulten (1996) draws attention to the importance of maintaining an *effective* stock of infrastructure. Using World Bank indices for road condition, locomotive availability, electricity loss and telephone faults, the paper finds a link between the effectiveness of infrastructure and the rate of economic growth. A large positive impact on growth of improving the effectiveness of a given stock of infrastructure is found, especially among poor countries. Bogart (2006b), using cross-country evidence for the nineteenth century, finds a strong and positive correlation between the level of investment in railways and the proportion of private ownership. Further, the rate of railway diffusion is positively related to the extent of private sector involvement.

So policy can have a role to play in the development of infrastructure, and this role can have implications for financial development. But we do not seek to draw firm conclusions on the role of policy in the finance of infrastructure. Counterfactuals can always be found to any argument based on case studies. The experience of Germany may be one such counterfactual. We rather think of policy, with apologies to Robinson (1952), as an element in the general atmosphere of encouraging or retarding the finance of effective infrastructures.

3 Some Analytics of Growth, Finance and Infrastructure

Given what we have learned from the historical analysis above, we now proceed to construct a theory of finance and growth that can account for a number of the disaggregated and dynamic aspects observed. We wish to capture the stylised facts

from our historical analysis in a relatively transparent model of finance and growth that can be, broadly, matched to data. Our model is distinct from work such as Acemoglu and Zillibotti (1997) primarily because an economy in our model can be caught in a low-growth trap. In the paper of Acemoglu and Zillibotti, industrial take-off is an inevitability. Though it might reflect on some levels the relationship between finance and growth in countries (or regions) that *do* industrialise, it does not help us to understand why some countries do and other countries do not enter periods of sustained high growth.

We first describe the structure of our model before presenting it in more formal terms. We have a closed economy with two major regions. Factors of production are capital and infrastructure. Following the discussion above, we also consider that this infrastructure is the product of private enterprise. A local supply of infrastructure benefits all those firms who pay for it.

Firms have no trouble raising capital; they can use profit-ploughback or sell claims on future profits. But infrastructure projects are subject to significant fixed costs; they cannot be funded by individual firms or individual agents alone. Entrepreneurs exist to see the demand for infrastructure and organise finance via financial intermediation to construct and lease infrastructure to firms. In this vein, we account for the interaction between infrastructure and financial intermediation by thinking of infrastructure as a direct input to production; the efficiency of financial intermediation then determines the costliness of raising finance for that infrastructure. Firm output is determined in part by the level of infrastructure that the firm is willing to pay for, given the costs of raising finance for that infrastructure.

In Trew (2007) we consider in greater detail the interaction between the costliness of exchange and the institutional, economic and social environment in which exchange takes place. The purpose of the remainder of this paper, however, is to lay-out the implications of the discussion from Section 2 for a relatively standard theory of finance and growth. This then serves as a bridge between the critique of current theory and a closer look at the fundamentals driving these interactions.

So, the employment of infrastructure as a factor of production incurs the costs of financial intermediation. The economy is populated by agents endowed with a money income each period. We could otherwise have thought of agents endowed with a unit of labour earning a money income by renting their labour to firms. When agents in the economy see the demand for infrastructure they can become entrepreneurs. Entrepreneurs use the services of a financial intermediary to raise finance for the construction and maintenance of an infrastructure. Entrepreneurs then rent that infrastructure to the firm.

We do not have to restrict the intermediary, or even the entrepreneur, to being external to the firm; we simply want to allow for an effect of intermediation costs on spatial decisions and growth. Of course, it is likely that specialised financial intermediation will emerge, so we naturally think of the existence of a market for financial intermediation. Additionally, it may be that the financial intermediary is also the entrepreneur supplying infrastructure to the firm. For clarity, we think of firms, entrepreneurs and intermediaries in isolation.

3.1 Finance, Productivity and Economic Integration

We found a clear and consistent pattern in the historical evidence discussed above: In the early stages of development financial coalitions, infrastructure and markets are, broadly, local; as the economy grows infrastructures grow, financial intermediation becomes more sophisticated and markets become more national. We wish to account for and understand these effects: Why do firms choose local markets at low levels of development? Might an economy be trapped in a spatially disparate, low-growth trap? What characterises the transition from small, spatially concentrated markets to large, national ones? What part does the efficiency of financial intermediation play? What government policies might instigate faster growth paths?

In a set-up with two regions, funds can be raised at the regional level, via regional financial intermediaries, or at the national level, using national financial intermediaries. We make two central assumptions: 1) A regional financial interme-

diary can only finance a regional infrastructure; and, 2) a firm can only operate at the scale of the infrastructure that it employs. The costs of financial intermediation are subject to scale effects. Specifically, we impose that financial intermediation at the national level can, *ceteris paribus*, be more costly.

Part of the incentive for firms to operate at the national level arises from *extensive* scale effects, that is, scale effects resulting from the linking of separate economies. For McDermott (2002, p. 373), extensive scale increases potential income partly by enhancing "the productivity of research and study". Rivera-Batiz and Romer (1991) takes a similar perspective in the context of an endogenous growth theory. In Alesina et al. (2000) productivity is directly related to economic integration via the imposition of iceberg costs in the trade of intermediate goods. In our economy, the integration of two regions into a national economy raises firm-level productivity and can obtain a higher growth rate.

Extensive scale also has a role in financial intermediary conditions. We consider two types of effect: Fixed information costs and learning costs. The historical analysis above has indicated that both firms and investors can have a preference for local finance where markets are small. We have argued that this is the result of a bias towards exchange and finance with those who are geographically closer which arises when the returns to centralised finance are outweighed by its costs . This is what we call the fixed information cost: It is easier for an entrepreneur, E, to convince an investor, I, to invest if I knows and trusts E personally; if E has a good local reputation; if I knows the local market conditions well; if institutional factors are conducive to I evaluating E; if if I can more easily monitor the activities of E. We posit that these scale effects are fixed; they hold true no matter what the market size. What is important, however, is that these information costs can depend on the legislative and institutional environment within which exchange takes place. We use this fixed scale effect to capture exogenous changes in the institutional environment.

We have also seen that a transition from spatially concentrated finance and markets to economy-wide finance and markets can occur. We have suggested that this

is not entirely the result of exogenous changes in political or institutional factors. We can, in part, put it down to endogenous changes in financial intermediation conditions. We account for, in addition to the fixed information cost effect, a learning cost in financial intermediation. We have seen hints of this effect in the historical analysis. We can think of four separate effects, though there are, no doubt, more.

First, consider a demonstration effect: It is harder to raise finance for the first national turnpike/canal/railway than it is for the fiftieth because of the initial newness of a technology or as a result of the unwillingness to risk money when the demand is uncertain. As a new form infrastructure is tried and tested by those willing to make initial investments, and as the demand for said infrastructure is demonstrated, it becomes progressively easier to raise finance. Secondly, a scale effect in construction can be considered: The first national turnpike/canal/railway will be more expensive to build than the fiftieth. This can result from technological improvements in rolling-out an infrastructure as it is used more. Third, there will be a learning effect in the *technology* of financial intermediation at the national level. We have seen that sophisticated financial markets do only emerge gradually, and that this emergence often parallels the growth of the economy. Fourth, the demand for major infrastructure projects that require national financial intermediation only occurs over time, as the economy grows regionally and as regional infrastructure networks are contstructed.

Of course, we are abstracting from such market-effects at the regional level for simplicity. In practice, these learning effects will exist at the regional level. The difference is that at the regional level these effects can be greatly mitigated because of the local nature of the investors.

Intermediation at a regional level is thus optimal when learning and fixed costs are relatively high. As the regional economies grow so learning costs fall (with the building of a regional infrastructure) and national integration becomes more feasible. Likewise, if market-invariant information costs fall at a national level, we can move from an equilibrium with two regions to an equilibrium with one national economy. If the regional economy lies on the balanced growth path then over time

the learning-cost barrier to integration will become insignificant. There will thus be three possible outcomes, dependent on both the extent of information costs of national intermediation and initial infrastructure conditions: Information costs remain high and regional economies are optimal in the long run; information costs are low, initial infrastructure is good and economy-wide output is optimal from the start; or information costs and initial infrastructure are such that we begin with regional economies and (via falling learning costs or exogenous institutional shifts) we move endogenously to a national economy.

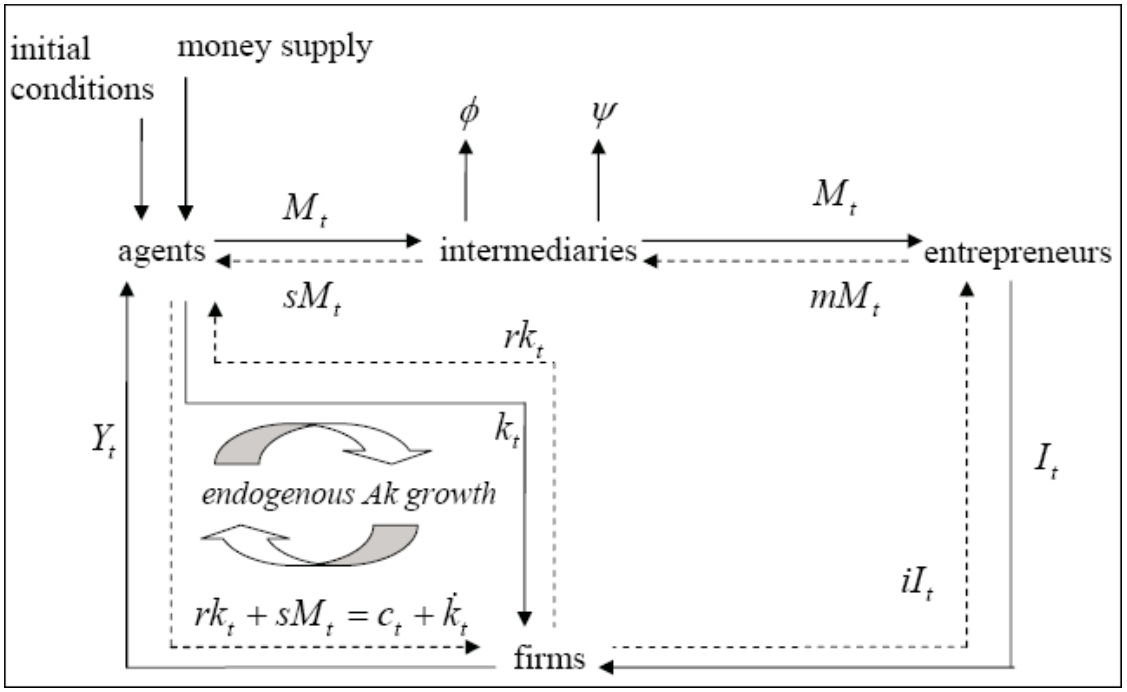
3.2 Formal Model

We have two regions, A and B, in the same closed economy (i.e., there are no exchange rate complications here). In each region there are $\#F^A$ and $\#F^B$ firms, respectively, and $\#C^A$ and $\#C^B$ consumers, respectively. We normalise each of these cardinalities to unity (though below we leave them in entrepreneurship equations for generality). One region cannot trade capital or finance with another without financial intermediation and infrastructure on a *national* level. There are two possible situations at any given point in time: Either the economy operates as two separate regions with no trade in capital or finance between regions; or we have a combined national economy with a national output.

Figure 4 depicts the flow of resources between consuming agents, intermediaries, entrepreneurs and firms in our model. Agents maintain a money supply and are given an initial capital endowment. Firms demand capital and infrastructure. Agents can sell capital direct to firms but infrastructure is supplied by entrepreneurs who use financial intermediaries to raise the finance from agents. The costliness of intermediation drives a wedge between savings and investments that impacts upon what both firms and agents receive. Consumption optimisation by agents, combined with a specific production function for firms, generates an endogenous growth based on externalities in the manner of Rebelo (1991). This story abstracts from any distinctions over integration, so we now proceed to consider the model

depicted in the Figure under both the regional and the national context.

Figure 4: Financial Intermediation and Growth Schematic



3.2.1 Regional Growth

Two factors enter the production function: Capital, k_t, and infrastructure, I_t. If we assume both regions are specified identically and that initial values for capital and infrastructure, k_0 and I_0, are identical in both regions then we can find equilibrium growth for one region knowing that it is equal to growth in the other region. So we 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 maximises profits,

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

where each takes the rates 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. Agents can recognise the demand for infrastructure by firms but cannot fund it themselves, they must obtain the services of financial intermediaries to raise the necessary capital. In so doing, they become entrepreneurs. Suppose that infrastructure is produced without capital, using money alone: $I_t = f(M_t)$. The entrepreneurs' incentive is the rent she can charge for firms' use of the infrastructure. Let us suppose that there are a large number, $\#E^A$, of agents who wish to become entrepreneurs. We normalise $\#E^A$ to unity; i.e., any agent can become an entrepreneur. Further let us suppose that there are no costs to *becoming* an entrepreneur. Perfectly competitive entrepreneurship will obtain,

$$\#F^A i I_t^A = mf(\#C^A M_t^A), \tag{5}$$

where m is the rate on finance supplied by the intermediary and M_t^A is the finance raised from each agent in region A. If we specify a simple linear production function for infrastructure, $I_t = M_t$, then $i = m$. This is the perfectly competitive outcome: If entrepreneurs could develop a monopolistic position with respect to firms or a monopsonistic position with respect to intermediaries then there would be a surplus to entrepreneurship in which $i > m$.

A financial intermediary exists to raise finance from agents and sell it to entrepreneurs. Any agent who sees the demand for financial intermediation can become an intermediary. Again, we are being purposefully loose about occupational choice here: An agent can become an entrepreneur or an intermediary or, indeed, can do both jobs. The mingling of occupations in this fashion is not contrary to reality, and so we do not require that agents formally choose between potential occupations.

We write the profit to an agent from financial intermediation at the *regional* level as,

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

where s is the private return that consuming agents obtain from selling finance to intermediaries.

Two costs are incurred by the intermediary. First, a cost ϕ of collecting finance 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 ψ of distributing finance to entrepreneurs reflects the cost of evaluating and monitoring potential entrepreneurs. For the purposes of this analysis, we do not specify the sources of these costs analytically. We simply take the view, following both the critique of current methodology and the historical analysis above, that these costs exist and can be significant. We will take on these more fundamental issues in Nolan and Trew (ming) and Trew (2007). Our purpose here is to capture the broad implications of our critique of current finance and growth theory. As such, we first construct a model in which these costs are exogenous and think about their microeconomic roots later.

We take the view that the market for financial 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 $\mathcal{F}^{\mathcal{A}} = 0$ under perfect competition, we have the following relationship between the rates of return on finance,

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

Equation (7) reflects the *wedge* between saving and investment: The more efficient the financial 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 function for infrastructure from 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 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 maximise 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 maintain an idiosyncratic stock of finance that is controlled by, for example, a central bank. The central bank ensures that aggregate money supply is a constant proportion of aggregate output. The consumer chooses how much capital to sell to firms, how much finance to sell to intermediaries and how much to consume.

The Euler equation in consumption is obtained,

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

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

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

Assume that a second market for finance exists that can give agents the same return as that on capital: Let us impose, equivalently, that agents are able to convert their money endowment into capital. If the return on finance is greater than the return

on capital all finance will be sold to the intermediary. If the return to agents from selling finance to intermediaries is less than the return on capital, the finance could be sold directly to firms as capital. Competitive intermediation thus ensures $s = r$ 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,

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

3.2.2 National Growth

In the light of the historical evidence discussed above, it is reasonable to allow for the possibility that there are significant scale-effects in the costs of financial intermediation; historically we have seen an initial pattern of regional industrial take-off in industry financed by local agents. Only once a local infrastructure is built and the regional economy becomes mature do financial intermediaries begin to operate on a country-wide basis. Additionally, information problems inhibit one region's ability to obtain finance from another, so there is a higher cost of coordinating investment on a national level relative to the regional level. So we might define the national financial intermediary conditions to be,

$$\mathcal{F}_t^* = (\#E^A + \#E^B)(1-\psi^*)i^*M_t - (\#C^A + \#C^B)(1+\phi^*)s^*M_t, \tag{15}$$

where $\psi^* = \Psi + \frac{2\omega}{I_t}$ and $\phi^* = \Phi + \frac{2\nu}{I_t}$, $\omega, \nu \geq 0$. The parameters Ψ and Φ reflect exogenous political and institutional factors. At early stages of development, or if fixed costs are always high, a financial intermediary incurs additional costs to operate at the national level, and to maintain zero-profit requires a higher return on finance sold to firms. The fixed cost premia, $\Psi - \psi$ and $\Phi - \phi$, reflect the difference in underlying efficiency of the regional cf. the national financial intermediary given the

institutional environment. The non-fixed costs, parameterised by ω and ν, reflect the learning costs of establishing an infrastructure in order to operate an economy at the larger level. As regional markets grow, so a regional markets gradually mature. 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 effectively have that the cost raising finance to build a national infrastructure is decreasing in the size of regional markets. In the long-run, therefore, these costs become insignificant.

Given an extensive scale effect on productivity, we make the assumption 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 $\bar{A} > A$, i.e. the incentive for agents to want to fund projects at a national level is the higher productivity of their capital and finance driven by the higher coefficient of technological progress, but this must be tempered by the cost of funding financial intermediation to facilitate that production. As in the case of the regions, we can find an analogous expression for the rate of interest to consumers on capital and finance 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,

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

The transition to this asymptotic growth rate follows,

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

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 inversely 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 realised 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, regional finance and capital supplies are combined 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.

The timing and transition to national integration here is, save exogenous institutional change, wholly endogenous to the model. This contrasts with work such as McDermott (2002) and Parente and Prescott (2005) where transition from one growth path to another is exogenously imposed.

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.

Given that over time the learning costs diminish into insignificance, 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, i.e. we could mitigate information problems by for example legislating for contract rights. Government intervention to build a public infrastructure will have no effect on the feasibility of integration so long as equation (21) holds because they will not overcome information costs this way; this result thus falls nicely into the category of France vs. UK industrial growth with regard to the different attitudes to public infrastructure.

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 very 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 most interesting case in terms of endogenous growth is the intermediate one,

where the economy begins in its disintegrated form and endogenously integrates when conditions become right. This requires,

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

Of the three equilibria, this case perhaps comes closest to reflecting the actual pattern of industrial growth. 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 disintegrated equilibrium, but also here we can bring forward the point at which we integrate via the public funding of infrastructure technology and improving awareness. We can, therefore, draw comparisons here to the 'big-push' literature of the type espoused by Murphy et al. (1989); while on a collective basis agents could gain by integrating at the same time, individually they face financial intermediary costs related to the size of the entire economy, which they cannot significantly influence by their individual action.

3.3 Numerical Solutions

Consumption, money, 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. So if we want to think of an annual growth rate while taking quarterly increments then we let $h = \frac{1}{4}$. 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,

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

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,

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

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

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

Table 1 gives a benchmark calibration with which we can demonstrate some of the growth dynamics. Figure 5 plots the course of the with an initial money stock of $M_0 = 20$ and initial capital stock of $k_0 = 40$. 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.

Table 1: Calibration for Finance, Integration and Growth

initial capital	k_0	40
initial finance	M_0	20
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

We can embark on a calibration of this model to the data of Bairoch (1982). There are too many free parameters to be able to pin-down a full calibration based on the evolution of financial efficiency, national integration and technological progress. We can, however, more generally consider whether the sorts of growth path implied by our model can capture historical trends. Table 2 gives an indicative calibration to US and UK data. Figure 6 depicts the numerical results. There are three things that we wish to capture from the data: First, the different levels of income in 1750; second, the different rates of growth through the period of industrial revolution; and, third, the different levels of income at the end of the period. We do not make any mid-period exogenous changes to the financial intermediation conditions; all growth effects here are endogenous.

Of course, this is one of many stories that we can tell; a different parameterisation might match the data equally well. There are two main differences that cause the numerical growth path: First, the US has a higher level of productivity

Figure 5: Example Growth Path

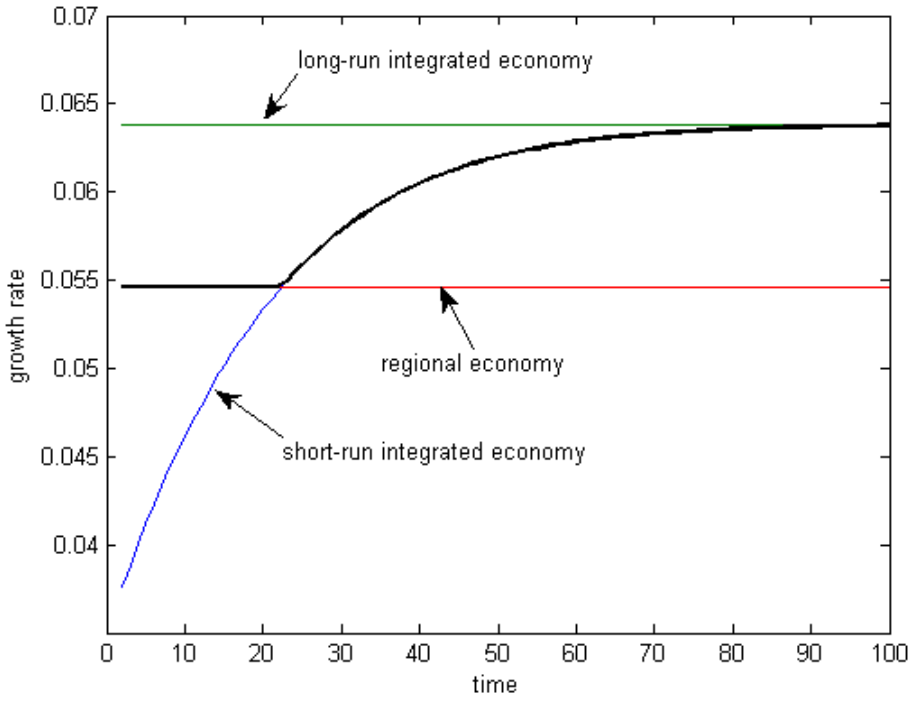


Figure 6: Calibrated US and UK Growth Paths

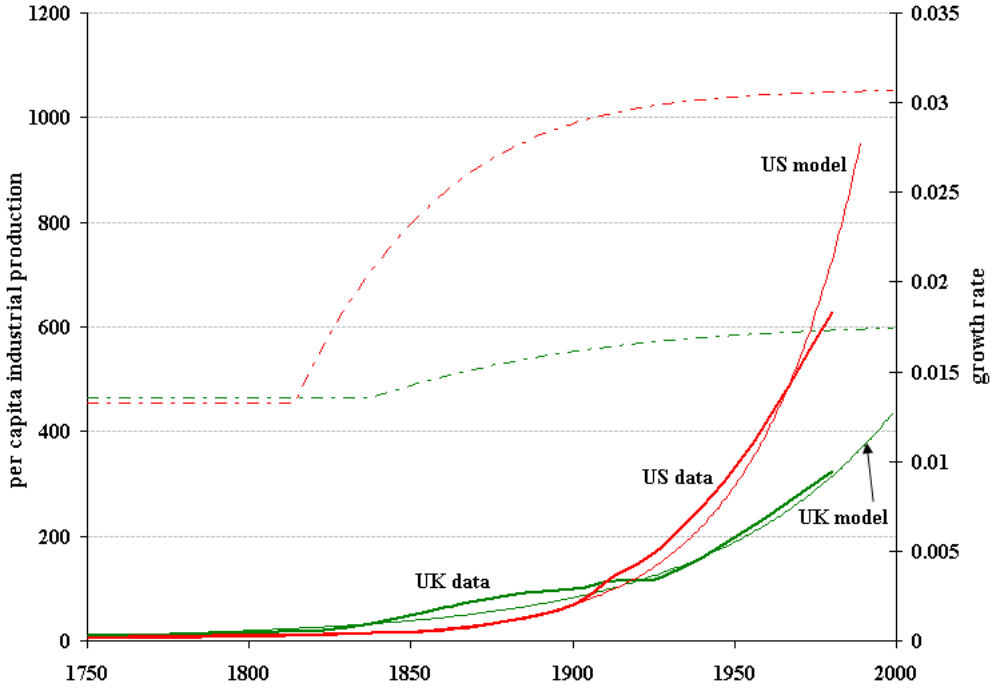


Table 2: Calibration for UK and US Growth Paths

		UK	US
initial capital	k_0	10	4
initial finance	M_0	5	2
capital share	α	2/3	2/3
subjective discount rate	ρ	0.02	0.02
elasticity of substitution	θ	5	5
regional coefficient of technological progress	A	0.15	0.15
national coefficient of technological progress	$\bar{A}$	0.2	0.32
fixed cost parameter on regional intermediation	ψ	0.25	0.275
fixed cost parameter on regional intermediation	ϕ	0.25	0.275
fixed cost parameter on national intermediation	Ψ	0.35	0.35
fixed cost parameter on national intermediation	Φ	0.35	0.35
scale cost parameter on national intermediation	ν	2	1.25
scale cost parameter on national intermediation	ω	2	1.25

at the national level, $\bar{A}$; second, the learning element of national intermediation is, in the US, substantially more rapid, i.e., the ν and ω are lower. This means that, despite beginning with a lower initial capital endowment, the US economy catches up and overtakes the UK one. In the US, integration occurs earlier and proceeds to a higher long-run growth path at a faster rate. These distinctions appear to match the historical growth patterns relatively well.

Of course, this interpretation is based on a very loose calibration. If we had data on, say, the endogenous or exogenous evolution of financial efficiency throughout the industrial revolution then we could make substantially firmer conclusions. The emerging time-series cliometric analyses of industrial take-off are likely to help us in this regard. Tieing these data with an analysis of the evolution of disaggregated coalitions would further restrict the range of possible calibrations. Moving towards the completion of rich datasets such as Shea (2007) is likely to prove invaluable in helping us to do this.

4 Concluding Remarks

We have demonstrated that by conceiving of finance and growth in a static and aggregative way we lose an understanding of the underlying transmission mechanisms. As a consequence, we are poorly armed to consider any policy implications. By looking at evidence from history, we have been able to identify a greater complexity in the transmission between entrepreneurial finance and industrial growth. Given an appreciation of the importance of fixed costs in the finance of any investment project, we identified the financial structures which supported the development of physical transport infrastructure. The development of an historical database on this matter will inform future work.

Further to the historical analysis, we developed a theory of finance and growth that can capture some of the interrelations between scale, finance and infrastructural development. The quantitative aspects of our theory can broadly replicate some observed historical growth paths. There are problems with the theory laid-out above, however. In terms of matching the stylised facts of aggregate finance and growth, we do not observe an increase in financial depth over time. There is obviously room for improvement in the theory. The model presented here is at least a step in the right direction. Again, completing a history of the finance of infrastructure through the industrial revolution will allow us to pin-down the quantitative implications of the theory more precisely.

A major advance in the theory would be to make optimal government behaviour endogenous to the model. We can outline in broad terms how this might be done: In the early period of industrialisation, when scale costs in financial intermediation are very large, a government might be tempted to promote the accumulation of infrastructure by allocating resources to the amelioration of economy-wide financial constraints. Of course, there is a trade-off between the marginal positive impact of spending on mitigating information and contracting problems and the marginal negative impact of taxation on welfare. On the basis of this simple model, when coalitions are spatially concentrated the marginal impact of government spending

in promoting centralised financial markets is minimal. The conclusion, then, is that in the early stages of growth, a government ought to behave with a relatively light touch, allowing private enterprise to form efficient financial structures that themselves mitigate information and contracting problems. The role of the government in the early phase of industrialisation seems to be the support of private enterprise by forming institutions that make it easier to write enforceable contracts. This has come out of both our historical analysis and the theoretical model we constructed to match our stylised facts. Similar messages come out of the work of Demirgüç-Kunt and Levine (2001). We turn to a more formal analysis of these propositions in Trew (2007).

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