Institutions and Incentives

The Strange Death of the Productivity Paradox

By the mid-1990s it appeared that the American economy might forever labor under the curse of Robert Solow. Despite enormous and continued investment in information and communications technology, American industry stubbornly refused to achieve the productivity gains that analysts had expected from such a general purpose technology. Although many of the key technological components of the ICT revolution had been developed in the early decades of the postwar era (the microprocessor by Intel in the 1960s, the personal computer in the late 1970s) it took until the late 1990s for Americans to finally witness a distinct shift from averages of 1.5% per annum productivity growth to over 2.3%. While the present recession has dampened the hyperbole of the dotcom years, a significant number of commentators predict that productivity will maintain its new plateau and that, consequently, Solow’s curse has been laid to rest.

Yet despite the clear consensus that American productivity did jump substantially in the ‘Roaring Nineties’ the exact mechanism by which this success became manifest remains somewhat nebulous. It is clear that general purpose technologies (GPTs), like information technology, facilitate the accretion of ‘micro-gains’ in efficiency. For example, more rapid communication between firms prevents inventory mismatch and misallocation of resources, and enables employees to work from more convenient locations. Such advantages were also visible in earlier GPTs. Electricity permitted reorganization of the workshop floor; the telegraph enabled rapid conveyance of inventory stock and employee

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tasks. Yet productivity gains such as these derive from reducing waste (in stock or time) rather than necessarily from increases in productive capacity or from the speed of the innovation cycle. Long-term acceleration of productivity requires more than just snipping away at slack around the edges of the production process. It necessitates fundamental reorganization of production and different factor mixes. According to Claudia Goldin and Lawrence Katz, as general purpose technologies force such a reshaping of production, the returns to skilled labor (i.e., human capital) demonstrate a secular increase. It is this replacement of unskilled labor, crude technology and obsolescent fixed capital by human capital and new technology in the production process that catalyzes productivity growth. Goldin and Katz label this phenomenon ‘technology-skill complementarity’.

This paper seeks to explain the necessary conditions for such ‘technological-skill complementarity’ to occur for a given GPT and thereby spark long-term productivity gains. I argue that most analysis of the end of the American productivity paradox in the 1990s has taken place at the level of mid-range theory. Caught up in the most immediate and conspicuous displays of productivity improvement at the firm and sector level, academics have largely ignored both the shift in composition of factor inputs at the micro-level and the institutional preconditions for productivity improvement at the macro-level. This paper seeks to remedy this imbalance by providing a coherent analytical thread linking developments in the broader political economy down through sectoral trends to the production function itself. Much existing work remains overly blinkered, indeed contradictory, positing different explanatory variables for each level of analysis. While I concede the impossibility of discovering a necessary and sufficient independent variable that magically engendered the productivity boom, I nonetheless believe a less limited analysis is critical if we are to truly comprehend the ‘miracle’ of the 1990s and avoid the mistake of focusing on symptoms not causes. In the spirit of Richard Dawkins’ The Blind Watchmaker, I adhere to a ‘hierarchical reductionism’ in my analysis. There were many different ‘motors’ driving the production boom and no ‘force

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informatique’. Nonetheless the overemphasis on macroeconomic stability combined with firm reorganization and efficiency gains blinds us to other key forces.

This essay concentrates on the institutional incentive to invest in human capital as a key motor driving the productivity boom. I show how technology-skill complementarities can only be unleashed if employees are willing to invest in training themselves in specific knowledge. However, this investment is risk-prone since specific knowledge is, by definition, utilizable only within the sub-sector or indeed firm. Since most GPT ventures are high-risk because of their novelty and the uncertainty of market demand, the chance of firm failure or down-sizing is very real during the rollout of a new general purpose technology. Moreover, the potential for innovatory high-risk ventures to even exist is predicated on the pre-existing industrial structure of the relevant sector. Oligopolies have an incentive not to allow GPT innovation to threaten their rents. Thus broad shifts in institutional structure are necessary conditions for the existence of innovatory firms and the incentive to invest in the human capital that will provide their key factor input. Put simply, to achieve technology-skill complementarity one must assure both the existence of innovative technology and the incentive to acquire skills. This paper stresses the importance of institutional transformation in achieving these goals: macro-changes are necessary conditions for productivity enhancing micro-mechanisms.

The structure of this paper moves from noting the deficiencies of existing theories before tying together micro- and macro-level explanations of how incentives to invest in human capital drove productivity gains. In the first section I outline these mainstream theories: firm level, sectoral and monetary/fiscal. I note that these theories tend to be piecemeal and fail to identify broad analytical threads that might unite the relevant variables and conditions. In order to resolve these lacunae the second section begins by examining the micro-mechanism of productivity growth – how human capital and technology combine complementarily in the production function. In order to explore this issue I ask how this combination might be measurable and offer some descriptive statistics. I then examine

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how innovation in technology and investment in human capital are incentivized. The third section of the paper asserts that innovation and investment can only be achieved via institutional change. I examine four key institutions (regulation in telecommunications, finance, labor and equity) and their transformation across the past two decades, firstly by tracing historical case studies and latterly by constructing a formal model demonstrating the underlying micro-mechanism. Finally, I conclude by asking whether my analysis constitutes a convincing explanation of the end of the productivity paradox and what it illuminates or neglects. I finish by postulating some future applications of this analysis on human capital investment to other GPTs and historical periods.

Existing Theories – Insights and Blind Spots

The stunning Internet boom of the late 1990s has created a cottage industry of analyses attempting to explain the exact mechanism by which productivity was galvanized. As noted above, whilst this research program has been extremely productive, theories are often piecemeal and it has proven exiguous to connect theorizing at the firm level to broader trends. There is no apparent reason why such theories explaining the effect of GPTs might not be compatible: the economy is, after all, subject to more than one critical variable. However, because of the exclusivity of different research paths, reassembling studies into a broader theoretical framework produces an often dissonant collage of arguments. In order to make clear the analytical separateness of different research I structure this literature review around three well-trodden paths of analysis (firm-level innovation, sectoral diffusion of GPTs, and macroeconomic conditions) before turning to a more recent, and somewhat under-theorized, program from political science that attempts to outline institutional forces. Since this latter research provides a starting-point for this paper I shall analyze its progress, its suggestions, and how my work connects with contemporary theories.

All actual innovation within the private sector must, by definition, take place at the level of the firm. Moreover the productivity statistics economists wish to connect to innovation must derive, at least in part, from the aggregated efficiency gains achieved at the firm
level. Thus, the analysis of case studies detailing how individual firms have improved business organization, information sharing and output volume thanks to the IT ‘revolution’ has been a key step in outlining the mechanisms by which this latest GPT has made its presence felt in galvanizing productivity. Erik Brynjolfsson and his collaborators have undertaken a number of detailed studies of how firms took advantage of these potential efficiency gains to restructure their businesses. In Brynjolfsson, Renshaw and Van Alstyne’s study of ‘MacroMed’ they detailed how this medical products manufacturer was able to reduce inventories, create more flexible management and customize products once IT innovation had been combined with organizational change\(^6\). Martin Kenney and James Curry have examined Dell’s manipulation of the personal computer value chain thanks to the advances in communications speed ushered in by the Internet (a classic example of the symbiosis between different sub-products utilizing a GPT). By adopting an Internet business model far in advance of its competitors Dell was able to shave fifteen percent of ordering costs off the price of purchasing PCs and was able to save $21 million per annum by avoiding order-status calls\(^7\). Clearly such efficiency gains produced very real spurts in profitability and because of the consequent reduction of now-superfluous workers, a jump in productivity per man-hour.

However, efficiency gains from reducing ‘waste’ are not the total sum of productivity. While inventories can be judged more effectively and unnecessary employees can be removed, these once-and-for-all cuts in the cost of a given output were accompanied by more permanent improvements in production speed, worker skill and organizational structure. None of these achievements are as cheap as clipping away inefficiencies, and they tend to require substantial investment in employee training and human capital formation. Brynjolfsson and Hitt acknowledge this necessity and referring back to the MacroMed study, note that cost-cutting efficiency gains could only be realized by hiring

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a new workforce in a green-field site and re-organizing from scratch. Such broad strategies are more dependent on factors lying outside the firm than the cost-cutting tactic: hirable human capital, labor market deregulation and, assuming that not every ‘MacroMed’ is willing to start afresh, the necessary financial institutions to provide venture capital to new firms wishing to organize in this more effective manner. Ignoring the institutional preconditions for successful investment blinds us to the impinging forces lying outside the firm.

There is also an unfortunate ‘business-school syndrome’ at work in many of these firm-level analyses, in that they fail to explain more broadly why such opportunities were not seized in the 1970s and 1980s. One would assume that if such efficiency gains were realizable purely because of the existence of IT, profit-maximizing firms would have seized the competitive advantage earlier and productivity would no longer have remained dormant. By ignoring the facilitating institutional change these firm level approaches falsely assume companies operate within a vacuum that provides no constraints on potential GPT-using strategies.

Sectoral-level analyses of the productivity boom tend to be far more aware of broader dynamics affecting companies and the constraints on development. Bresnahan and Trajtenberg’s 1995 article provides the analytical starting point for theorizing how General Purpose Technologies diffuse throughout relevant sectors. The authors note that the literature on endogenous growth theory, especially that of Paul Romer, fails to provide an adequate mechanism for evaluating how technological change affects specific sectors. Although Romer recognizes the significance of technology like ICT that with moderate fixed costs can produce increasing returns, his models portray technology as

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‘all-pervasive’11 and fail to trace the specific, sectorally-bound mechanisms by which technological improvements increase aggregate growth rates.

Bresnahan and Trajtenberg present a mid-range analysis analyzing incentives to innovate in the GPT and application sectors. They note that as the ‘quality’ of GPT technology improves, the technological performance of applications is raised and this will “cause an expansion of the set of AS’s [application sector firms] by making it profitable for extramarginal sectors to adopt the GPT”12. By demonstrating the diffusion incentives explicitly, Bresnahan and Trajtenberg provide a convincing and essential model of GPT adoption. However, they largely ignore how technology interacts with other factors of production, concentrating only on ‘levels of technology’ and relative prices – leading to the somewhat self-evident conclusion that with fixed prices application producing firms will wish to use better GPT technology. The paper also notes that without non-market intervention suboptimal amounts of investment will occur but leaves the necessary institutional preconditions as a suggestion in conclusion rather than following through on this logic. Nonetheless, Bresnahan and Trajtenberg’s recognition of the importance of institutional structure provides an important reminder of political forces, which shall be followed up throughout this paper.

Since the publication of Bresnahan and Trajtenberg’s formulation of GPT diffusion a number of growth accounting exercises have attempted to disaggregate productivity growth in the 1990s in order to specify separable influences in the production function. Nicholas Crafts has undertaken the most nuanced analysis of the impacts of ICT on growth and divides the influence into three factors: ICT capital deepening, reductions in the real cost of producing capital goods, and TFP spillovers13. By applying this growth accounting model, developed partly by Schreyer14, to previous GPTs like electricity and steam, as well as to ICT, Crafts notes that the impact of ICT on productivity has been

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12 Ibid. p. 90.
grossly underestimated. DeLong and Summers present an optimistic interpretation of this result: that despite the current ‘recession’ productivity gains remain impervious to broader economic woe.\(^{15}\) Because ICT is an industry for which income elasticity of demand is high and diffusion widespread, as ICT is used throughout the ‘old economy’ we can expect national productivity to keep up with innovation in the leading sector after an initial lag. Crafts himself showed a similar phenomenon occurred during the industrial revolution as productivity growth in the aggregate lagged the leading sectors by decades.\(^{16}\) However, Crafts’ recent work does note that TFP spillovers outside of the GPT sector appear negligible, a finding echoed earlier by Stiroh.\(^{17}\) The question remains unanswered as to whether ICT is a truly transformative technology creating new ‘tools for thought’ or an extraordinary innovation that nonetheless fails to dominate expenditure and production such as the creation of artificial illumination as outlined by Nordhaus.\(^{18}\)

This skepticism of productivity ‘osmosis’ has been most volubly asserted by Robert Gordon, who notes that ‘this spillover from intermediate to final goods industries is just what cannot be found in the official data on output and productivity growth’.\(^{20}\) Gordon’s dissent from the New Economy hyperbole is, to an extent, refreshing. And yet his explanations of why productivity gains have not occurred outside of the ICT sector itself remain somewhat unsatisfying. He notes that the Internet and ICT lead to recreation of

\[16\] Crafts, Nicholas. 1985. British Growth During the Industrial Revolution. Economic Inquiry 36
old activities, duplicative activity, market-share redistribution and on-the-job consumption\textsuperscript{21}. Indeed, these may be important brakes on productivity growth. However, we can only make this assertion in the assumption that all firms have used ICT to the most complete extent feasible. Gordon lists productivity failings of the use of ICT itself, ignoring that the absence of gains might derive from the failure to employ any significant level of ICT amongst many firms. And the explanation for this could well be driven by institutional constraints on computerizing the service industries or the public sector, amongst over examples. The question then, is whether spillovers are even feasible yet, rather than whether, once ICT is applied, they occur.

What conclusions can we emerge at from an analysis of the literature on sectoral diffusion and on growth accounting? It seems that at times these studies have assumed diffusion and then attempted to explain its failure to galvanize productivity, rather than questioning how much diffusion has actually occurred and what might be constraining this roll-out. Bresnahan and Trajtenberg provide the clearest answer with their assertion that institutional interference with the market might be necessary to ensure adequate roll-out but this is not a suggestion that has been adequately seized upon. At the national level analyses have, instead, centered on monetary or fiscal conditions rather than changes in the American political economy. Explanations, thus, focus on beneficial conditions rather than the removal of impediments. The French economist Pierre-Alain Muet, for example, attributed American growth to the quality of macroeconomic policy, which combined a return to a balanced budget and fortuitously prophetic monetary policy from the Fed. These conditions led to innovatory dynamism because of the beneficial expectations businesses had thanks to a stable macroeconomy, thus leading to greater investment in risky projects\textsuperscript{22}. Certainly there must be an element of truth to this assertion, after all its reverse, a period of high inflation and labor unrest would certainly work against long-term risk-acceptant investment. However, given similar conditions in the mid-1980s why did American not see a comparable productivity boom at this time?

\textsuperscript{21} Ibid, p.69.
Moreover, the causal chain could be reversed. As Alan Blinder and Janet Yellen note, supply shocks from an ICT productivity burst (of unspecified cause) can themselves lead to a stable macoconomy. They might reduce the short-run NAIRU, as Alan Greenspan believed, or instead might ‘confuse’ workers who fail to recognize the productivity boom and thus fail to raise their wage demands. Whichever hypothesis is seized, it seems clear that supply-side shocks could have beneficial macroeconomic consequences. However, this line of argument still fails to explain where such shocks might emerge from, leaving us marooned at the beginning of our question once more.

Are institutions the missing link? This was the suggestion hinted at by Bresnahan and Trajtenberg and some recent work has begun to move in this direction. However, the existing literature is somewhat speculative, methodologically ambiguous and hardly a coherent research program. Robert Boyer, the regulation school economist has presented a somewhat unwieldy, if stimulating, attempt to demonstrate a number of differing trajectories toward productivity growth: Gershenkronian catch-up, rates of investment and ICT diffusion. Unfortunately, despite this interesting typology Boyer adopts a frustrating Boolean methodology to explain effects, which culminates in assigning binary values to countries depending on whether they have or do not have certain institutions. Casper and Glimstedt have adopted a less extreme analysis of institutional complementarities by noting how sectors requiring general or specific human capital might require differing institutional backdrops in order to successfully align incentives – a theoretical device I employ in my own analysis. Unfortunately, Casper and Glimstedt’s analysis is tailored toward Germany and Sweden and thus its depictions of institutional complementarities are not especially helpful in interpreting the American boom.

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Paul David’s work appears to be the most relevant institutional analysis when attempting to decipher the end of the American productivity paradox. After all, David’s ‘The Dynamo and the Computer’ explicitly analogizes the hesitant productivity spurt from electrification to that occurring in the early 1990s. David noted that it took institutional change in electricity regulation (removal of price controls, in particular) before the gains from electricity could be realized, some four decades after the first power station opened. David’s recent article in the Oxford Review of Economic Policy makes similar assertions surrounding the importance of policy and institutional structure in developing the Internet and in the future of high-speed data transfer. However, David’s work remains frustrating to pin down. Is there any explicit mechanism, other than a facile recognition that history matters? Too often David is happy to insert the theoretical shortcut of ‘increasing returns’ without close tracing of the causal pathway from change in the political economy to change in the production function and vice versa. While David’s insights are stimulating they do not provide an adequate formalization of how productivity gains are made manifest. This paper now attempts to draw much clearer lines from institutional change to transformation of production by concentrating on the key variable of incentives to invest in human capital. But before the institutional argument can be fully developed it is appropriate to demonstrate why human capital matters in the development of revolutionary technologies.

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Catalysis at the Micro-level – Technology Skill Complementarity and GPTs

Since the aim of this paper is to argue that institutional change is necessary to incentivize the investment in human capital necessary for productivity take-off, before broaching the core argument we should first make clear exactly why human capital is so important. As an input into the production process human capital is an important factor on its own. However, a considerable amount of research, examining the United States since the turn of the century, has shown that when combined with certain technologies human capital creates powerful complementarities. In other words, unskilled labor and fixed capital are not perfect substitutes for human capital under certain technologies. The recognition that educated labor might interact beneficially with other factors dates from Griliches’ 1969 formulation of ‘capital-skill complementarity’ but has been increasingly slanted towards interaction with technology in the production process.

Claudia Goldin and Lawrence Katz’s work provides the key demonstration of this logic. Goldin and Katz examine the returns to unskilled and skilled labor throughout the first half of the twentieth century and postulate that the latter became more valuable as technological progress pushed manufacture production from factories and assembly-lines to continuous and batch production and later robotized assembly-lines. Different production processes appear to favor different combinations of fixed capital, skilled labor (or human capital) and unskilled labor. As general purpose technologies diffuse throughout the economy there appears to be a secular trend towards production processes favoring human capital. For example, electricity facilitated the move to continuous production and robotics that require less unskilled labor but more highly skilled labor to maintain, operate and reprogram machines. These later production processes proved to have far higher rates of productivity than their predecessors. Moreover, human capital is not only a factor input but also a mechanism for creating new ‘ideas’: more efficient production processes emerge from the employment of human capital. Thus ‘technological

skill complementarity’ is both symptom and cause of productivity bursts: it is a necessary ingredient for present-day processes but also the inventor of future processes.

How can we measure technological skill complementarity? The typically used methodology is to compare skilled and unskilled wage rates. This is usually operationalized through assessing the returns to a given level of education, following Goldin and Katz’s original work. The ‘race’ between education and technology alluded to by the aforesaid authors provides the key motif in understanding how GPTs tend to widen inequality in wage rates by increasing the returns to skilled labor and substituting for unskilled labor. While some authors claim that supply-side shocks tend to cancel one another out and, thus, that the sudden emergence of a GPT may not be the sole arbiter of consequent inequality, most economists concede that information technology is not a mere ‘trend break’ but a long-term influence on the wage gap. A number of other forces could conceivable be working on wage inequality, particularly international factor equalization under globalization as emphasized by Scheve and Slaughter and by Acemoglu. However, these results often appear contradictory and fail to explain the worldwide increase in returns to skill.

The logic of technological skill complementarity appears particularly appropriate in the computer age, and indeed a number of recent papers have sought this connection. David Autor, Lawrence Katz and Alan Krueger have noted that the relative demand for college graduates has increased greatly since 1970 and this can be explained ‘entirely’ by within-industry changes in skill-utilization rather than between-industry shifts. These growth rates are largest in those industries with the largest increase in computer usage, leading to the authors to postulate that the spread of ICT might account for nearly half of the growth

in demand for skilled workers\textsuperscript{32}. These analyses have been combined with recent work detailing exactly which skills ICT is complementary with. Frank Levy and Richard Murnane have conducted in-depth case studies focusing on this question. Their investigation of Tammany Bank concluded that computerization removed the need to focus on data entry, data transfer, and keeping ledgers, allowing skilled workers to concentrate on tasks requiring conceptual, analogical thought and communication\textsuperscript{33}. The same authors’ most recent paper, with David Autor, demonstrates that whereas computer capital substitutes for relatively unskilled work involving routine tasks, it acts as a complement for activities involving problem solving and interactive tasks\textsuperscript{34}. Thus, as the usage of computers has moved from mainframes performing calculations that were originally solved on abaci, to design, communication and self-expression, the returns to human skill have increased.

However, human capital is not a homogenous commodity. The very complementarities with technology that make human capital so productive are also extremely limiting in the narrowness of their applicability. Advanced technology requires highly specific human capital that is often only utilizable in a single firm or sector. While this specialization of tasks is extremely efficient it raises the risk of investment in specific human capital. Supposing an employee invests a year of education in learning a proprietary software language used only by their firm and that firm becomes bankrupt, a considerable, if not the entire, amount of that worker’s human capital can be nullified. Yet, the most productive firms at the cutting edge of a new GPT will likely be those who require most very specific knowledge: for example ‘middleware’ firms producing proprietary networks\textsuperscript{35}. Hence in order to reap the gains from technology-skill complementarities, employees must be incentivized to invest in high-risk human capital.

This requires methods of employee compensation that may necessitate institutional change. It may also require financial and telecommunication institution transformation in order to create new companies willing to undertake high-risk strategies and venture capital willing to invest in them. Moreover, labor market deregulation may also be necessary to encourage firms to hire human capital without fear of being unable to fire employees if investments turn sour. Indeed, without labor market deregulation employees may be unwilling to invest in risky human capital if there is little possibility of finding another job rapidly (as it might be the case in an insider-outsider risk-averse system like Germany\textsuperscript{36}). Thus institutional change can incentivize both the ‘technology’ (by enabling small innovatory firms to develop rapidly) and ‘skills’ (by providing incentives to invest in specific human capital) that constitute Lawrence Katz and Claudia Goldin’s concept of complementarity.

\textsuperscript{36} Ibid.p.270.
Institutions and Incentives – Seismic Shifts in the US Political Economy

This section of the paper discusses how the structure and / or transformation of four American institutions – labor markets, telecommunications, finance and equity – enabled the US economy to reap productivity gains from the GPT of information technology. Although some of these institutions already existed before the end of the productivity paradox I emphasize the importance of complementarity – put simply, the gains from institutional transformation relied upon a complementary mix of institutions. Thus, the productivity boom did not emerge until the 1990s because it was not until this period that the institutional complementary had become stabilized. Institutions are not quick-fixes but must become understood by the relevant actors for incentives to bite. Because of the systemic interaction between these institutions it should be noted that their influence is more than the sum of their parts, in that each alone might not incentivize innovation and human capital investment.

Demonstrating institutional influence is an exiguous task and one that inherently relies on counterfactuals. Since we cannot return to the 1980s and prevent AT&T from being dismembered we cannot categorically state that the productivity boom would not have occurred. We can, however, distinguish effects in two somewhat limited manners. Firstly we might analyze sectors that were negligibly affected by institutional change but had potential to exploit the GPT and account for differences in their relative productivity gains. Unfortunately this exercise is hindered by the obvious presence of spillovers: no firm is an island, and productivity gains in ‘institution-effected’ firms are likely to be absorbed by firms experiencing little comparable institutional change through the mechanism of lower intermediate product prices. Moreover, the institutions I am examining are not especially limited in scope – it is hard to conceive of a firm utilizing GPTs who would be unaffected by new incentives to invest in innovatory technology or human capital.

A second, and perhaps more fruitful technique, would be to analyze the experiences of other nations who were exposed to the same GPT but unable to achieve the same
productivity gains. One could then draw the conclusion that they possessed the ‘wrong’ institutions to encourage investment in innovation and human capital. Certainly, the popular image of Europe, propounded by Alan Greenspan, as stagnating because of the sclerotic labor markets, fits into this vein of analysis. However, in extending the analysis to other countries, we need to go back and visit the mainstream theories I outlined earlier to assess their relevance to the European situation: how do European firms differ; does sectoral diffusion operate differently; how effective are TFP spillovers; was there a macroeconomic brake on European development? Moreover, can we be sure that other patterns of institutional complementarity do not exist? An emerging literature in political science on ‘varieties of capitalism’, associated with Peter Hall, David Soskice and Torben Iversen, suggests that certain combinations of ‘wrong’ institutions (in American eyes) can form complementarities as ‘organized market economies’ that challenge the American paradigm.

In the recognition of these analytical dilemmas this paper seeks to operate as a ‘plausibility test’ and examine how institutions affect incentives to invest in innovation and specific human capital through short case studies of the relevant institutions. Thus, mechanisms are outlined but not conclusively tested with econometric methods. Such a task, despite the difficulty in operationalizing institutions, will be a critical future step in this research but one not undertaken in the context of this paper. However, once the case studies have been concluded a brief formalization of incentivizing investment in specific human capital is undertaken in order to provide analytical confirmation of the suggested mechanism.

**Labor Market Institutions**

Since the focus of this essay is on the manner in which individuals are incentivized to invest in specific human capital, and how this investment leads to productivity-boosting technology-skill complementarities, it seems appropriate to examine the institutional
context in which this skilled labor exists. Indeed, American labor market institutions have a very unique flavor that has been credited by many economists and other commentators for the dynamism of the US economy. My argument does not deny this assertion: that flexibility is a key determinant of innovative economies. However, I hope to show how this lack of labor market regulation must be accompanied by complementary institutions (specifically those ensuring adequate compensation for job risk and those enabling widespread start-ups of new firms) if the gains from encouraging risk and flexibility are to be reaped. Analyses of these complementary institutions follows and it should be borne in mind that the analysis of labor market institutions does not occur in a theoretical vacuum.

In contrast with the other institutions I analyze, there was no truly dramatic piece of deregulation or a ground-breaking court case during the late 1970s and 1980s in America. This section, thus, strives to sketch the contours of American labor institutions partly by contrast to other states, rather than to earlier periods in American history, in order to best clarify the differing possibilities that institutional forms might take. This is not to say that American labor institutions have remained glacial and untouched. The NIRA of 1933 and Fair Labor Standards Act of 1938 had enormous effects in wage dispersion, especially in the South. However, the 1970s and 1980s, while they saw a pronounced secular decline in union membership, saw little key legislation affecting workers in higher income brackets other than Reagan’s culling of recalcitrant air traffic controllers. Instead of focusing on change in labor regulation at the upper end of the income scale in America, I characterize labor market institutions by comparison to their more rigid counterparts in Europe. This allows for a clearer comparison of how the differing design of labor institutions can significantly affect incentives to invest in specific human capital.

The ability to hire and fire cannot be taken for granted. Rather, the ease with which firms can adjust their demand for labor is a political decision often embodied in rigid labor institutions. Continental Europe is commonly characterized as having an ‘insider-

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outsider’ labor market, where those workers employed in long-term, full-time, unionized employment can sustain their wages above competitive equilibrium because of laws constraining the ability of firms to make workers redundant. Because of this impediment to the firing of labor, firms have less incentive to hire new workers because they know they will be unable to fire them should the economy turn sour later. Horst Siebert argues that European institutions ‘are a central reason for Europe’s poor labor market performance’. The particular institution upon which my paper focuses is the regulation of hiring and firing (rather than minimum wages, wage bargaining and the duration of benefits, which are critical institutions for lower income workers but perhaps not as relevant for those investing in high-return specific skills). Many of such regulations first appeared in Europe in the 1970s, for example, Italian firing regulations by 1970 made the cost of firing ‘almost infinite’ and in 1972 Germany imposed mandatory social plan requirements for firms being closed. Even timid attempts to open up labor markets in the 1990s have, as yet, had little impact on massive long-term European unemployment rates.

In contrast, such regulations are barely evident in the US political economy where labor requirements are allowed to fluctuate with market forces (for better or worse). However, we should be careful when interpreting the arguments of Siebert, Lindbeck and Snower and others to remind ourselves to peruse the statistics closely. Stephen Nickell’s regressions of unemployment on labor hiring/firing laws show little effect of regulation. Nickell notes that more stringent laws may increase long-term unemployment by reducing outflow from employment but they also, by increasing firm’s caution about hiring, tend to reduce inflow and thus short-term unemployment. Thus, the trends in short and long-term unemployment cancel one another out. While the broader unemployment figures consequently remain controversial, they do support the assertions made in this paper. I argue that it this caution in hiring that de-incentivizes investment in specific

40 Lindbeck, Assar and Dennis Snower. 1988. The Insider-Outsider Theory of Employment and Unemployment
42 Ibid., pp.40-41.
human capital. Workers employed by a risky specific firm know that if the firm folds, finding new employment will be made that much more exiguous.

Let us explore further how this logic plays out in terms of en-/discouraging investment in specific human capital. Casper and Glimstedt, in their analysis of innovation in high-technology industries in the US, Germany and Sweden, note that, all else equal, rigid labor markets tend to discourage such investment. They reason that, firstly, under inflexible labor markets less small firms are likely to appear, partly because creating a new workforce is more costly in Europe where firms must pay larger contributions to social insurance than in the US, and also because would-be entrepreneurs are discouraged from leaving firms to start up new ones because of the ‘rents’ accruing to insiders. This leads into the second point; there is a greater danger in continental Europe for workers joining risky firms. Casper and Glimstedt note that the increased risk of being forced back onto the labor market for workers in risky, innovative firms, is sharper in Germany than in the United States because the possibility of being quickly re-employed is much more remote. Thus, fewer workers acquire the kinds of specific human capital that could be utilized by high-risk innovator firms.

We can contrast this scenario to US labor markets quite clearly, even tritely, by picturing the classic Silicon Valley model where workers move swiftly between jobs and having worked for a failed start-up is a boost to, rather than a stain on, one’s resume. Certainly, the American system can match newly formed specific human capital much more quickly to employment and funding than can the more rigid continental systems where training involves apprenticeships and often lifelong employment. Nonetheless we should be careful in attributing any clear superiority to the American model. As Wolfgang Streeck, amongst others, has pointed out, attempts to institute American style labor markets in Germany is likely to fail because it would ignore the institutional complementarities that exist between rigid labor markets and other German institutions including tripartite bargaining, a male breadwinner social insurance welfare state and organized wage

bargaining\textsuperscript{44}. Likewise the American system flourishes because of, not despite, the existence of a number of other institutional mechanisms, chief amongst which are easy access to venture capital, compensation via equity and lenient bankruptcy law\textsuperscript{45}. In the next three sections I discuss some of these institutional structures and how they mitigate the potential flaws of a deregulated labor market and encourage investment in specific human capital.

Telecommunications Institutions

It seems self-evident that the institutional structure governing the regulation of a GPT will affect incentives to invest in human capital related to that technology. Indeed, many commentators have noted that the deregulation of the American telecommunications industry during the 1980s was the key determinant of American success in exploiting computer networking - and thus set the stage for the Internet boom. This section analyzes the importance of the shift in telecommunications institutions in two manners. Firstly, I investigate the labor market repercussions of removing control of the telecom market from AT&T and Bell Labs who operated as virtual monopsonists of specific human capital in ICT. Secondly, I analyze how the creation of an ‘end-to-end’ innovation environment following telecom deregulation enabled individuals to exploit their specific human capital in a far more open manner than under the limited Bell system.

The breakup of AT&T was an exceedingly protracted affair\textsuperscript{46}. The private monopoly (in contrast to most European states and Japan, which had public PTTs) had been facing attack from a variety of sources – competitors, courts and regulators – since 1919 when it was forced to divest Western Electric. The Hush-a-Phone and Carterphone cases running through the 1950s and 1960s provided the first key challenge to the Bell’s system’s most

\textsuperscript{44} Streeck, Wolfgang. 1997. “German Capitalism: Does it Exist, Can it Survive?” in Colin Crouch and Wolfgang Streeck (eds.), \textit{Political Economy and Modern Capitalism: Mapping Convergence and Diversity}.

\textsuperscript{45} I do not deal with the importance of Chapter 11 bankruptcy law in this paper. However, the significance of this institution is huge, especially when compared to the very strict, career-ending bankruptcy law in, for example, Germany. Future research should investigate the importance of such ‘turnover’ laws.

\textsuperscript{46} Much of the following information comes from Vogel, Steven. 1996. \textit{Freer Markets, More Rules: Regulatory Reform in Advanced Industrial Countries}. See also Temin, Peter. 1987. \textit{The Fall of the Bell System: A Study in Politics and Prices}. 
prized asset: the telephony network. These cases forced AT&T to permit interoperability of foreign devices and were followed by the FCC’s decision to permit MCI to create a rival, albeit microwave-based, communications network to AT&T.

Nonetheless, AT&T maintained its monopoly on fixed-line access through to the mid-1980s and this proved to be a stranglehold on innovation within communications technologies, which was largely confined to Bell Labs. Specialists in such technologies were largely obliged to work for Bell Labs or one of the regional Bell operating companies (RBOCs), who could thus act as pseudo-monopsonists of available talent. This is not to deny that Bell employees were paid well. However, the kinds of hiring incentives for specific human capital that exist in a competitive market for skills were very much muted by the dominance of AT&T. It would require the break-up of the Bell system, together with the expansion of venture capital and equity compensation (discussed in the next two sections), for lucrative incentives to be offered competitively for specific human capital. Such incentives would inspire the great burst of innovative energy of the 1990s.

Judge Harold Greene’s Modified Final Judgement, breaking up AT&T in 1984, and the consequent Telecommunications Act of 1996 forcing the RBOCs to open up local, ‘last-mile’ access to competition, did not only have the effect of reducing call prices and enabling entrepreneurial employees to set up rival companies. These highly contested institutional changes, by freeing up the national communications network, also precipitated the development of ‘end to end’ innovation that characterized the Internet era. Whereas GPT innovation had largely been confined to Bell Labs before the 1980s, and was thus concentrated on engineering advances in the network itself, once ‘open access’ to the network had been established innovation took place in the nodes at the ‘ends’ of the network. The era of the ‘smart network’ was replaced by innovation at the ends of the ‘dumb network’, which perhaps counter-intuitively was to prove far more dynamic. Decentralized innovation was much more prolific than the hierarchical Bell

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Labs approach and ideas could be tested in the market far more rapidly following their inception. Unshackled from the dictates of how the Bell system envisaged technological development, there was a proliferation of experimentation by a myriad of firms, and indeed individuals, all attempting to apply specific skills to communication on the network.

Thus the potential for individuals to utilize specific human capital in ICT, outside of the strictures of the Bell system, and the possibility of end-to-end innovation was only realized once the political decision to end the private monopoly of AT&T had been made. This was not a foregone conclusion. As Derthick and Quirk noted, had Congress been unrestrained AT&T might have lobbied for a far more favorable resolution. The combination of situating the break-up in Judge’s Greene’s court, the extremely neoliberal attitude towards regulation held by William Baxter of the Justice Department, and the FCC’s relatively ‘hands-off’ attitude toward re-regulation, facilitated the break-up. Without the impetus to innovation and skill formation provided by this injection of competition into telecommunications, it is arguable that the productivity boom might have been severely attenuated. Such a scenario is not ancient history. The fight over ‘open access’ in communications has re-emerged over encroaching oligopoly in broadband access. The same arguments surrounding innovation and human capital formation ought to apply equally to this contemporary dilemma.

Financial Institutions

In the previous two sections I have shown how the relatively unregulated labor markets of the United States favor employment in the kinds of high-risk ventures that fuel growth,

49 This point has been made in a number of locations: see Bar, Francois, Stepehn Cohen, Peter Cowhey, Brad DeLong, Michael Kleeman and John Zysman. 2000. “Access and Innovation for the Third-Generation
and how telecommunication deregulation prevented AT&T and Bell Labs from maintaining a pseudo-monopsony on specific human capital in ICT and a monopoly on innovation. It should be noted, however, that the possibility of being able to start up, or join, a small innovative, high-risk firm is entirely dependent on the availability of necessary financing. I have discussed how labor and telecommunication deregulation frees up individuals who wish to exploit specific human capital. However, because firms utilizing specific knowledge are often highly risky ventures they may not have access to traditional sources of finance. Thus, in order to realize the innovatory gains from specialization in human capital, the US economy required a firmly institutionalized venture capital system. Although the first modern venture capital firm, American Research and Development, was founded in 1946, the American venture capital system remained constrained by a number of regulatory instruments until financial deregulation in the late 1970s and 1980s enabled supply of venture capital to match potential demand. The clarification of the Employment Retirement Income Security Act (ERISA) by the Labor Department in 1979 - the focus of this section – proved to be the key institutional modification enabling a flood of venture capital into new ICT firms.

The critical section of ERISA, in terms of encouraging venture capital funding, was the ‘prudent man’ rule, which stated that pension-fund managers must invest with the care of a ‘prudent man’. This had traditionally been interpreted as forbidding investment of pension funds in ‘high-risk’ businesses, typically those funded by venture capital. The adjustment forwarded by the Department of Labor, centered on a reinterpretation of ‘prudent’ investment. This requirement was clarified to include ‘diversified’ investment as a sign of prudence. Such a transformation in interpretation had an enormous effect, not only because pension funds were such huge institutional investors but because they are tax-exempt and therefore can invest in moderately riskier firms than standard financial institutions are able to. Thus pension fund managers, because of this tax-exempt margin, require a lower expected rate of return than other investors and can thus invest in marginally more risky projects.

In a rather simplified manner, one could conceive of the change that ERISA made by thinking of the shape of the supply curve for venture capital\(^{50}\). Before ERISA the supply curve sloped upwards somewhat shallowly (the exact elasticity depending on the substitutability of other investments for investment in venture capital) and then suddenly becomes perfectly vertical at the point at which all investors other than pension funds had invested an optimal quantity in venture capital. When ERISA enabled pension funds to invest in venture capital this artificial constraint on supply was removed and the supply curve maintained a shallow upwards slope for all quantities. ERISA’s effect was thus largely a supply-side shock, allowing pre-existent demand for venture capital to find a new equilibrium.

Gompers and Lerner have attempted to estimate the magnitude of the effect of ERISA on venture capital funding. New commitments to the venture capital industry shot up from less than $500 million in 1979 to $5.5 billion in 1983, although the level has tended to mimic the volatility of the business since then (falling to $1.5 billion in 1991, back up to $5 billion in 1994). Regressions in industry-wide fundraising also show that a dummy variable for whether ERISA had been clarified is significant at the five percent level.

We should, however, be careful when asserting the efficacy of ERISA’s clarification. Because this was a once-off institutional transformation, our ability to prove its significance in a statistically tractable and convincing manner is somewhat suspect. Gompers and Lerner use of a dummy variable coded 1 in every year from 1979 does not provide especially robust proof of ERISA’s importance in galvanizing the venture capital industry. One could make a strong case for arguing that there were not enough small innovatory firms demanding venture capital, or ones thought of as good risks by investors, until around the early 1980s. Moreover, this period might also mark the evolution of ICT as an exploitable GPT and thus technological developments exogenous to the venture capital industry could be driving these results. Kortum and Lerner have

shown that the number of patents issued rose dramatically in the late 1980s and 1990s. However, such a surge in patenting did not occur in the late 1970s and early 1980s when the first surge in venture capital funding occurred.

Thus, a strong case can be made that although the GPT itself drove later funding, the one-off institutional transformation of ERISA was necessary to kick-start any initial venture capital industry that might exploit ICT as a GPT. Thereafter the investment cycle became self-maintaining. This analysis, however, misses a crucial element. Although the supply of financing for firms with specific human capital increased dramatically after ERISA we also need to analyze the demand for venture capital. This is dependent on the correct incentives to invest in risky specific human capital and is best explained by reference to the institutional structure of equity policy.

Equity – Policy and Compensation

As with labor regulation, much of the institutional structure of American equity regulation and compensation has a long history and is not necessarily traceable to policies enacted in the 1980s or 1990s, which might link institutional nature more cleanly to the productivity boom of the 1990s. Certainly, the use and regulation of equity in contemporary America is more usefully contrasted to that in Germany or Japan (as with labor law) than it is to earlier periods of American history. Nonetheless, the manner in which equity in firms is employed in the United States has a distinct institutional form that differs sharply from a number of other possible alternatives and thus should not be ignored in the attempt to provide an institutional explanation to the productivity boom. Indeed, because of the focus on incentives to invest in human capital in this paper, concentrating on the use of equity as compensation is absolutely essential. This section of the paper demonstrates that without a ‘culture’ of providing stock options to employees, the incentive to invest in specific human capital can be significantly eroded. Owning company stock provides an additional income above salary that compensates for the

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increased risk of losing one’s job (and therefore losing one’s investment in specific human capital) that occurs in high-risk, specific-knowledge, innovatory firms. Such a mechanism will be explored in a formal model at the end of this section. The level of capital-gains tax provides an additional institutional effect on such incentives since it affects the real value of held equity. Capital gains tax was lowered on a number of occasions over the past quarter-century and this shall also be analyzed as an important stimulus.

Given the quandary of how to encourage investment in the kinds of risky specific human capital necessary for innovation and hence the exploitation of the productive potential of GPTs, a number of different institutional alternatives exist. Casper and Glimstedt, analyzing innovation in ICT ‘middleware’ have noted that the ‘knowledge properties’ of a technology create particular challenges for employers. Because firm-specific ‘knowledge’ cannot be transferred across firms employers have to make a credible commitment that employees will not be exploited. As Casper and Glimstedt remark:

Employees have an incentive not to invest in large amounts of firm-specific knowledge, such as proprietary software languages, when there is a strong probability that their employment tenure at the firm will be short (or that the firm could quickly fail).

Given that small, innovatory firms cannot credibly guarantee that they will not go bust, or be forced to make employees redundant because of financial difficulties, some incentive system is needed to compensate employees for this risk and thus maintain levels of investment in specific human capital. Two broad options exist: a European and an American model.

The European model has been formalized by Torben Iversen and David Soskice, adapting a model by Karl Ove Moene and Michael Wallerstein. Iversen and Soskice examine

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individuals’ ratios of specific to general skills to create an ‘asset theory of social preference’. They note that the traditional political economy model of redistribution interests, the Meltzer-Richard model that ties greater inequality to greater redistribution, fails to explain why highly egalitarian countries like Sweden and Germany have far higher levels of redistribution than those of Latin America. The adapted model, first formalized by Moene and Wallerstein, notes that previous academics have failed to recognize that public spending has two distinct elements: redistribution and social insurance. The latter can dominate provided that individuals have a high enough relative risk aversion and thus wish to assure themselves compensation should they lose their present employment. Iversen and Soskice note that individuals with a high ratio of specific to general knowledge are likely to prefer high levels of social insurance given the risky nature of their asset composition. Thus, the European model can incentives investment in specific human capital by assuring state-provided compensation in the (likely) event that innovatory small firms collapse.

Although this model is intuitively convincing for the European example, it fails to fit the contours of the American political economy. Instead, I suggest American firms have circumvented the lack of a broad social insurance system by providing compensation in the form of equity to potential investors in specific human capital. Although such compensation does not provide a post hoc safety net it does constitute a prior financial incentive to work for specific-knowledge firms. Of course, general-knowledge firms are also able to offer compensation in the form of equity and this could offset the success of specific-knowledge firms in hiring or keeping employees. Nonetheless, whatever the market outcome, it is clear that equity does provide a sustainable method for encouraging specific human capital investment. This logic will be formalized in the next section, demonstrating how parameter changes in share ownership, the probability of losing a job in the specific sector, and the rate of return to specific versus general human capital can create a number of sustainable equilibria.

Before examining the precise formal mechanism of how equity compensation can incentivize human capital formation, I turn to investigate how capital gains taxation affects this logic. While capital gains tax rates stood at nearly 50% in 1978, they had been lowered to 20% in the mid 1980s and after a brief raise to 28% in the early 1990s were lowered to 14% by the Clinton administration in 1994. James Poterba notes that shifts in the capital gains tax affected venture capital funding in a very different manner than the influence of ERISA, outlined in the previous section. Where ERISA affected the supply of venture capital, capital gains tax, for Poterba, affects the demand for such funding. Lower capital gains tax increases the incentives for individuals to start their own companies since most of an entrepreneur’s compensation derives from capital appreciation on the equity of the company. Thus reducing capital gains tax encourages innovation by promoting the returns to entrepreneurship. This benefits potential investors in specific human capital in two ways. Firstly, the entrepreneurial owners of specific human capital who wish to start a firm that exploits this knowledge will be incentivized to do so. Secondly, potential employees of specific knowledge firms (the firms being obliged to offer equity as compensation in order to incentivize specific skill formation) will get a higher return on their equity. Thus, capital gains tax reduction has a beneficial interaction with incentives to invest in specific human capital: the lower the tax rate, the higher the equilibrium rate of investment.

Formalizing Incentives to Invest in Specific Human Capital

The following formal model is intended to illustrate some of the mechanisms influencing the decision to invest in specific human capital. It is a necessarily simplified abstraction of the impact of interrelated institutions but nonetheless it helps to clarify the argument of this paper by presenting it in a more rigorous form. The model is a two-stage set-up in which the worker is assumed to be working in a specific firm in the first stage (this assumption could be transferred to having them work in the general sector in the first period without loss of generality). During the first stage the worker decides how much time to invest in specific skill training and how much to invest in generalized education (respectively $A_{S}$ and $A_{G}$). This decision depends on the following parameters: $\beta_{S}$ the level of revenue sharing in specific firms; $\beta_{G}$ the level of revenue sharing in general firms; $l$ the standard wage representing payment for labor; $p$ the probability of losing his job and being employed in the general sector in round two; $R(.)$ the concave revenue function that transforms capital, wage labor and human capital into revenue; $V(.)$ the convex cost function that represents the cost in loss leisure/time; and $d$ the discount rate. It should also be noted that $x$ represents leisure, a represents individual productivity and is normalized to mean 0.

The welfare function for an individual in round one is as follows:

$$w_{s}^{i} = A_{S}^{i}l^{i} + \beta_{S}R(A_{S}^{i}, K, l^{i}) + V(1 + \alpha^{i} - l^{i} - A_{S}^{i} - A_{G}^{i})$$

The welfare function is thus comprised of three elements. Firstly there is the employee’s salary: the wage payment to labor input ‘$l$’, multiplied by the investment in specific human capital. This reflects the salary return to specific skills. The second term represents revenue sharing as a function of capital, labor and specific human capital inputs multiplied by a share parameter $\beta$. The third term represents the value of leisure, where leisure has been replaced by time-absorbing activities like work, investment in specific skills and investment in general education. The time constraint under which
individuals operate is:

\[ 1 + \alpha^i = l^i + x^i + A^i_S + A^i_G \]

Welfare in the second stage in the specific sector is:

\[ w^i_{s,t+1} = A^i_S l^i + \beta^i S (A^i_S, K, l^i) + V(1 + \alpha^i - l^i - A^i_S - A^i_G) \]

Welfare in the second stage in the general sector is:

\[ w^i_{g,t+1} = l^i + \beta^i G R(A^i_G, K, l^i) + V(1 + \alpha^i - l^i - A^i_S - A^i_G) \]

A couple of points should be made here. In this model, because we assume firms cannot ‘tell’ how much general education employees have (or rather because employees are unable to signal this) the salary rate is competed down to \( l \). This assumption is made for analytical convenience to demonstrate that employees are less well remunerated in the general sector. However, employees also can receive a share of revenue in the general sector that in part reflects their general human capital. This is because their general education increases productivity at the firm so revenues increase: however, as noted, employees cannot signal their general education level so the salary is competed down to wage rate \( l \).

Total welfare over two periods is first period welfare plus \((1-p)\) times the welfare from remaining in the specific sector and \(p\) times the welfare from joining the general sector. Both latter terms are discounted.

\[ W^i = w^i_S + \delta (1-p) w^i_{s,t+1} + \delta p w^i_{g,t+1} \]

Having established the analytical framework the optimal levels of investment in specific human capital and general human capital are calculated.
First order conditions for investment in specific human capital:

\[
\frac{\partial W^i}{\partial A^i_S} = l^i + \beta S R_{AS} - V_{AS} + \delta (1 - p) \left[ l^i + \beta S R_{AS} - V_{AS} \right] - \delta p V_{AS} = 0
\]

which, by rearrangement, is transformed into:

\[
l^i + \delta (1 - p) l^i + \beta S R_{AS} + \delta (1 - p) \beta S R_{AS} = V_{AS} + \delta V_{as}
\]

In this arrangement, we see that the marginal cost of investing in specific human capital equals the marginal benefit of today and tomorrow’s wages (which in their original formulation are multiplied by specific human capital as the salary return to wage and specific human capital combined) plus specific firm revenue share today and discounted specific firm revenue share tomorrow. With further manipulations:

\[
V_{AS} = l^i - p \left( \frac{l^i}{1 + \delta} \right) + \beta S R_{AS} - p \left( \frac{\beta S R_{AS}}{1 + \delta} \right)
\]

It is clear from this first order condition that an increase in the specific firm revenue share ‘\( \beta \)’ will encourage higher investment in specific human capital. An increase in the wage rate will also increase optimal investment since salary is a function of wages multiplied by specific human capital for employees in specific firms. Furthermore since specific human capital has an increasing effect on revenue this will also increase the optimal investment. Conversely, an increase in the likelihood of being fired ‘\( p \)’, will lead individuals to invest less in specific human capital.
First order conditions for investment in general skills (general education):

\[ \frac{\partial W^i}{\partial A^i_G} = -V_{AG} - \delta(1 - p)V_{AG} + \delta p \left( \beta_G R_{AG} - V_{AG} \right) = 0 \]

Which after transformation becomes:

\[ \delta p \beta_G R_{AG} = V_{AG} + \delta p V_{AG} + \delta(1 - p)V_{AG} \]

Here the marginal cost of general education over two periods matches the marginal benefit of profit sharing in a general company in the second period (all workers in general firms are paid a wage of \( l \), unaffected by levels of general education, the differences in which enter only as an increase in firm revenue). With further manipulations:

\[ V_{AG} = \frac{\delta p \beta_G R_{AG}}{1 + \delta} \]

Thus, as the probability of being fired, the share of revenue received in general firms and the effect of increased education of firm revenues all increase the optimal level of investment in general human capital (general education) increases.

Intuitively these results link neatly with the institutional analysis laid out in the previous sections. As noted, specific firms need to offer higher degrees of equity compensation in order to encourage individuals to invest in specific skills, which if they are fired will no longer be rewarded. This is achieved in two manners, firstly wages are higher for skilled labor (perhaps a consequence of the telecom deregulations investigated earlier, whereby skilled employees finally received their market return). Secondly, through higher shares of equity vis-à-vis general skill firms, specific firms can provide another clear incentive to invest in specific human capital.
This mimics our earlier discussion of the rise of stock-option employee compensation. Although there is no a priori reason why specific firms should offer higher equity shares than general firms the arguments made earlier should clarify why they would have a strong incentive to do so. Specific knowledge firms tend to be riskier and thus have a higher likelihood of going bust. In this model this riskiness is reflected in a higher ‘p’, which would encourage less investment in specific human capital. In order to compensate for this risk factor, specific firms are forced to offer higher equity stakes. This has indeed been common practice amongst many start-up Silicon Valley firms.

Of course, a lower ‘p’, as would be reflected in German or Swedish labor law also increases the optimal investment in specific human capital. Indeed, this is the implicit logic underlying arguments asserting that European states encourage human capital formation by their very rigidity: if employees do not fear redundancy they are more likely to invest in specific skills. Moreover, such governments have more extensive publicly subsidized training programs than are available in America. My response to this line of argument would be two-fold.

Firstly, because the model outlined above is a highly simplified two-stage model it does not give individuals released from the specific firm in time t+1 the opportunity to try to re-enter the specific sector in time t+2. Thus the key failing of the European system - that fired workers cannot re-enter specific employment as easily as those in America – is not incorporated into the model. Secondly, if we re-analyze the model by thinking about p and (1-p) as measuring the likelihood over an infinite horizon of working in the general sector and working in the specific sector our evaluations of the likely magnitude of these parameters in the US and in Europe changes substantially. Because re-entry into specific firms would be much easier in the American system, its value of ‘p’ would be far lower than seems immediately apparent; likewise the European value would be much higher. Of course, to fully reflect this adaptation in the model would require us to change the discount factors and perhaps to introduce a probability of re-employment ‘q’. However, the two-period model is adaptable enough to reflect our general intuition.
Human Capital as Skeleton Key? How Extendible is this Analysis?

The analysis I have offered does not portend to present any more than one segment of what must ultimately be a more complete analysis of the many determinants of the productivity boom. As such, one could offer many alternative suggestions that might provide equally convincing accounts. I have discussed both the insights and blind-spots of earlier research in order to demonstrate that a panoply of potentially significant arguments exist. As outlined in the introduction to this paper I view changes in broad macro-economic trends as reducible to many varied motors: as I put it, there is no ‘force informatique’. Such an assertion of the necessary incompleteness of any analysis should not, however, serve as a shield to protect the analyst from flaws in their argument. If my assertion that investment in specific human capital is a key driver of productivity growth can be shown to be false, it matters little how much of the broader question I claim it is limited to. With this qualification in mind I turn to present a number of caveats.

Firstly, I have offered no discussion of incentives to develop specific human capital by parties other than the relevant individual. Put more simply, I have discussed an individual’s own incentives to invest in their human capital but neglected the incentives of firms or of the government to invest in training these individuals. It seems clear that many of the institutional arguments I made would be weakened by re-focusing the analysis onto training schemes. For example, a firm, instead of offering revenue share to encourage employees to invest in specific human capital, might choose instead to train these workers as a compensation for the riskier nature of working in a specific skills firm. Certainly, this would then reduce the cost of training that workers might otherwise have to pay to receive higher wages. Training in specific skills might then become an institution of its own and one that I have not chosen to explore in this analysis57. On the other hand, if these skills are extremely specific, the worker will still be disadvantaged if

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57 Some interesting recent work has explored under what conditions firms have an incentive to invest in general human capital. According to Acemoglu and Pische, such investment will only occur under imperfect labor markets (perhaps an interesting institutional analysis of its own but one not realizable in
made redundant. Equity compensation might, thus, exist as a mechanism to compete for available labor rather than as a pseudo-insurance mechanism as I have asserted.

My inclination is however, that introducing training while modifying the micro-mechanism somewhat does not fundamentally alter the conclusion of this paper: that there are institutional preconditions to the development of the specific human capital that through technology-skill complementarity raises productivity. Future research ought to compare investment equilibria depending on whether individuals or firms pay the costs of training and how different institutional arrangements might alter outcomes. Such studies might present a rather less rosy picture of US institutions than has been presented in this paper, noting as Lynch and Nickell do, that levels of basic skills are far lower in the US than in Europe. These authors also assert that while American institutions may favor quick rollout of GPTs, the relative absence of state-sponsored training will weaken American productivity vis-à-vis that attainable in France and Germany ‘because of [the latter’s] effective systems of training at all levels of the ability range’.

A more methodological problem with my analysis is the absence of a simple operationalization of specific human capital investment. Without a clear measurement of a critical intervening variable I am unable to provide statistical significance to my assertions. Whilst this paper has largely served the purpose of outlining mechanisms rather than exploring the relevant data, it is not clear that were statistical tests to be conducted they would be desperately meaningful. Mulligan and Sala-i-Martin have noted recently that traditional methods of human capital measurement do not adequately reflect true worth: arguing that the usually employed variable of years of schooling is not as useful as analyzing salary levels, which represent the market return to human capital. In fact, the model presented in this paper could use both standards since it comprises general capital (general education) and specific human capital (which is reflected in the

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wage rate paid, as well as in the production function). Despite this potential approach, deriving a truly satisfactory measurement of specific human capital appears to be extremely complex.

The statistical difficulties are not merely confined to human capital as an intervening variable but also to testing the prime independent variable in this study: historical transformations in institutions. Because we only have one ‘history’ to study, the impossibility of performing perfect ‘replications’ to verify the significance of statistical results is an inherent quandary. The very passage of time is collinear with institutional change and other potentially significant variables might interfere with results: for example, broad technological progress, a ‘softening’ of the business cycle or an aging baby-boomer population. Given this inherent dilemma it seems more appropriate to try to model a potential mechanism as I have done rather than to struggle with intractable data problems.

However, it should also be noted that the model I provide is a far from complete account. It fails to model the firm’s incentives explicitly and ignores the possibility of training. Moreover it assumes that the possibility of losing one potential employee motivates firms to raise equity compensation: clearly, this event would only occur if an aggregation of employees were lost and the model thus ought to include a much more elaborate formalization of the labor market in specific human capital. A final problem with the model is broader and perhaps more fundamental given the avowed intention of this paper – to demonstrate that ‘institutions matter’\textsuperscript{60}. Although this model purports to demonstrate how institutions matter it does so by proxying them as parameters for the probability of being fired and the share of revenue devoted to equity compensation. This is hardly a satisfactory analog to my earlier assertions that institutions only take their effect when partied with other complementary institutions: this model takes place in a rather


\textsuperscript{60} Of course I am hardly the first analyst to attempt to prove this! Much of the interest in economics can be drawn back to Douglass North’s seminal work, see for example, North, Douglass. 1994. ‘Economic Performance Through Time’, American Economic Review 84, 3.
institution-free world. Part of this dilemma is the essence of modeling itself in that models must by definition abstract away from reality. However, it is potentially debatable as to how far my model is coherent with the earlier qualitative institutional assertions.

Despite these caveats I believe this research has illuminated a number of key points. Firstly, it offers an explicitly dynamic theory to explain why productivity shifted. Institutional changes are explicitly historical and provide a much cleaner reason as to why productivity was floored for decades but suddenly recovered than static analyses. Although this research clearly cannot detail the exact moment of recovery it does have predictive potential in that it portends institutional transformations will have traceable, if lagged, consequences. Secondly, this paper improves on much recent work on the causes of productivity gains\(^{61}\) by actively incorporating rules, regulations and the institutional structure of political economy into theorizing about the economy. I note not only that regulations can have detrimental effects on encouraging innovation in the private sector through, for example, labor rigidities, regulatory capture or excessive taxation of capital gains, but also that institutions might, in certain cases, produce more desirable outcomes than the unconstrained market. A number of potential market failures in the diffusion of GPTs exist, including those outlined by Bresnahan and Trajtenberg preventing optimal downstream adoption of new technology. The introduction of factors like the riskiness of specific factor endowments creates a more complicated world, in which institutions might become more desirable than in the neoclassical paradigm.

Finally, this paper has presented an analysis that seeks to operate at numerous ‘levels’ of the economy. By focusing on institutional change much of the action occurred at the macro-level of the political economy, however, this was linked by a simple mechanism (specific human capital) through to complementarities at the production function by thinking about the dilemmas firms and employees face when seeking to employ specific skills. Although this thread of analysis may be more convincing at one level rather than

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\(^{61}\) A notable exception is DeLong and Summers’ forthcoming thoughts on the roots of productivity.
others, it nonetheless presents an important step forward by depicting a variable that is coherent from the individual to the firm to the sector to the political economy.

Future research along the lines presented in this study might profitably follow two courses. Firstly, one could apply this analysis to past GPTs and investigate how important the formation of specific human capital was in increasing productivity. Since the engineering of the first steam-power operated looms and the first electrical generators was exceedingly complicated, it seems a potential analog could be found in these examples. However, the relevant institutional change might be very different from that I have outlined occurring the 1980s and 1990s. For example, one could make the Northian argument that the British lead in the industrial revolution was a function of an early development of parliamentary institutions that protected property rights from the incursions of the monarchy.\textsuperscript{62} Similarly, Paul David has made the argument that American productivity gains from the development of electricity were delayed until prices were deregulated in the 1920s.\textsuperscript{63} As to how clearly institutional change is related to incentives to invest in specific human capital in these earlier examples, it is as yet unclear.

The second route one might wish to take is to extend the analysis outside of general purpose technologies to incorporate a number of other earlier spurts in productivity not necessarily related to the development of a revolutionary technology. The post war ‘Golden Era’ and the meteoric growth of a number of East Asian countries provide such examples and, once more, clear institutional shifts pre-dated these bursts in productivity. For example, American postwar growth could be attributed partly to the boost in demand following the NIRA and the imposition of an international financial institutional structure supporting free trade. Growth in Europe has been attributed not only to the actual financial aid of the Marshall Plan but also to its conditionality requirements which forced

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\item \textsuperscript{62} North, Douglass. 1994. ‘Economic Performance Through Time’
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governments to undertake institutional change. East Asian growth, meanwhile might have been predicated on the development of strong government-business ties in zaibatsu-era Japan and to the land reforms following the Second World War in Korea and Taiwan. Once again, we would have to make clear theoretical links from such institutional transformations down to the microincentives to invest in human capital in order to support this analysis, but it seems clear that these new institutions often provided more favorable environments for such investment. Like any analysis, that presented in this paper offers just one lens through which to view the infinite complexity of political and economic interaction. Nonetheless, by picturing change in wide-focus we can capture the economy’s depth much more effectively than from a single-point perspective.

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