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ABSTRACT

This paper is an exercise in comparative institutional analysis, asking what kinds of arrangements most facilitate innovation. After identifying pervasive market failures in innovation, it explains why those associated with the Nordic model may be particularly conducive to innovation, and demonstrates that, in general, the optimal policies of the leader should differ from that of followers, but that both leaders and followers can benefit from active government policies (like industrial policies, public investments, and systems of social protection), not only leading to more innovation, but ensuring that more innovative activity is directed in ways that lead to the enhancement of living standards.

It concludes by constructing a simple model in which knowledge flows slowly across national borders but moves easily within borders. We show there is a leadership-followership equilibrium, in which some countries are leaders, others are followers. Contrary to Solow's analysis, there need not be convergence. Focusing on technological progress that is a result of learning by doing, where learning occurs within the industrial sector but spills over to other sectors, we demonstrate the optimality of policies to expand the industrial sector beyond that which prevails in competitive equilibrium.

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Leaders and Followers:

Perspectives on the Nordic Model and the Economics of Innovation

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There are marked differences in productivity across firms and countries. We look up to the "leaders," those that are at the technological frontier and who are pushing that frontier ever forward. The laggards are urged to emulate the leaders. And yet, it is not apparent that it is optimal for them to do so. The lagging countries benefit from the lower prices that result from competition among the leaders. And both lagging countries and firms can benefit from the learning that results from the investments in R & D and innovation of the leading firms, with far lower expenditures. Even with the strongest intellectual property regimes, there are important knowledge spillovers and appropriation of the benefits of knowledge acquisition is far from complete.

Even if profits at firms or standards of living in countries that are persistent leaders were persistently higher than those of firms that were persistent followers, it would not mean that the followers should change their corporate or national strategies. For there is a cost to catchup—large investments in learning—and these costs may well exceed the differences in profits. At the same time, every firm or country that is in a leadership role needs to consider whether it should rest on its laurels: live off its accumulated knowledge capital, eventually becoming a follower. The short-term boost to the present discounted value (PDV) of its consumption may more than exceed the PDV of the subsequent lower steady state level of consumption (from the dissipation of its "leadership" rents.)

This paper asks three central questions:

(a) What kinds of policies and institutional arrangements—what kind of economic systems--are most conducive to being an innovation leader—not just obtaining patents, but designing an innovation system that generates large and persistent increases in standards of living? Is it cutthroat competition? Or is the more gentle Nordic model, in which government takes on a larger role and in which a broad array of policies provide social protection and result in less inequality, more conducive to innovation?

(b) Should we expect that the policies of the follower differ from those of the leader, and if so, in what ways? Can we explain the successes of the Nordic model as a result of its policies being well adapted for the leader, or for the follower?

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[1] University Professor, Columbia University. This paper is part of a broader work on innovation, undertaken with my colleague Bruce Greenwald, and of a more long standing research agenda undertaken with Partha Dasgupta and Giovanni Dosi. This paper in particular builds off of Greenwald and Stiglitz (2006, 2014). My debt to each is gratefully acknowledged. I am greatly indebted to Karle Moene, Brett Gordon, Martin Guzman, and two referees for their helpful suggestions. I also wish to acknowledge financial support from the Institute for New Economic Thinking (INET), and research assistance from Laurence Wilse-Samson, Feiran Zhang, Sandesh Dhungana, Eamon Kircher-Allen, Jun Huang, and Quitze Valenzuela-Stookey.

(c) Can there be an equilibrium in which some countries persistently remain leaders, and others followers? If so, can we say anything about the nature of the equilibrium and the kinds of policies pursued by each in that equilibrium?

Acemoglu, Robinson, and Verdier (2012) have recently put forward the hypothesis that the Nordic welfare model may be all well and good for the follower, but the American style of cutthroat capitalism, with its high level of inequality and strong incentives, is better suited for the countries at the frontier. While contentions of such a broad sweep are hard to evaluate with any precision, similar sentiments have played a central role in policy debates and therefore it is important to assess them, marshaling whatever theoretical, empirical, and historical arguments that can be brought to bear on the issue. We thus begin with a general theoretical analysis (in section I) of why (i) unfettered markets are not likely to engage either in the optimal level or direction of innovation; and (ii) why government policies—including those that have characterized the Nordic countries—can and should play an important role. We follow this with a broad historical discussion and a closer look at (a) whether it is as clear as, say, Acemoglu *et al.* suggest that the US is in fact the technological leader; and (b) if so, to what that should be attributed. Section II provides an historical perspective on the U.S. experience.

Section III turns to the formulation of a leader/follower equilibrium. The model bears some similarity to two earlier important contributions by Krugman (1981) and Matsuyama (1992), but there are important differences in the questions being asked and in the model formulation which we describe more fully below (Appendix B). Our concern is to construct a global general equilibrium model in which there is a steady state with constant growth characterized by persistent differences in standards of living, without any convergence; and to ask, should followers follow different policies than those that are optimal for the leader?

This analysis turns on its head a central question posed by neoclassical growth theory since the work of Solow (1956). The theory predicted *convergence,* that countries with different initial conditions should converge to the same growth rate; differences in savings rates would be reflected in income per capita, but not in growth rates.[2] In fact, the evidence on convergence has been disappointing. [3] Our theory explains this absence of convergence.

[2] Growth rates were determined by the rate of growth of population and labor augmenting technological progress, assumed exogenously given. The results are strengthened once we allow for international trade (Stiglitz 1970), and hold in models where the savings rate is not fixed, but endogenously determined, as in the work of Ramsey, Cass, and Koopmans.

[3] De long (1988), Durlauf and Quah (1999). (For earlier studies, with somewhat different perspectives, see Dowrick and Nguyen, 1989; Barro and Sala-i-Martin, 1991; Mankiw Romer and Weil, 1992). More recently, the World Bank has suggested that there may be a "middle income trap," i.e. that middle income countries systematically do *not* converge towards to the higher income countries. See Im and Rosenblatt (2013). The empirical literature on convergence is complex. Note that the theory referred to earlier focuses on countries with the same production functions, and says simply that it is the rate of growth of the labor force and labor augmenting technological change that are the underlying drivers of growth *rates*; growth rates in per capita income among countries with the same labor augmenting technological change should be the same, even if savings rates differed. And if knowledge flowed freely across boundaries, presumably countries would have the same rate of technological change. It is precisely this question upon which section III of this paper focuses.

In the leader-follower equilibrium, it is optimal for laggard countries to remain laggards, and never catch up. They sufficiently benefit from the dissemination of knowledge from the leader that it doesn't make sense for them to make the "Big Push" to join the club of leaders. But, except in some limiting cases, the followers are not fully passive—they pursue policies designed to close the gap between themselves and the leader, but even as they do so, the leader pursues policies that open the gap further. Not surprisingly, even though both leaders and followers pursue "innovation" policies, the policies that are optimal for each can be markedly different from those of the leader. As usual, one size fits all policies don't work.[4]

We end the section with a discussion of several examples of such differences, but observe that the Nordic model may (with suitable adaptations) be desirable not only for leaders, but also followers.

We should emphasize at the onset that while we talk about leaders and followers, our characterization is too stark. Knowledge is multidimensional. Some firm/country could be on the knowledge frontier along some dimension, but well within the frontier on another. That is certainly true among countries that claim to be "at" or "near" the frontier, implying that they have a considerable amount to learn from each other.

I. Market Failures and Innovation Theory and Policy

1.1. Market failures and innovation

The fundamental theorems of economics argued for the (Pareto) efficiency of a competitive market economy.[5] But the Arrow-Debreu model had nothing to say about innovation--the state of technology was assumed given. Schumpeter (1943) had argued that contrary to the finding of standard welfare economics, monopolies (or more accurately, a sequence of monopolies, where firms competed to be the monopolist) were desirable, because they maximized the pace of innovation. A host of studies have shown that Schumpeter's conclusions were wrong[6], and

[4] This was one of my critiques of IMF policies in the late 90s, later extended in demands for excessively similar intellectual property regimes both in the WTO Uruguay Round negotiations and at subsequent negotiations at the WTO and at bilateral and regional levels. See Stiglitz (2002), Charlton and Stiglitz (2005), Dosi and Stiglitz (2014), and Cimoli *et al.* (2014a) and the works cited there.

[5] Though as I showed (Stiglitz (1994)) under the conditions hypothesized, a socialist market economy would have done as well.

[6] For instance, Dasgupta and Stiglitz (1980a) showed that monopolies have the ability and incentives to persist, and Fudenberg *et. al.* 1983 and Dasgupta and Stiglitz (1988) show that incumbents can deter entry with only limited investments in innovation: potential competition may not prove the spur to innovation that Schumpeter thought. While the earlier proofs of pre-emption assumed non-stochastic returns, the results are more general, as Greenwald and Stiglitz (2014) demonstrate. (See also Gilbert and Newbery, 1982.) Still, Schumpeter was partially correct: in a wide variety of circumstances, more competitive markets may be less innovative. Greenwald and Stiglitz (2014) develop several reasons for this: (a) While overall production for a monopolist is smaller, the production of each firm is larger, and incentives to innovate, e.g. for cost reducing innovation, are related to the scale of production of the firm. (b) The expected returns to investments in innovation depend on the chances of success, and that may be decreased if there is more competition in the innovation market (simply because there are more competitors.) But there are forces also going the other way: With imperfectly correlated research

that the endogenous market structure and the associated levels and patterns of innovation arrived at by the market (which may be a monopoly or an oligopoly) can be improved upon by government intervention.

It should come as no surprise that markets are not efficient, since, with or without patents[7], social and private returns to innovation are markedly different, partly because of the difficulties of appropriating all the returns to innovation—knowledge spillovers are pervasive; partly because much of the returns that are appropriated are rents that otherwise would have accrued to other firms. Imperfections of risk and capital markets and of competition are other market failures that are inherently associated with innovation--imperfections of competition and imperfections of risk and capital markets.

Innovative activity, especially when patents play an important role, is associated with imperfections of competition. This has consequences not just for the level of investments in research, but also for the direction of research: firms have incentives to innovate in ways that enhance and extend their market power, while entrants have incentives to attempt to "steal" some of the rents away from others.[8]

Most fundamentally, knowledge can be viewed as a public good, and the private provision of a public good is essentially never optimal. While intellectual property may enhance the appropriation of returns, in doing so, it introduces a static inefficiency, in the restricted use of knowledge.

These market failures in innovation are compounded by broader market failures in the economy. If private returns to investments in any sector differ from social returns, there will be a misallocation; and this is true for investments in R & D as well. If the private returns to financial innovation exceed social returns, there will be excessive resources devoted to financial innovation relative to innovation in other sectors of the economy. If environmental resources are underpriced, there will be too little resources devoted to innovation reducing

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strategies among different firms, the more firms engaged in innovation, the higher the probability of success. And monopolies may suffer from "agency" problems (Hart 1983): competition can be a spur to effort, e.g. as in a contest (Nalebuff and Stiglitz 1983). Market structure is itself endogenous (Dasgupta and Stiglitz 1980b), and the relationship between competition and innovation may depend on underlying structural parameters, such as cross elasticities of demand. (Goettler and Gordon, 2011, 2014).

In recent years, within the macro-innovation literature, a few have claimed that there exists an inverted-U (or monotone increasing) relationship between competition and innovation (Aghion 2005, Scherer 1967). There is little generality to this relationship, as Stiglitz, 2014c points out. For a broader discussion of the welfare economics of innovation, see Greenwald and Stiglitz, 2014. For further discussion of the more recent literature on what has come to be called Schumpeterian competition in the more macro-focused literature, see Aghion, Akcigit,and Howitt, 2013. For a survey of both the theoretical and empirical literature from a more micro-economic perspective, see Gilbert (2006), who provides a critique of much the empirical literature. See also Vives (2008).

[7] Greenwald and Stiglitz (2014) provide a more comprehensive discussion of market failures and the ways in which social and private returns differ. For instance, the social return to *faster* innovation is the increased present discounted value of benefits from having the innovation arrive earlier than it otherwise would, markedly different from the private returns: the first to file the patent gets the entire innovation rents.

[8] There are numerous examples of each of these phenomena: patents aimed at enhancing hold-ups, research on me-too drugs, innovation directed at "evergreening."

environmental impacts. If wages are such that there is unemployment (perhaps because of efficiency wage considerations), then will be excessive incentives for labor-saving innovation.[9]

There are, in short, a myriad of ways by which private and social returns to innovation (with or without patents) differ, leading to systemic inefficiencies, both in the level and direction of innovation. [10]

We will discuss below how, in the most innovative economies, many governmental policies can be viewed as mitigating the consequences of some of the more important of these market failures.

1.2. Translating innovation into higher living standards

While it is often taken for granted that innovation makes society as a whole better off, this may not be the case. Some innovations may decrease the demand for some factors (unskilled labor saving innovations[11]), even as they increase the productivity of others. The result is that some groups may be better off, others worse off. It is not in general the case that innovation is Pareto improving; and if those that are made worse off are poor individuals, it is not even the case that social welfare is improved, if we evaluate the change with an inequality averse social welfare function.

The proponents of innovation argue that it is always the case that the winners could compensate the losers. But even if as a result of innovation, the winners could compensate the losers, in most societies, they don't.[12] As a result *most* citizens can be worse off. Of course, arguably, that is precisely what has been happening in the US, with median household income lower than it was almost a quarter century ago[13], and with median income of a full time male worker lower than it was in 1968, almost a half century ago.[14]

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[9] For a discussion of the misallocation of resources towards financial innovation, see the discussion below. For a model showing that markets invest too much in labor-saving innovation in an economy in which there is unemployment generated by efficiency wage considerations, see Stiglitz, 2014d.
[10] See, e.g. Stiglitz (1987), Greenwald and Stiglitz (2014), and Dosi and Stiglitz (2014).
[11] See, e.g. Hicks (1932)
[12] Even the proposition that free trade can lead to Pareto superior outcomes needs to be qualified: in the absence of good risk markets, the increased risk associated with free trade can make everyone in all countries worse off. The new equilibrium can be Pareto inferior, under quite plausible assumptions. See Newbery and Stiglitz (1984). This result has a direct bearing on the welfare gains associated with innovation. Ex ante, the general equilibrium consequences of innovation are always going to be uncertain. Thus, in the absence of good risk markets, the introduction of an innovation can lower ex ante expected utility of *all* individuals, even if the innovation will (almost certainly) increase productivity, as we note in the last paragraph of this section.
[13] U.S. Census Bureau, Historical Income Table H-09, available at https://www.census.gov/hhes/www/income/data/historical/household/ (accessed May 8, 2014). While there is considerable controversy about the explanation of these adverse trends—they are related not just to changes in technology but to other societal changes (such as the weakening of unions and globalization), a major strand of research assigns a central role to skill-biased technological change. See, e.g. Autor et. al. (2008)
[14] US Census Bureau, Historical Income Table P-36,available at https://www.census.gov/hhes/www/income/data/historical/people/ (accessed May 8, 2014).

Indeed, recent research has shown how in the presence of imperfect and costly labor mobility, *all* (or almost all) individuals can be worse off. If, for instance, there is labor saving innovation in some sector at a fast enough pace (outpacing the growth of demand), employment and wages in that sector will fall. With perfect mobility, those in that sector will move to other sectors. But with imperfect mobility, workers in the innovative sector may be trapped. But as their incomes decline, they decrease their demand for goods from other sectors. The economy may enter into a sustained slump. Delli Gatti *et al.* (2012a, 2012b) construct a model demonstrating this, arguing that it provides a new interpretation of what happened during the Great Depression (where productivity increases in agriculture contributed to 50% decreases in income in that sector; but the workers were trapped, partly because the value of their assets, both human capital and real estate, had diminished greatly as a result of what was happening.) They suggest it is part of what is contributing to the Great Recession. Partly because of the capital and risk market imperfections to which we have repeatedly alluded, markets on their own are not very good at ensuring the smooth structural transformation that is required if innovation is to lead to an increase in societal welfare, and especially one in which most citizens benefit.

Even in the absence of these very adverse outcomes, most individuals in society can be worse off in the presence of a faster pace of innovation (in the absence of adequate systems of social protection and redistribution) for another reason: Individuals are risk averse, and even if the benefits of innovation were randomly distributed, so that all individuals had an equal chance of benefitting, if the risk is large enough, ex ante expected utilities are lowered.

These adverse effects on the standards of living of many, if not most, citizens plays an important role in the political economy analysis of section 1.5.

1.3. National innovation systems

Recent research comparing different economic systems has looked at markets as just one of many possible institutional arrangements by which resources get allocated, decisions get made, and risks get shared. (See, e.g. Hall and Soskice, 2001, and Esping-Anderson, 1990).

This is especially relevant when it comes to innovation. In particular, recent years have seen extensive studies of the determinants of innovation, with a focus on *national innovation systems* (Freeman, 1995, Lundvall, 1992, Nelson, 1993, Patel and Pavitt, 1994). David (2004a, 2004b) and Dasgupta and David (1994), building on a long tradition of work in the sociology of science (e.g. Merton,1973) have argued that peer recognition is more important than pecuniary incentives. Societal attitudes--the acceptance of science, the questioning of authority, the embracement of change--also are pivotal.[15]

[15] These attitudes themselves are, at least to some extent, endogenous, and are affected by the economic and political system.

The analysis of national innovation systems calls attention to the multiple inputs into the innovation process (skilled researchers, finance, the pool of ideas upon which researchers can draw) and multiple steps in the innovation process—from basic research, which underlies many of the most important advances, to applied research, from "big" innovations to the smaller refinements, which cumulatively may be far more significant.[16] The pace of these follow-on innovations can be adversely affected by patents-- the most important input into follow-on research is prior knowledge, and to the extent that the patent system makes access to this prior knowledge more difficult, the pace of follow-on innovation may be slowed.[17]

The single-minded focus on one part of the innovation process and one set of determinants (material incentives) may give misleading views on the overall determinants of the pace of innovation—and provide misguided policy advice.

For instance, there is evidence that more important than (pecuniary) incentives in determining the pace of innovation is the set of innovative opportunities,18 and the patent system, combined with cutthroat competition, encourages firms to try to take as much out of the available pool of knowledge and contribute as little to it as they can. The result is that policies (like stronger intellectual property rights) that, at any given size of the pool of knowledge, may provide stronger pecuniary incentives lead to a smaller set of "opportunities" available for others to draw upon, so much so that the pace of innovation will, under plausible conditions, actually be reduced. (Stiglitz, 2014a).19

Indeed, there is a large and growing literature arguing that strong[20] patent systems *undermine* innovation, even beyond the important adverse effects noted earlier in reducing the size of the pool of knowledge from which others can draw and by increasing the cost of access to knowledge, partly by diverting scarce innovative resources to circumventing and extending patents and enhancing the monopoly power that is derived from patents, and partly because of

[16] For a discussion of national innovation systems from these perspectives, see Stiglitz, 2013, 2014e. Nordhaus has also written usefully on the subject; see for example Nordhaus (1969).
[17] There is an extensive literature detailing the adverse effects of the patent system on follow-on innovation. A recent dramatic example is provided by the patent on the BRAC genes (which play a critical role in determining the likelihood that a woman gets breast cancer.) Before the US Supreme Court ruled against the patenting of genes, Myriad, the patent holder, suppressed the development of better tests for identifying the presence of the gene.
[18] See Dosi and Stiglitz (2014) and the works cited there.
[19] In these models, the result noted earlier, that even if stronger incentives lead to more investment in R & D, the pace of innovation may be lower, also holds.
[20] There are many dimensions to a patent system, so that it is not always possible to identify when one patent system is stronger than another. Some of the adverse effects of "strong" patent systems derive from particular features, e.g. the absence of well-defined provisions for "opposition," resulting in over-patenting (see Henry and Stiglitz, 2010), the granting of excessively broad patents, or patents lacking in sufficient novelty. Some of the adverse effects associated with, say, the US patent system could be ameliorated by patent reform. Others could not.

the patent thicket and hold-ups to which it is increasingly giving rise.[21] Even when stronger incentives lead to more *investments* in R & D, it may not lead to more innovation of the kind that leads to increases in standards of living.

There are still other reasons that the patent system may not lead to a higher standard of living or a faster pace of its increase. It undermines the "open" architecture characteristic of the best innovation systems, which has traditionally been viewed as one of the virtues of research universities. Openness affects not only the pace at which the frontier is moved out, but the pace by which frontier ideas disseminate *within* a country. Even in the best performing economies, there are large gaps between best and average practices.[23] A reduction in that gap can lead to substantial increases in productivity and standards of living. Even if the patent system, for instance, resulted in the frontier moving out faster, it might actually impede the closing of the knowledge gap.

Strong financial incentives especially when combined with the patent system can actually be counterproductive for other reasons: they undermine the "open" architecture that is characteristic of the best innovation systems, and which has traditionally been viewed as one of the virtues of research universities.[24] A focus on strong financial incentives has broader societal consequences: creating value systems that put less emphasis on the pursuit of knowledge—so essential for basic research which is the foundation upon which *all* innovation rests—than on the conversion of existing knowledge into marketable products. But unless the wellspring from which applied technology draws is replenished by advances in basic science, eventually the pace of applied innovation itself will have to slow. Moreover, in science, because peer recognition plays a far more important role than financial rewards, a system that emphasizes material rewards effectively downgrades the relative importance of the incentive structure that is at the core of science.

Furthermore, a hallmark of American-style financial capitalism is its *short-termism,* its focus on quarterly returns, which is antithetical to the undertaking of long-term major innovation.

More generally, in complex "games" of innovation, e.g. involving patent races, with differing patterns of ex post competition (e.g. Bertrand or Cournot), different degrees of exclusivity (to

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[21] There is a large body of research on each of these topics, and several overall assessments of the contribution of the patent system to innovation. See, e.g. Boldrin and Levine (2013), Greenwald and Stiglitz (2014), Heller and Eisenberg (1998), Huang and Murray, 2008, Moser, 2013, Williams (2013). On the subject of patent thickets and hold-ups, see, e.g. Shapiro (2001, 2010). It appears that the patent thicket is a particular problem in certain sectors, e.g. software and nano-technology. See European Commission (2008), Clarkson *et. al.* 2006.

Historically, the adverse effects of the patent system in the development of the automobile and the airplane have been often noted. Most recently, Goldstone (2014) notes that the attempt by the Wright brothers to inhibit follow on innovation had a disastrous effect on the development of the American airplane industry, to the point where with the onset of World War I, no American plane was good enough to go into combat. The industry only developed once the government insisted on cross-licensing.

[23] See Baily *et. al.* 1992, Greenwald and Stiglitz (2014) and the references cited there for evidence.

[24] This is viewed as one of the adverse consequences of the Bayh-Dole Act in the United States.

what extent does the patent exclude other innovators), and different structures to the research process[25], the relationship between incentives, the intensity of competition (in the innovation market as well as in product markets), and the level of innovation is at best ambiguous. Incumbent firms may be able to pre-empt entrants[26], at least to a large extent, perpetuating for an extended period their dominant position, often with only limited innovation. In such models providing more incentives, especially incentives that are not carefully designed, may have no or limited or even an adverse effect on innovation.

National innovation systems involve, of course, more than the design of *financial* incentives to R & D, narrowly understood. Behavior is affected not only by how much one wins when one succeeds, but also the consequences of failure. Research is very risky, and the amount of risk-taking that is undertaken within any society depends on how risks are mitigated. We argue below that it is not self-evident that American style capitalism provides the best system of risk mitigation.

The flow of resources into any activity depends on *relative* rewards. The financialization of the American economy has resulted in disproportionately large rewards to those in the financial sector, discouraging more talented individuals from engaging in other, socially productive research. Moreover, as we noted in the introduction of this section, in science, peer recognition plays a far more important role than financial rewards; indeed, an economic system that emphasizes material rewards effectively downgrades the relative importance of the incentive structure that is at the core of science, effectively discouraging innovation.

A country's national innovation system determines the flow of resources (inputs) into innovation in other ways. The other vital input into research, besides access to prior knowledge, is trained personnel. This requires an educational system that taps into the most talented individuals, regardless of the education and income of their parents. The Scandinavian

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[25] Much of the theoretical work has assumed that the arrival of an innovation can be described by a Poisson process. Stiglitz (2014b) not only explains why that model probably does not provide the best description of the innovative process, but that results about, say, the impact of increased competition are sensitive to the nature of the innovative process. Markedly different results obtain with different processes.

The analysis of the effect of competition on innovation entails balancing several different effects. Consider a cost reducing innovation. The incentive to engage in this research is affected by the size of the market; sales in a more concentrated market of any particular firm are likely to be larger. Incentives are also affected by the likelihood of being the winner in a patent race. This can be adversely affected by the number of competitors in the patent race. But while any individual firm in the patent race may thus invest less in innovation, with diversified research strategies, the more competitors, the more likely that one will succeed. On the other hand, if competition in the product market is less intense (if there is less of a "winner take all" market), then those who lose the "race" to be the best still can earn significant returns to their innovative activity. Innovation becomes less risky, and this encourages innovation.

[26] Under more cutthroat or intense competition rules (games), the leading firm in any sector has the ability and incentive to actions which encourage others to drop out, resulting in effect in lower performance. See Nalebuff and Stiglitz (1983).

countries have achieved the highest level of opportunity, the US, the lowest level among the advanced countries.[27] While it is perhaps not inevitable that a society with cutthroat competition and high levels of inequality will have a low level of economic opportunity, it appears that there is a systematic relationship between the two, and ongoing research has helped explain why that is likely to be so.[28]

Earlier, we noted that there were many stages to the innovation process. All innovation rests on the foundation of basic research, which is overwhelmingly financed by government. But government even plays an important role in financing applied research. [29] Recent research has highlighted the role of the *entrepreneurial state* in promoting innovation. Mazzucato (2013) shows that even the US has, almost from start, been a *developmental state,* in which government promotes new industries and sectors (such as telecommunications, through investments in the first telegraph line, and creating the internet), and in which government plays a leading role in increasing productivity in established sectors, like agriculture (both through research and extension services).[30] Governments have actually played key roles in financial sector innovation, in the kinds of innovation that actually led to greater societal well being--helping create deep mortgage markets and banks oriented to the provision of long term credit.[31]

The reasons that the government has played this pivotal role can be closely linked to the "market failures" described earlier in this section. In some cases, government played a role because of the importance of diffuse externalities—it would be hard for any single firm to appropriate the returns. This may have been particularly relevant for government support of agricultural research. In some cases, capital constraints seem to have played a dominant role, especially in the context of inadequate systems of risk sharing and in situations where the scale

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[27] See Stiglitz, 2012a and the references cited there.
[28] See Krueger (2012), who refers to the relationship as the Great Gatsby Curve.
[29] In the US, the federal government funds around 30 percent of R & D and more than half of basic research. Note that there can be significant externalities arising even from applied research. (National Science Foundation, 2014. Figures are for 2011, which was the most recent available data at the time of writing. http://www.nsf.gov/statistics/seind14/index.cfm/chapter-4/c4h.htm).
[30] Other recent studies of innovation in the US and other market economies have similarly emphasized the role of the state. Janeway (2012) observes, "From the time Britain established the first industrial economy...state policies [have]...repeatedly succeeded in driving economic development," (p.7) echoing List's observation in 1841, "had the English left everything to itself--laissez faire and laissez aller--the merchants of the Steelyard would be still carrying on their trade in London, and the Belgians would be still manufacturing cloth for the English, England would still have been the sheepyard for the Hansards."
[31] Recent failures in the financial sector should not, however, be attributed to these activities, as the Commission established by Congress to investigate the 2008 crisis concluded (2011). The US mortgage agencies Fannie Mae and Freddie Mac were privatized in 1968. State level authorities that continued to offer conventional mortgages, such as that of New York, even managed their way through the housing crisis well.

of the required investment is very large (Cf. the role of government in financing the first telegraph line or development of the internet.)[32]

In short, creating a learning/innovation economy and society entails far more than just establishing strong monetary incentives; and such incentives may in fact have an ambiguous effect on the pace of innovation, and an even more perverse effect on the overall level of standard of living and the pace of increases in those standards.[33]

1.4. The Nordic Model, Cutthroat Competition, Market failures, and Innovation

In the previous section we explained why it is that we should not expect markets on their own to produce the optimal rate and direction of innovation. We argued, moreover, that the encouragement of innovation needs to be viewed far more broadly than just the provision of pecuniary incentives. We need to view innovation within the context of a national innovation system, with due attention to the pool of innovation opportunities, the stock of well educated people capable of being innovators, and the structure of the economy and society. And within this broader perspective, a single minded focus on pecuniary rewards may be, as we have seen, counterproductive.

With these ideas as background, we address the critical question of "comparative innovation systems": Why might we expect the Nordic Model to be better at addressing the market failures associated with innovation? Why might we expect societies that follow that model to be highly innovative? By the same token, we need to ask, if the United States is the innovation

[32] Schumpeter (1943) emphasized the importance of capital constraints, e.g. because research (unlike investments in real estate) could not be collateralized. While venture capital funds have been an important American innovation, providing funds to new research enterprises, their scope is still very limited, both in scale and across sectors.

[33] We could formalize the insights provided in this section by hypothesizing that, say, the pace of innovation (say measured by the rate of labor augmenting technological progress in productive enterprises) I, is a function of (a) the level of private investment in innovation, i; (b) the supply of critical inputs, like trained personnel, E (or the cost of such personnel, itself a function of E); (c) the set of opportunities, P; and (d) the fraction of the private investment that goes into socially productive investments, as opposed to me-too-research, research directed at increasing the ability of private firms to exploit market power or to take advantage of others (e.g. by increasing the addictiveness of cigarettes), β; and (e) the productivity of these investments, e.g. either in terms of how productive inputs translate into innovations (e.g. as a result of a focus on long term versus short term returns), or in terms of how quickly these innovations disseminate through the economy, leading to increased productivity, ζ. Each of these variables, in turn, are a function of the design of the economic system, e.g. the patent system, the system of financial rewards (including the progressivity of the tax system), the systems of social and intellectual property rights protection, the educational system, competition policy, bankruptcy laws, etc. We have argued that the nature of financial awards is just one factor, and not the most important factor, in determining the pace of innovation; and that indeed, the total derivative of the pace of innovation with respect to an increase in financial rewards (the degree of cutthroat-ness of the economy) may well be negative. Stiglitz (2014a) develops a simple model exploring a subset of these interrelations (focusing on IPR, investments in R & D, and the pool of opportunities, P), and shows that even a change that increases the level of investment in R & D, at a given set of opportunities, can under plausible conditions, have an adverse effect on the pace of innovation, because of the adverse effect that that has on the stock of opportunities.

leader and Scandinavia are followers, to which of the policies and institutional structures do we attribute the US role? If the US model is good for innovation, is it because of its financial sector (the invention of the venture capital industry), its superior research universities, or, as Acemoglu *et al.* seem to suggest, because its cutthroat competition? If the Nordic model is *not* good for innovation, the question is, what aspects of that model are most problematic?

Among the common attributes of the Scandinavian model are low inequality[34], partly a result of wage compression, partly the result of tax and transfer policies; strong systems of social protection; strong policies of gender equity and child protection; high levels of openness; pro-active industrial and labor policies, including heavy government investments, efficiently executed, in education, technology, and infrastructure; strong and open democracies, with strong support for a competitive and critical press and a long tradition of right-to-know laws. Presumably, critics of the Nordic model are not complaining about the openness and transparency of government or of its efficiency, but the diminution of incentives, particularly associated with its egalitarianism.

Here, I want to argue that there are theoretical grounds for arguing that the Nordic model may in fact be better for innovation than the "American" model--suggesting that if the US adopted at least some of the institutional arrangements that are associated with the Nordic model, innovation would be higher--and societal welfare would be improved even more.

(Any normative discussion of comparative institutional analysis has to address the issue of how one is to assess performance. The analysis of the previous subsection has explained why we should not focus on an intermediate measure, like expenditures on R & D, since those expenditures may not be directed at improving societal performance, but rather at enhancing market power[35]. Later, we will explain why patents may prove to be an even less satisfactory indicator. Commonly, the focus is put on GDP, but a wide body of research, growing out of the work of the international Commission on the Measurement of Economic Performance and Social Progress (Stiglitz, Sen and Fitoussi (2010))has emphasized the inadequacy of that metric (especially if one evaluates welfare using an inequality-averse social welfare function).)

The meaning of cutthroat competition and its impact on innovation

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[34] Fochesato and Bowles (2014) argue that what is distinctive of the Nordic countries is not inequality in wealth but inequality in living standards and in mobility. Blundell, Graber, and Mogstad (2014) describe the role that Norway's progressive tax-transfer system plays in attenuating the magnitude and persistence of income shocks.

[35] As we have noted, so long as there are large discrepancies between social and private returns, there may be large discrepancies between societal benefits and even increases in profitability.

The advocates of the advantages of the American model for innovation, such as Acemoglu *et al.* argue for it on the basis of the stronger incentives that it provides.[36] The discussion of the previous section should have made clear, however, that assessing the relationship between some notion of competition and the level of innovation directed at increasing standards of living is, at best, difficult. More competition in *research* (to be the next dominant firm in a Schumpeterian world with sequential monopolies) may reduce the marginal return to research and therefore the level of investment of each firm, more than offsetting the benefits of having additional researchers. More competition in the product market typically reduces the scale of production of each firm, and therefore attenuates incentives for cost reduction.

The analysis of the previous subsections, establishing that unfettered markets lead to Pareto inefficient outcomes, has an immediate implication: unrestrained markets do not result in the optimal level of socially productive innovation. To be sure, they may result in more innovation of an unproductive form (enhancing, for instance, market power or the ability of firms to exploit others). Cutthroat competition can be associated with actions (such as that of Microsoft) discouraging the entry of rivals, and directly impeding innovation. While the question of whether restricting the degree of concentration that would naturally emerge in a market would result in more competition is an unsettled matter (with, as we noted earlier, results depending critically on the nature of competition in the market and the nature of the innovative process), actions directed at stifling *innovative* competition is different, and is more likely to have adverse effects. Some forms of competition policy restricting such anti-competitive practices ("cutthroat competition") will have a beneficial effect on innovation.

An alternative interpretation focuses on the strength of intellectual property rights. We have already pointed out, however, that even if stronger intellectual property rights leads to more innovation *given a set of technological opportunities,* the set of technological opportunities available for development is itself a function of the intellectual property regimes, and once this is taken into account, stronger intellectual property rights can have an adverse effect on the pace of innovation. [39]

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[36] Interestingly, in many manufacturing sectors, US R&D outlays by the *private sector* as a percentage of sales is lower than in other countries. In office, accounting, and computing machinery, in 2008 it was only 13.6%, compared to Sweden’s 13.9%; in electric machinery, it was 2.5%, compared to Sweden’s 3.2%, and Japan's 8.0% (France was 3.5% in 2006); in motor vehicles it is 3.2%, as compared to Japan's 4.4%, and Germany's 5.0% (France was 4.4% in 2006). Even in aircraft and spacecraft, a sector in which the US dominates, in 2007 it was 9.9%, as compared to Italy's 13.4% (though the U.S. edged up to 15.4% in 2008, a year for which the OECD has not yet provided data for Italy). (OECD Structural Analysis (STAN) database.) (One has to be careful about the use of reported R&D data for certain sectors, such as pharmaceuticals, because marketing expenditures are intertwined with R&D expenditures, contributing to the high levels of reported research in that sector.)

[39] Empirically, as we discuss in more detail below, the importance of intellectual property rights (even in the partial equilibrium sense) varies greatly across industries.

There are still other interpretations of what might be meant by cutthroat competition: A culture that glorifies litigation at the expense of cooperation. But this litigation exerts a large toll on the innovative process, with some suggesting that as much is being spent on litigation as on research itself (Dosi and Stiglitz, 2014; Cimoli M., G. Dosi, K. Maskus, R. Okediji, J. Reichman, and J. Stiglitz, 2014b) and the constant threat of suit as a result of the patent thicket dampening innovation itself.[40]

If cutthroat competition is set in contradistinction to cooperation, there is another reason that its effects can be adverse: Cooperation is particularly important in the context of complex products requiring large numbers of innovative inputs.[41]

Finally, "cutthroat competition" could mean a social system in which there are weaker social protections and in which the state plays a less central role in the economy. We will explain later why stronger social protection may actually have a positive effect on innovative activity.

Acemoglu *et al.* have constructed a model showing that for one interpretation of cutthroat competition more competition *could* lead to more innovation: but the results follow directly from the assumptions; they are hard-wired into the model. It should be obvious that one can write down models in which more cutthroat competition or less progressive taxation or stronger intellectual property rights leads to a faster pace of innovation. But that is not the question, for it is equally possible to write down models with just the opposite results, where strong intellectual property or more intense competition leads to lower levels of innovation, and elsewhere we have done that.[42]

Contrary to Acemoglu *et al.* it is simply not the case that institutional arrangements that lead to more cutthroat competition[43] will necessarily be associated with higher levels of investment in innovation, let alone higher standards of living.

Our earlier discussion explained that a society's innovation system is far more complex. *If* it is the case that the US is most innovative country (in the relevant sense—a hypothesis which we question below), there are many other reasons *other* than cutthroat competition why this

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[40] The adverse effect on this litigation on the development of key innovations, such as the airplane, have been extensively discussed (see, e.g. Goldstone (2014) and Stiglitz (2006)).

[41] When cooperation is achieved, it is often achieved in a way which make it more difficult for new firms to enter the market. The established firms create a patent pool, but intellectual property acts as a strong and effective barrier to entry.

[42] See Greenwald and Stiglitz (2014) and Stiglitz (2014a, b, c)

[43] Indeed, cutthroat competition is often associated with attempts to raise rivals' costs (Salop and Scheffman 1983), socially destructive activities that put one at an advantage over competitors. Moreover, dominant firms may engage in ruthless practices to foreclose opportunities of rivals—the actions taken by Microsoft against its competitors Netscape and RealNetworks, firms that were the real innovators alluded to earlier provide telling examples. While some of its actions were eventually found to violate anti-trust laws, its strategy worked—the rivals never recovered—with an almost surely adverse effect on other potential innovators in this crucial market.

might be so. The success of the US may have more to do with the large role played by the government than to the entrepreneurial role of the private sector (Mazzucato, 2013). Even when we turn to private sector innovation, we find a picture quite different from that painted by Acemoglu *et al.* Probably the most innovative American firm during the twentieth century was a regulated monopoly, largely shielded from competition, with its research budget funded by, in effect, a tax on telephone service.[44] There are several reasons why that was so: Some of these are related to the fact that because a monopolist has a larger output (than say a duopolist, where though total output is higher, the amount produced by each firm is smaller) it has more incentive to bring down costs. Moreover, shielded from cutthroat competition, it could focus on the long run, including the benefits which it might receive in the long run from investments in basic research.[45]

The more general analysis referred to earlier, showing that the relationship between innovation and competition (however assessed) depended on a variety of characteristics, e.g. of the stochastic process of innovation, the substitutability among goods, the nature of the market barriers, etc. suggests that the American model may be good for innovation in certain areas, adverse in others.[46] It may be good, for instance, in those sectors where patents play an

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[44] See Gertner, 2012.

[45] Note that it was *not* Schumpeterian competition—the threat of entry—that drove the innovation.

[46] As we have noted, various theoretical and empirical studies on the relationship between competition, intellectual property rights, and innovation come to conflicting results and/or show that even under plausible assumptions, results are ambiguous. One of the reasons for these results is that competition and innovation are both endogenous variables, and as Goettler and Gordon (2014) have pointed out, changes in structural parameters that affect the equilibrium level of competition can have differing effects on the equilibrium level of innovation. Moreover, the theoretical literature has established countervailing forces--a larger size of the market facing any individual firm (associated with, say, *less* competition in the context of Cournot) increases incentives for innovation; while agency issues, which may lead to less innovation, decrease with competition (Hart, 1983). While if firms are pursuing imperfectly correlated strategies, an increase in the number of potential innovating firms increases the pace of innovation; an increase in the number of potential innovators may reduce the (marginal) expected return to investments in innovation. Further complicating the analysis is the fact that marginal returns and average returns may move in opposite directions. For a discussion of the ambiguous effects of competition on innovation from a theoretical perspective, see Stiglitz 2014b, 2014c. Aghion *et al.* (2005) report an inverted U shaped relationship between competition and innovation, consistent with Scherer's (1967) earlier findings; and Aghion, Howitt and Prant (2013) report empirical results showing that the effect of increased competition depend on the strength of property rights, though they look at what should be viewed as intermediate variables (R & D intensity, patents) rather than the real outcomes, the pace of innovation. As we discussed, an increase in R & D expenditure in a market economy drawing upon a common pool of knowledge may not lead to a higher level of innovation.

More generally, one of the difficulties in ascertaining the determinants of the pace of innovation beyond the difficulties of its measurement is that many of the critical determinants (including, as we have noted, the level of competition) are themselves endogenous variables, and while some of the careful studies cited above attempt to address the issue of endogeneity through the use of instrumental variables, the extent to which they do so successfully remains a subject of some contention. It is arguable, for instance, whether any of the empirical studies provide a structural model or adequately control for some of the structural properties which have been shown in theoretical models such as that of Gordon and Goettler (2014) to affect the relationship between competition and innovation. See also Gilbert (2006).

important role, adverse in those in which it does not. This provides a different interpretation of the patent data referred to by Acemoglu *et al.* and discussed more extensively in the next section. We suggest that patent data (even adjusted in the careful way that they do) is not a good indicator of *overall* innovativeness, especially innovativeness in the meaningful sense--innovations that lead to increases in standard of living. Consistent with that, this "global ecology" interpretation suggests that the US may have focused its innovative efforts in those sectors where patents are important and where rent-seeking is encouraged (as in the financial sector). If this is the case, then from the perspective of global innovation, it may be advantageous to have an ecology in which there are different institutional arrangements: there is no dominant one. At the same time, one has to ask questions about political processes which result in choices of institutional arrangements which, even if advantageous to innovation from a global perspective, are disadvantageous to the majority of its citizens.

Broad perspectives on institutional design

There are several key aspects of the Nordic model that may be particularly conducive to innovation. Earlier, we noted the importance of the (inherent) absence of a full set of risk and capital markets, both for the efficiency of the economy in general and for innovation in particular. Research is risky, and better systems of social protection can thus be more conducive to individual's undertaking research. Even high taxes can be conducive to risk taking: the government can be seen as a silent partner, sharing in the gains as well as losses, with the result that there will be more risk taking.[47] [48]

A major input into research is high quality research personnel. It is generally recognized that without government intervention, because of imperfections in risk and capital markets[49], there will be insufficient investments in education. In the US, with heavier reliance on private financing of higher education, with its adverse bankruptcy laws (in which student loans are essentially impossible to discharge), with the virtual absence of income contingent loans,

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[47] This is the essential insight of Domar and Musgrave (1944) and Stiglitz (1969). The details of the tax system affect the extent of risk sharing, and thus, the extent to which innovation is encouraged.

[48] Earlier, we referred to the important role that social attitudes and mores can play: the Enlightenment was a change in mindset, and that change in mindset was far more important than any change in property rights or incentive structures. So too here: attitudes towards failure can affect individual's willingness to undertake risks. The determinants of these social attitudes would take us beyond the scope of this paper; but there is a growing body of research emphasizing the role that government policies can play. See the forthcoming World Bank 2015 World Development Report.

[49] As noted earlier, themselves endogenous, and easily explained by theories of imperfect and asymmetric information. This is not the only reason that there may be underinvestment in education. Some individuals, particularly from underprivileged families, may not fully appreciate the returns to education; the assumption of fully rational expectations assumed in conventional models is clearly wrong. Most individuals rely on public provision of education at the elementary and secondary level, and there may be under provision of investments, especially in communities in which there are large numbers of poor individuals, especially in divided societies where rich individuals have access to private schools.

investments in education--especially in areas where returns are risky and limited, such as in science--will be more limited. And access to quality education by those whose parents have limited income will be greatly circumscribed.

Worse still, given the high cost of higher education and the skewed material rewards system, it is not a surprise that a disproportionate share of the most talented individuals have, in recent years, gone into finance; and while that may have resulted in a higher level of innovation in the financial sector, it has not resulted in a higher overall pace of innovation in the relevant sense—an increase in standards of living, or the pace by which standards of living increase. Indeed, much of the innovation was directed at figuring out better ways of manipulating the market, exploiting more those who were financially unsophisticated, enhancing the ability to leverage market power, and circumventing regulations that attempted to stabilize financial markets and reduce the risk of large adverse externalities.[50]. While these innovations may have generated more rents for those in the financial sector, there is no evidence that they improved the overall performance of the economy, as Paul Volcker, former chairman of the Federal Reserve pointed out[51]. The innovations did not help, for instance, borrowers to manage risk. Quite the contrary: there is good reason to believe that both directly and indirectly (both as a result of the misallocation of scarce innovative resources and through the economic volatility and increased rents to which their actions gave rise) the economy's overall economic performance was lowered in recent years by these so-called financial innovations.[52]

Education is not the only critical factor that is complementary to private investments in innovation. Good investments in infrastructure can increase the returns to private investments (as Alex Field has shown (2011)) in general, including investments in innovation.

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[50] Other innovations, such as high frequency trading , were directed more at obtaining rents that would have otherwise accrued to others. Not only may such expenditures by dissipative--the gains of the High Frequency Traders occur at the cost of losses to others, but in the process of this "redistribution" real resources are used; but high frequency trading may actually make markets less informative, with adverse effects on the efficiency of resource allocation. See Stiglitz (2014f) and Biais and Woolley (2011).

[51] See for example the report Volcker coauthored, Group of Thirty (2009).

[52] The US is viewed as the center of financial innovation. Yet growth in the US in the era of financial innovation (beginning with deregulation around 1980) was markedly lower than in earlier decades. At the same time, this "financial innovation" contributed greatly to the 2008 crisis. As this paper goes to press, the US economy, for instance, is still some 15% below its trend rate of growth, and there is little evidence of a closing of the gap. To the contrary, there is concern that the extended period of high unemployment will lead to an extended period during which potential growth is significantly lower than it otherwise would have been. Wilcox et. al.. 2013.

Notice that these remarks tacitly employ GDP as a measure of economic performance. If we use alternative measures of performance, US performance looks even poorer. There has been zero growth in median household income adjusted for inflation over a span of twenty five years--including the era of rapid innovation. And even that measure does not take into account the increased insecurity that has been engendered by these financial innovations.

It could thus be argued that the Nordic model, with heavier public investments in education, technology, and infrastructure, progressive taxation which reduces incentives for rent seeking, and better systems of social protection, increases the willingness and ability for innovative risk-taking. For an excellent discussion arguing that that is in fact the case, see Barth *et al.* 2013. They go further, showing that in a vintage model of innovation, wage compression induces older vintages to be scrapped earlier, thus accelerating the process of creative destruction.[53]

Not only can the Nordic model lead to more innovation, it can lead to faster dissemination of ideas throughout the economy (in ruthless competition, firms strive to keep whatever knowledge they acquire to themselves), and even more importantly, ensure that innovations lead to an increase in societal well-being.

Moreover, they show how government policies can ensure that society as a whole benefits from innovations, e.g. through active labor market policies and Keynesian demand policies. But these too are part of the "Nordic model."

Specific policies

We now move from the broader question of how the Nordic model enhances innovation and the positive benefits that can be derived from it to several more specific policy issues. Consider the narrower question: Could innovation be encouraged by taxing financial and land speculation more and using the proceeds to invest more in education, especially for science and technology; or to pay scientists more, to attract more into these innovative activities? Standard arguments would suggest that higher taxes on land will not affect the land supply. And given the evident low (negative) marginal social returns to innovation in the financial sector[54], the reallocation of resources in ways which are associated with the Nordic model, would presumably be innovation[55] enhancing. Or consider the slightly broader question: could innovation be enhanced by taxing those at the top at higher rates, and using the proceeds in a similar way? It has been argued that little of the income at the top is derived from innovations, at least those innovations from which society as a whole has benefited (even if innovations which have enhanced the ability of a monopoly to exploit its customers or of a bank to exploit those who are financially less sophisticated have led to increased private profits) ; indeed, much

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[53] In their model, higher wages at the bottom effectively induce more innovation. There is a long tradition among economic historians arguing for the innovation benefits of high wages and labor scarcity. See, e.g. Salter (1962), Hakkakuk (1962), Sutch (2010), and Wright (1986). For a theoretical discussion, see Acemoglu (2010), Greenwald and Stiglitz (2014), and Stiglitz (2006b, 2014c).

[54] Including the absence of any social returns to the "innovations" in the financial sector, which were mostly directed at circumventing regulations designed to enhance the stability and efficiency of the financial system. See Group of 30 (2009) and "Paul Volcker: Think More Boldly," an interview with Paul Volcker, *The Wall Street Journal*, December 14, 2009, available online at http://online.wsj.com/news/articles/SB10001424052748704825504574586330960597134.

[55] Using the term in the more narrow definition, referring to innovations that enhance societal welfare.

of the income is derived from rent seeking.[56] If that is the case, then an increase in taxes at the very top would have little effect on growth, and that is what Piketty *et al.* (2011) have found.

While section III will show that the optimal policy of the leader and the follower will be different, this analysis suggests it is not necessarily the case that the leader has less of a "social model" than the follower. The extent of society's social protection/social investment can have a positive effect on the pace of productivity growth even at the frontier. Obviously, this is an oversimplification, since there are many dimensions to social protection and social investment, and each can have a different effect on the pace of productivity improvement. But what should be clear is that it is not necessarily the case that better social protection leads to lower growth at the frontier.

The Nordic model consists of exactly the kind of policies that one would expect to see in a leader, especially if there is a positive income elasticity to the social goods provided within the Nordic model. While it may not be optimal for all countries to follow the same model, those countries that aspire to be on the frontier should at least consider emulating some aspects of the model that has worked so well in the Nordic countries, not only in maintaining a high rate of growth in productivity, but high levels and rates of growth in standards of living.

1.5. Political and economic equilibria

The discussion so far has explored the consequences of alternative economic policies; but as is now widely recognized, public policies are enacted through political processes, which themselves are affected by the economy, including by the extent of inequality. We have to view the economic and political equilibrium as being jointly determined. It is easy to show that there can be multiple equilibria.[57]

In particular, in this context, there can be an equilibrium with a high level of inequality supporting low levels of public investments (including in education and technology), low levels of tax progressivity, and high levels of rent seeking, generating high levels of inequality; and another equilibrium with a low level of inequality with high levels of public investment, high levels of progressivity, a strong welfare state, and strong policies against rent seeking (the Nordic model). The representative individual is likely to be better-off in the latter--and so is the pace of innovation.[58]

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[56] See Stiglitz (2012) and Piketty (2014) and the references cited there. For empirical evidence, see Piketty *et. al.* 2011.

[57] See, e.g. Hoff and Stiglitz 2004.

[58] There are multiple links between inequality and the economic-political equilibrium. There is, for instance, a large literature arguing that more divided societies are less likely to make high return public investments; the rich seek a weaker state, worrying that it might use its powers to redistribute. See Stiglitz (2012) and the references cited there. See also Benabou (1997) for a survey of studies on economic growth and inequality, and Ostry *et. al.* (2014) for more recent evidence. There is now strong evidence of a negative relationship between the two.

There is no reason to believe that the US has adopted the policies that it has because they are designed to maximize innovation, let alone societal welfare, rather than because they are simply the outcome of political processes in which those with money have disproportionate influence, an outcome that one might expect given its high level of economic inequality.[59]

If this analysis is correct, then it is possible the US could maintain a position of technological leadership for some period, even if *current* policies (not only the weaknesses in systems of risk absorption, but inadequacies in investments in education and research) are such as not to sustain that leadership. But the US could increase the pace of innovation (and the level of economic welfare) by making some moves in the direction of the Nordic model. Not only would the institutional and policy reforms promote greater innovation directly, but by reducing inequality and the insecurity associated with innovation and openness, generate more support for innovative policies and ensure that those displaced by innovation are "recycled"—retrained so that they can be more productive members of the economy.

By contrast, many aspects of the Nordic model were explicitly designed with this political-economic equilibrium in mind (see Barth *et al.*, 2012). The Scandinavian countries are small. To be prosperous, they had to be open to the outside world. But openness would impose high costs on manyindividuals. So too, as we saw in the previous section, for innovation. And in truly democratic societies, if a majority of citizens are losers—even if a minority are large “gainers”—it will be hard to sustain policies supporting innovation and openness.

To sustain innovation and openness, one either has to move away from democracy (e.g. by moving towards a system where money has *more* influence), so that the winners have a disproportionate role in determining outcomes, or one has to ensure that a majority of citizens are in fact better off—and that is the intention of the Nordic model.

II. Historical perspectives and the U.S. experience within a historical context

Taking for granted for the moment that the United States is in fact *a* technological leader, if not *the* leader, the question arises, how can we reconcile such a position with the above analysis, which suggests that a characteristic of such leadership is a socio-economic system which is good at risk-absorption and makes high levels of public investments, recognizing that in the absence of good risk and capital markets, there will be underinvestment?

There are several possible explanations, which we cannot adequately assess within the confines of this limited paper. But an historical analysis is suggestive. The United States was not always the leader. In the nineteenth century, it borrowed voraciously from Europe. (See, e.g. Chang,

[59] I say this with some confidence, having watched closely and participated in decision making in the US, and especially relevant for this paper, decision making related to innovation, such as the design of intellectual property rights and the level and pattern of expenditures on research. Special interests often dominated; the question of what was good for the progress of science or the advancement of health was given short shrift. For a discussion of some aspects of this, see Stiglitz, 2006.

2001, 2002). Interestingly, even then, when it was a follower, it had a form of capitalism that was marked by high inequality--the extremes of the Gilded Age have only been reached in the Roaring 20's and in the first decade of this century. The innovator of the period, Germany, was the first country to introduce social security. The pattern clearly seems to be the opposite of that suggested by Acemoglu *et al.*

World War II marked a turning point in US technological leadership—a historical accident, partially at least a "gift" of that war, as large numbers of those on the forefront of science and technology fled to the United States.

This leadership was then reinforced as a result of *government* actions, in response to the Cold War, that led to heavy investments in military research, which had large spillovers to the civilian sector (including, arguably, the development of the internet.)[60] The large technological leadership of American universities, reinforced by World War II and government Cold War investments in the decades following the War, attracted among the most talented young people from around the world, many of whom stayed in the United States.

A closer look at many of the critical inventions and innovations that have transformed the economy shows that they were not the result of cutthroat competition. They were financed either by government or by a monopoly (Bell Labs).[61] Innovations attributed to the latter include the transistor, the laser, the CCD, information theory, and the programming language UNIX.[62]

If America is the innovation leader, it is hard to ascribe its position solely, or even mainly, to cutthroat competition. There are, in fact, multiple institutional and cultural factors that influence the ability of a technological leader to maintain that leadership position and push the technological frontier forward at a rapid rate.[63] On the positive side, for instance, America's attitude towards bankruptcy—it's acceptance of bankruptcy as part of the price to be paid for risk taking in an innovative context—and the development of the venture capital industry are often cited as two institutional characteristics that are highly conducive to innovation, though Mazzucato (2013) persuasively demonstrates the limited role of the VC industry in innovation.[64] But even in these areas of strength, there are questions: US bankruptcy law gives first claim to derivatives, and student loans can almost never be discharged, even in bankruptcy. This distorts the allocation of resources—towards finance and away from higher education, distortions that almost surely result in less *real* innovation than there would otherwise be.

[61] And as we noted earlier, Bell labs was essentially funded by a dedicated research tax on all telephone services.
[61] And as we noted earlier, Bell labs was essentially funded by a dedicated research tax on all telephone services.
[62] In addition, there were many innovations that were of less commercial relevance, such as the development of radio astronomy. Many of these developments rested in turn on theoretical insights derived from research in other countries, supported by government or academic institutions.
[63] For a more extensive discussion of these issues, see Greenwald and Stiglitz, 2014.
[64] The venture capital industry is a very small part of the financial sector, and was adversely affected by the global financial crisis, brought on by the dominant part of that sector. Kaplan and Lerner (2010) find that historically venture capital investments in companies represent a remarkably constant 0.15% of the total value of the stock market.

Another critical advantage of the US is its elite universities, *none of which is a for-profit institution.* They are either not-for-profit or state institutions. They have attracted the best students from around the world. In the past, an immigration policy that allowed these students in, and allowed many of them to stay, clearly led to a brain drain from the rest of the world to the US. As the leader of one of the emerging markets commented, the US was taking their most important intellectual property—their most talented young people.

While the quality of its elite universities is clearly a favorable factor, the unevenness of the quality of its education—and the evidence deficiencies in average performance (e.g. as measured in PISA scores[65]) work in the opposite direction. So too does the fact that such a large fraction of its innovative talent has been diverted to finance (and zero sum activities *within* finance) and other rent-seeking activities, as we previously noted. While large corporations may have access to the large amount of resources needed to undertake large, long term research projects, the misalignment of interests between management and shareholders and more broad societal interests, widely recognized deficiencies in corporate governance (leading often to excessive short termism), and the bureaucratic processes that many large corporations have established as part of their control mechanism, may enervate innovation, especially the kind that enhances standards of living.

2.1. Is the US *the* leader?

The central contention of this paper is that the Nordic model is not only good for the well-being of most citizens, but that it is also good for innovation. Previous sections have explained why an American model of ruthless competition is likely to be less innovative, given the pervasive market failures that characterize the innovative process. Even if there are some sectors in which America has been highly innovative—like finance—the innovations have not necessarily lead to higher living standards for most citizens, or even higher rates of growth, no matter how measured.

Moreover, the previous section argued that *even if the US is more innovative*, the reasons have more to do with historical accidents, with government support of research (partly as a result of the Cold War), and with the central role of its not-for-profit research universities (combined with immigration policies) than with anything else.

But the discussion of the previous section begged the question: Is the US really more innovative? Establishing that would require showing that there was a *disproportionate* flow of innovations, appropriately weighted, from the putative leader, the US, to the Scandinavian countries, adjusting, of course, for differences in the size of the two countries.

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[65] The Programme for International Student Assessment, administered by the OECD, evaluates 15-year-old students' aptitude reading, mathematics, and science literacy. According to PISA, the US education performs at about the average level of OECD countries overall, but lags behind the OECD average in mathematics. (Organisation for Economic Co-operation and Development 2011). The low level of equality of opportunity implies those born to poor and poorly educated parents are less likely to live up to their potential. See Stiglitz, 2012. These adverse outcomes can be thought of as a natural outcome of the American model of capitalism, which has led to high levels of economic inequality, especially given the manner in which these economic inequalities interact with political processes (as noted in the previous section), leading to low levels of public investments.

It should be clear that assessing the level of innovativeness of an economy is no easy matter. Earlier, we explained how even if it could be shown that American institutional arrangements and policies, such as those associated with more cutthroat competition, led to higher levels of *investment* in innovation, that does not necessarily lead to an enhanced pace of increases of standard of living overall, and especially so for the typical household, especially given the marked discrepancies between social and private returns. Even assessing the importance of any particular innovation may be difficult.

Moreover, in a world in which knowledge flows in all directions, assessing the origins of any idea, let alone the impacts, is nearly impossible. For instance, many of America's recent advances in medicine build on work done in the United Kingdom by Watson and Crick leading to the discovery of DNA. America's development of the computer rested on fundamental work done by Alan Turing in the United Kingdom.

The Swedish innovation of worker quality circles or the Japanese innovation of just-in-time production--neither of which were patented-- may have had more profound impacts on American productivity than that associated with multiple patents. To be sure, Scandinavia benefited from Intel's innovations in chips, but presumably the value of those patented innovations would be (largely) captured in the profits of the patenting company, and in the GDP of the originating country. But parsing out the source of the "real" innovations is difficult if not impossible. .

Interestingly, while many suggest that the US has been highly innovative, say in the last thirty-odd years, it doesn't seem to show in GDP statistics, where increases in GDP per capita, or even estimates of total factor productivity growth, seem to be far lower than in the decades after World War II. In 1987, economist Robert Solow – awarded the Nobel Prize for his pioneering work on growth – lamented that "You can see the computer age everywhere but in the productivity statistics."[66] There are several possible explanations for this. Perhaps GDP does not really capture the improvements in living standards that computer-age innovation is engendering. This may be partly due to the fact that GDP does not provide a good measure of well-being (see Fitoussi, Sen, and Stiglitz, 2010), though there are reasons to believe that when full account is taken, for instance, of the increase in insecurity, economic performance is even more dismal than GDP statistics suggest.

Alternatively, it may be that as exciting as recent innovations seem, they are less significant than the enthusiasts believe. The United States may have made great strides in inventing better ways of targeting advertising, or designing financial products that are better at exploiting uninformed individuals. It takes innovativeness to design better ways to exploit and leverage market power, and this is likely to show up in higher profitability. But not surprisingly, these "innovations" may not show up in GDP statistics.

[66] Solow (1987).

Macro-data

Data on levels of GDP or its growth (partly for the reasons just alluded to) do not adequately answer even the question of which country is more advanced or more innovative. Resource rich countries have high incomes, but those incomes have little to do with innovativeness. And the discovery of new resources and their exploitation or an increase in the price (or scarcity value) of its resources may lead to a high rate of growth--but this growth cannot be attributed to innovativeness. The United States has benefited from an abundance of natural resources, and certainly at various times in its history, its growth has been enhanced by the discovery of new resources or an increased ability to exploit them (some of which may, of course, be related to innovativeness).

Norway's recent growth and its current income per capita exceed that of the US[67], but that is clearly related to the discovery of oil and gas. But Barth *et al.* (2013) show that looking over the 80 year period from 1930 to 2010, Sweden and Norway have had a growth rate that *exceeded* that of the United States and other countries of Western Europe with less strong welfare systems.[68]

Moreover, output per worker hour in several countries exceeded that in the US (Norway by 41%, Ireland by 15%, Luxembourg by 30%, in Belgium by .5%, and in several (Germany, France, Netherlands Denmark) the differences were small.[69] [70]

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[67] At official exchange rates, in current US dollars, the United States GDP per capita was $49965 ($48113, $ 46616) in 2012 (2011, 2010), while that for Norway was $99,558 (99,143, 86,156) in 2012 (2011, 2010). At PPP (current international dollars), Norway's GDP per capita was still considerably greater than the US, at $65640 (61046, 57452) in 2012 (2011, 2010). The real GDP growth rate in US was 2.2 in 2012, while this number in Norway was 3.1. Source: World Bank DataBank.

[68] Growth rates can, of course, be affected by initial conditions. By taking a long period, the effect of initial and terminal dates becomes less important. In their study, they exclude Norway's income from the extractive sector, but include US income from these sources, thus biasing the calculations *against* the Nordic model.

The result that Sweden and Norway have a higher growth rate than the US is, of course, not inconsistent with the Acemoglu *et. al.* contention that they are laggards. They could have been benefiting from the appropriation of knowledge produced elsewhere. But data on higher output per work hour would be inconsistent, setting aside measurement issues. But under the Acemoglu *et. al.* hypothesis, effort and investments in human capital should be *higher* in the US, with its "better" incentive system, thus suggesting, if anything, US should have a higher quality, harder working labor force and therefore higher output per hour. (If one were to focus on particular sectors, such as manufacturing, there might, in addition, be differences in the sectoral sorting of workers by ability, but the smaller manufacturing sector, and the large wage differentials, should again give US manufacturing the advantage in productivity.)

[69] According to OECD data for 2012. And taking into account some of the measurement problems noted by the Commission on the Measurement of Economic Performance and Social Progress, the US probably had an even smaller GDP per hour worked.

[70] The interpretation of such data are open, of course, to multiple interpretations. The numbers can depend on the degree of vertical integration (if there are some parts of the production process with higher value added per worker, a country specializing in those stages of production might appear to have higher productivity, even though productivities in *comparable tasks* are identical) and the choice of skilled vs. unskilled workers (obviously, a firm or country that chose to use unskilled workers would have a lower productivity *per worker,* but just as high total factor productivity.)

By most accounts, Sweden and Norway may have a higher standard of living or welfare (e.g. reflected in say median income or UNDP's Human Development Index)[71]. But this, they point out, is not inconsistent with their model, since the follower has the benefit of appropriating some of the knowledge produced by the frontier country; it enjoys the fruits of being, in a sense, a free rider on the investments in innovation of the leader. If that is the case, there is something deeply collectively irrational in the leaders, at least in the case where there are several of them: for a leading country could always become a follower, by resting on its laurels. In doing so, its well-being would be even greater than that of the followers. (The converse is not true: the follower could only become a leader by investing so much that it is not worth its while to do so.)

Patents[72]

Acemoglu *et al.* try to establish the greater innovativeness of the United States by looking at highly cited patents (registered in the US patent office) per million residents. Putting aside technical issues, such as differences in demographics and the presumed lower overall transactions cost associated with an American registering a patent in the United States versus a foreigner registering in the United States, there is a more fundamental issue—patents play markedly different roles in different sectors. In some sectors, like hi-tech and pharmaceuticals, they play a very important role, though in the former often more in a "defensive" way, to put oneself in a position to countersue when someone sues. In other sectors, like metallurgy, they play a very unimportant role. By the same token, the number of citations is not necessarily a good index of importance. We referred earlier to two critical innovations—just in time production and quality circles. These were not patented, and accordingly, there is no index of the number of citations. But there is little doubt of the profound effects. Or take another Swedish innovation: dental implants. Whether the original research spawned a large follow on research, with many citations, is not the critical determinant of the impact that this innovation had on the quality of life of hundreds of millions of individuals. (Moreover, to repeat what we argued earlier: perhaps the most important American innovations of recent decades, the

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Data on GDP per worker (which avoid some of these issues) are equally plagued by multiple interpretations, particularly related to the fact that GDP is not a good measure of economic performance. e.g. because of problems associated with health care and "defense" spending. See, e.g. Stiglitz, Sen, and Fitoussi, 2010.

[71] In 2012 , US ranked #3, Sweden #8, and Norway #1; in the perhaps more relevant (as a measure of well being) inequality adjusted HDI, US ranked #15, Sweden #3, and Norway #1.

[72] We should note that there is much controversy over the explanations and implications of differences in the rate of patenting across countries and over time--and the relationship between these differences and differences in the pace of innovation (e.g. changes in time may be more related to changes in patent laws and how they implemented than to the pace of innovation.) For a brief review of some aspects of this controversy, see Dosi and Stiglitz (2014). In this section, we will be able to touch on only a few of the most salient aspects of this controversy that are most relevant for the purposes of this paper. (For further discussion of these issues, see also ; Levin *et. al.,* 1987, Cohen *et. al.* 2000; Schankerman**.** 1991. And Tellis and Golder 1996; these studies not only question the importance of patents, but even the significance of the first mover advantage) Elsewhere in this paper, we have noted one of the reasons that differences in the rate of patents may not be closely related to increases in standards of living: considerable expenditures may be directed to circumventing existing patents, me-too innovations (especially in the pharmaceutical industry), research directed at extending and enhancing the market power derived from existing patents, or research directed at enhancing the power of hold-ups.

transistor, the laser, and the internet were the product either of government funded research, or research funded by a dedicated tax to the telephone monopoly.)

And the most important innovations, generating the most cited research, typically cannot be patented—from the Turing machine, to the discover of DNA and electromagnetic fields.[73]

In short, it *may* be the case that the United States is more innovative, *in a relevant sense,* than some of the Scandinavian countries, adjusted for size. But the case has yet to be made in a convincing manner. And if it is more innovative, *in some sense,* it is not the case that this higher level of innovativeness is a result of its system of cutthroat competition or reflected in higher standards of living for most citizens.

The United States may have focused its innovative efforts in those sectors where patents are important and where rent-seeking is encouraged (as in the financial sector). If this is the case, then from the perspective of global innovation, it may be advantageous to have an ecology in which there are different institutional arrangements: there is no dominant one.

III. Equilibrium gaps between leaders and followers

We noted in the introduction the large literature growing out of Solow (1956) that argued that there should be convergence in income per capita; but that in fact convergence has, by and large, not occurred. Some countries remain "leaders," others followers. Why that is—what are the assumptions in the standard neoclassical model that are "wrong"—is an important question in its own right. In the model presented below, we provide an answer; but our real interest is elsewhere: in this model, those at the frontier are pursuing certain policies, balancing out the costs and benefits of pushing out the frontier faster, so too for those behind. Those behind may have "catching up" policies, policies aimed at closing the gap between them and the leaders; but they fail to catch up, simply because as they do so, the leader moves on. This is the essence of equilibrium gaps. Policies designed to catch up are, however, different from those designed to move the frontier outward. We provide a theoretical characterization of these differences, and illustrate with some relevant policy examples.

3.1 Equilibrium Knowledge Gaps Across Firms

To set the stage, we provide a simple reduced form model of equilibrium gaps in productivity across firms *within the same sector within the same country.* There is ample evidence demonstrating the persistence of knowledge gaps amongst firms within any economy. In this subsection, we construct a simple model in which knowledge gaps are part of an equilibrium. The costs of closing the knowledge gap are sufficiently great that the lagging firms decide never to do so. We assume that there are two types of firms, those on the frontier, and those that lag.

[73] And for good reason, related to an assessment of the costs and benefits of patents. As in the case mentioned in footnote 17, The US Supreme Court has recently ruled that isolating genes cannot give rise to a patent, invalidating Myriad's patents on the BRAC genes.

The rate of growth of productivity of the laggard, g_l , is a function of the firm's investment in productivity enhancement, i_l (measured as a share of, say, its output), and the relative gap that exists between it and the best practice firms, G:

(1A) $g_l = H(G_l, i_l)$.

The rate of increase in productivity of the firm(s) on the frontier is given by[74]

(1A) $g_f = H(0, i_f)$.

A full analysis would entail each firm beginning with a given level of technology (initial values of productivity, defining then the initial productivity gaps). Given its beliefs about the actions (investments in productivity enhancement) of other firms, each firm chooses an optimal path of investments in productivity enhancement (i[t]) which maximizes the present discounted value of its profits. An equilibrium is one where beliefs about others' actions are consistent with their actual optimal policies.

We simplify by focusing on steady states. The present discounted value (PDV) of profits is given by Π (G, i). Then an equilibrium knowledge gap is a set of $\{i_f^*, i_l^*, g^*, G^*\}$ such that all firms are maximizing profits, and at the given gap, G*, the rate of productivity enhancement of the frontier firm and the laggard firms are identical. The gap persists:

(2) $\Pi^f_i (G^*, i_f^*) = 0$

(3) $\Pi^l_i (G^*, i_l^*) = 0$

(4) $g^* = H(G^*, i_l^*)$

(5) $g^* = H(0, i_f^*)$.

A frontier firm could, of course, always decide to join the laggard firm, saving in the interim considerable investments in productivity enhancement; but a laggard firm could only become a frontier firm by spending considerably more than it is currently doing to close the knowledge gap. Hence, $\Pi^f (G^*, i_f^*) >> \Pi^l (G^*, i_l^*)$, and the differences are its knowledge rents.[75]

[74] This formulation assumes that there are no learning spillovers across the firms that are at the frontier (or that there is a single firm on the frontier.)

[75] More generally, the non-convexities associated with the production and acquisition of knowledge imply that the profit functions may not be single-peaked. Even if firms started with the same knowledge base, there might be no equilibrium in which all acquired knowledge at the same pace. The only equilibrium may entail some firms saving on investment in R & D, and "poaching" off the knowledge acquired by others. The present discounted value profits for the two strategies might be the same. It can be shown that even if there exists a symmetric equilibrium, it may be unstable.

We note that there are many public policies that can affect the size of the knowledge gaps (and therefore the average level of productivity of the sector.) For instance, knowledge is transmitted from one firm to another by individuals, and labor market policies that facilitate mobility across firms, for instance, can help close equilibrium knowledge gaps.[76]

3.2 Equilibrium Knowledge Gaps Across Countries

Basic Model

Here, we use the intuition provided in the simple model of equilibrium disparities among firms to analyze equilibrium disparities among countries. We assume there are two types of goods—one industrial or manufacturing (M) and the other agricultural/craft (A). Both are produced using only labor as an input with technologies that at any point in time embody constant returns to scale. We define

$c_M(c_A) \equiv$ amount of labor per unit of industrial (agricultural) output in the economy.

The production possibilities curve is a straight line with a negative slope of $- c_A/ c_M$. (See Figure 1A.) All individuals are identical with utility functions among goods[77] of the form (each period)

$$U = \alpha_M \ln C_M + (1 - \alpha_M) \ln C_A$$

C_A is the level of consumption of the A-goods, and C_M is the level of consumption of the M goods. We assume throughout this paper that the labor supply is fixed.[78]

If there were a single country, static utility maximization would occur at the tangency between the indifference curve and the production possibilities curve.

We assume now that there are two countries (or two groups of countries), the developed, denoted by a superscript D, and the less developed, denoted by a superscript L. Individuals in each have the same utility functions. We assume the developing country has an absolute disadvantage in all production (i.e. $c^D_M < c^L_M$ and $c^D_A < c^L_A$), but a comparative advantage in agriculture.

[76] For a broader discussion of this and other policies designed to increase the flow of "learning" amongst firms, see Greenwald and Stiglitz (2014.) It is worth noting that America's "ruthless competition" has often been marked by restrictive practices. Steve Jobs, when he was at the helm of Apple, helped engineer a collusive labor market agreement designed simultaneously to reduce labor mobility and to lower wages of researchers. (The agreement was found, not surprisingly, to violate anti-trust laws.)

[77] We are also assuming time separable utility functions and utility functions which are separable in goods and leisure. Nothing essential depends on these assumptions.

[78] This is not an innocuous assumption. With endogenous labor, one can establish a steady state equilibrium only under a restrictive set of utility functions, of which the logarithmic utility function is one. If, as here, we assume a fixed labor supply, all that we require for steady-state analysis is constant elasticity utility functions. This parameterization simplifies the calculations. Qualitative results would be similar in these more general models.

$c^D_A / c^D_M > c^L_A / c^L_M$

To simplify the analysis, we assume the developing country is relatively small. This means that in free trade, the terms of trade are set by the developed country. As a normalization, we assume that in the first period $c_M^L = c_A^L = 1$.

Because the developed country has a comparative advantage in industrial goods, under free trade, the developing country specializes in agricultural goods.

Figure 1B shows the country's "consumption possibilities curve", which because of trade is far better than its production possibilities curve. With free trade, the developing country specializes in agriculture. The country will choose the point on the consumption possibilities curve that maximizes utility.

Dynamics

We now introduce technological progress into this static equilibrium. In this paper, we assume that learning-by-doing[79] associated with industrial production *within the country* is the sole source of productivity increases, but that the learning by any firm spills over to all other firms—both within its sector and in other sectors.[80]

Formally, we will assume first that productivity improvement affects the industrial and agricultural/craft sectors equally, i.e. there are perfect spillovers

(6) $g= d(\ln c_M)/dt = -d(\ln c_A)/dt$,

so that

(7) $d[\ln(c_M/c_A)]/ dt= 0$

This has one important simplifying implication: Productivity growth does not affect the production costs of industrial goods relative to agricultural/craft goods. The production possibilities schedule in the second period is a straight line with a slope of -1, just as it is the first period; but if there has been learning, it has moved out.[81]

There is considerable evidence of the presence of substantial spillovers. Not only are there technological spillovers, but improvements in human capital which arise in one sector inevitably confer benefits on others, e.g. as workers migrate to other sectors of the economy. So too institutional innovations (like a well-developed financial sector which is essential for the functioning of a modern industrial sector) confer benefits on other sectors. The assumption that the cross-sector spillovers are *perfect* is, of course, a polar case. We can loosen this assumption, but none of the qualitative results depend on it.

Next we assume that for the follower country, growth also depends on the gap in knowledge between the developed and less developed country. For all countries, the rate of technological progress, g, increases with the output of the industrial sector or its input of labor or its relative size, measured say by the proportion of labor force allocated to the industrial sector, π, or the ratio of the outputs.[82] For simplicity, we take the latter view: While in an industry with larger

[79] There is a large literature on learning by doing, with empirical work even pre-dating Arrow's (1962a) development of the theory. For a more recent review of some of this literature, see Greenwald and Stiglitz (2014)

[80] Again, this assumption greatly simplifies the analysis, but the results can be generalized. Note, however, that if there are imperfect spillovers, each firm will take into account the reduction in its future costs from increased production as a result of learning-by-doing. Firms that produce more will face lower costs. The competitive equilibrium will not be sustainable. With many commodities, there can exist a monopolistically competitive equilibrium.

[81] As we note in the appendix, this model is very similar to that of Matsuyama (1992), except he assumes no spillovers. This changes the results in important ways.

[82] Under our stylized assumptions, these are closely related.

production, there can be more learning, what happens in one part of the industry has to diffuse to the rest of the sector. For simplicity, we assume that that these effects offset each other, and thus postulate:

(8a) $g^D = f^D(\pi^D, 1)$,

(8b) $g^L = f^L(\pi^L, \kappa)$.

where $\kappa = c^d_M / c^L_M$, the gap in productivity in the industrial sector, $\kappa < 1$. We assume that (in the obvious notation) $f^L_2 < 0$ for $\kappa < 1$ (recalling that a larger value of κ means a smaller gap); and $f^L_2 = 0$ for $\kappa \geq 1$, i.e. learning in the country which is more advanced is unaffected by the state of the less advanced country, and the "developed" country never learns from the other country, even should it succeed in surpassing it.[83] [84] For simplicity, we assume $f^D(\pi^D, 1) = f^L(\pi^L, 1)$[85], for $\pi^D = \pi^L$ and where there is no loss of ambiguity, we drop the superscripts on g and f.

The crucial assumptions that distinguish this model from conventional growth theory are that productivity growth is *endogenous* and that knowledge does not flow freely across borders. In conventional growth theory, the rate of growth is exogenous, not affected by anything the firm (or society) does. In standard "convergence" models, knowledge flows freely from one country to another, so that, effectively by assumption, $\kappa = 1$. In this Ricardian version of the neoclassical model, convergence occurs instantaneously. If we add non-mobile capital, then convergence occurs gradually as the different countries with the same knowledge reach the same capital labor ratio, with the rate depending on savings functions. If countries have different savings functions, and capital is immobile, there will convergence in the rate of growth but not in levels of income. If capital flows freely, even if savings rates differ, output per capita will be the same in different countries, then incomes will differ. The critical assumption, however, is that knowledge flows freely across borders, more freely than other factors of production.

While some forms of knowledge do move easily across borders, many others (tacit knowledge, knowledge related to the conduct of particular institutions) may be far less mobile than labor or capital. In this model, then, we have formulated the simplest model where capital accumulation plays no role[86], and there is only limited knowledge diffusion, but the diffusion occurs effectively through the industrial sector, but once within the country, it spills over to the

[83] In other words, f^D does not depend at all on κ. We write the equation in this way simply for convenience. As we have noted earlier, even countries that are, in general, behind may make innovations from which the leader benefits (America learned from Japan's just-in –time inventory control system), and it might be argued that there are thus learning benefits from the laggard to the leader, and that these increase the closer the two are together. Extending the model to incorporate this effect is straightforward.

[84] In the appendix, we deal with what might be viewed as a peculiar case, where the laggard country is so assiduous in pursuing its industrial policies that it eventually surpasses the leading country. To analyze such a situation, we have to analyze what happens when $\kappa > 1$. There, we assume that should the less developed country surpass the more developed country in productivity in the industrial sector (even though its comparative advantage remains in the rural sector), the growth trajectory of the developed country is unaffected. Generalizing the results to the case where it is, is a trivial matter.

[85] That is, when there is no knowledge gap, they have the same learning functions. In fact, even when there is no knowledge gap about technology, there can still be a gap in learning capacities.

[86] The results would be very similar, if capital moved freely across borders. See Stiglitz 1970.

agricultural sector. (The analysis can easily be conducted for other learning architectures. This is the simplest, and in many ways, the most plausible.)

With free trade, the global general equilibrium is easy to describe. For the large, developed country, with full learning spill-overs, each firm takes the state of technology next period as given --unaffected by what it does itself--and hence the competitive equilibrium in the absence of trade is the same as it was without learning, represented by the tangency of the indifference curves to the production possibilities locus.[87] We denote the competitive equilibrium levels of output by $\{C_M^*, C_A^*\}$.

The small developing country takes prices as given, essentially set by the large developed country at its relative cost of production, and so the developing country specializes in agriculture.

Under free trade, because the developing country specializes in agricultural goods, with no knowledge spillovers from the developed to the less developed countries the developing country stagnates. This is the market equilibrium.

Long run analysis with industrial policies

Assume instead that the developing country directly controls production, allocating a fraction π of its labor force to producing industrial goods, so its income (using agricultural goods at time 0 as our numeraire) is $Y = \pi k + (1 - \pi)$, where $k = c^L_M / c^D_M < 1$ represents the lower productivity associated with industrial production[88]. Then, using (5')

(9) $U = \alpha_M \ln (1 - \lambda) + (1 - \alpha_M) \ln \lambda + \ln Y = U^*$.

where λ is the proportion of income allocated to agricultural goods.

U, short run utility, is maximized by maximizing Y, and Y is maximized at $\pi = 0$; that is, the country specializes in the production of agricultural goods. This is the conventional static result, noted above. It is also easy to show that $\lambda = 1 - \alpha_M$.

We now put this into a dynamic setting, asking how taking into account learning benefits affects resource allocations. The present discount value of utility is

(10) $W = \sum \delta^t U^t$,

[87] In effect, each firm puts no value on the learning generated from its production.

[88] k is a measure of the difference in *comparative* advantage; κ is a measure of the difference in absolute advantage in the industrial sector.

where δ is the utility discount factor. First consider a case where the knowledge gap has no effect on productivity growth. It is easy to show that in this case, whatever policy is optimal at time t is optimal at time t + 1. This means that we can rewrite (10) as [89]

(11) $W \equiv [U + \delta (\ln (1+ g)/1- \delta)]/(1 - \delta)$.

Maximizing long term social welfare (W) does *not* in general entail $\pi = 0$. To see this, observe that optimality requires (for an interior solution)[90]

(12) $\partial U^*/\partial \ln \pi + f_{\pi} \pi \delta /(1 - \delta) (1+ g) = 0$.

We take into account the future learning (growth) benefits of the "static" distortion in the pattern of investment, the increase in future utility, so long as $f_{\pi} > 0$ (there is a marginal benefit to growth from expanding the industrial sector) and $\delta > 0$ (the country cares about the future), optimality requires that $\partial U^*/\partial \ln \pi < 0$, i.e. $\pi > 0$.

The country should produce some of the industrial good, even though it is not its comparative advantage (and under our assumptions, *never will be.)* The dynamic benefits of learning exceed the static costs. Industrial policies pay off.

What is at issue is illustrated in Figures 2A and 2B. Assume the country, rather than specializing in agriculture, produces some manufactured goods, and then trades agriculture goods to buy the rest of the manufactured goods it desires. Its new consumption possibilities curve is depicted in Figure 2A, decidedly inferior to the "free trade" solution. But Figure 2B shows what happens in future periods. Because now there is learning, which benefits both sectors, the production possibilities curve has moved out. Even with the trade restriction, the consumption possibilities curve is better than in the free trade solution. There is a trade-off: a loss in well-being in the short run, for a gain in the long run. Equation (12) says that it always pay to impose *some* trade restriction.

The greater the learning benefit and the higher δ (the lower the discount factor), the higher π, the larger the industrial sector; that is, the higher the optimal static distortion.[91]

A similar analysis follows for the frontier country, with two differences: $\kappa = 0$, and in the absence of industrial policies, its production possibilities schedule is moving out, reflecting the preferences of its consumers for manufacturing vs. agricultural goods. Since relative prices in the developed country do not change over time, neither do relative consumptions or labor

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[89] $U^{t+1} = U^t + \ln (1+g)$,

and, using standard techniques ,

$W = \Sigma U^0[(1 + n(\ln (1+g))]\delta^t$, from which (11) follows directly.

If U is not logarithmic but exhibits constant elasticity with respect to the scale of consumption (as before), with the elasticity of marginal utility of η, there is a parallel analysis.

[90] If at π = o, $\partial U^*/\partial \ln \pi + f_{\pi} \pi/(1 - \delta) (1+ g) < 0$, then there can be a corner solution at $\pi = 0$, and if at $\pi = 1$, $\partial U^*/\partial \ln \pi + f_{\pi} \pi/(1 - \delta) (1+ g) > 0$, there can be a corner solution at $\pi = 1$. In particular, this means that if $f_{\pi} (0,\kappa)/(1-\delta) (1+ f(0, \kappa)) < 1 - k$, then $\pi = 0$

[91] This follows from the fact that that $\partial U^*/\partial \pi = - (1 -k)/Y < 0$ and $\partial^2 U^*/\partial \pi^2 = -(1 -k)^2 /Y^2 > 0$. There is always a marginal cost to increasing π , but the larger is π, the smaller is Y, and therefore the larger is the marginal cost.

inputs. Denote by π^D_o the value of π in the developed country in the free trade-no industrial policy equilibrium. It follows directly that so long as $f_1(\pi^D_o, 0) > 0$, it pays for the developed as well as the less developed countries to undertake industrial policies. It should be obvious that the extent to which they do so (and as we show later, the manner in which they do so) may differ between the two.

Thus this paper shows that *both* the leader and the follower countries should have innovation policies.[92] In particular, the follower should pursue policies which, given the gap between it and the advanced countries, maximizes its rate of growth, taking into account the costs associated with moving away from the policies reflecting just static comparative advantage.

Steady state gaps: the normal case

So far, we have ignored the role that the knowledge gap plays in the determination of the optimal level of "distortion" of static production. The larger the gap, the more there is to learn; and by our assumption, learning only occurs within the industrial sector.

Thus, we assume not only that $f_2 < 0$ (recall that an increase in κ is a reduction in the knowledge gap), but that $f_{12} < 0$, i.e. the greater the knowledge gap, the greater the marginal return to learning (at any value of π), which means from (12), the higher the equilibrium level of π, i.e. the greater the distortion in the static allocation.

In steady state, the less developed country stays a certain distance behind, i.e. there is a steady state value of κ, denoted κ^*, such that

(13) $g^* \equiv f(\pi^{D*}, 1) = f(\pi^L, \kappa^*)$,

where, it will be recalled, we have assumed for simplicity that the developing country is very small relative to the developed, so that the developed country's equilibrium value of π (essentially) depends on its own internal conditions.[93] (That is π^{D*} is set simply by the demand for industrial goods domestically, and depends on whether it undertakes industrial policies).

(13) defines a positively sloped curve between κ and π^L: as κ increases, the pace of learning slows (there is less to learn), and so for the developing country to maintain the same distance from the frontier, π^L must be increased. This is depicted as the upward sloping "steady state curve" (SS) in figure 3.

The steady state solution is defined by the solution to (13) and the first order condition for the less developed country's welfare maximization, which we write in reduced form as

(14) $W_\pi = 0$.

[92] For the follower, we note an exception in the appendix.

[93] It would be an easy matter to generalize this to the case where the lagging country is non-negligible in size, and continues to import some industrial goods. We would then need an additional equation to solve simultaneously for π^{L*} and π^{D*}.

κ is the state variable describing the less developed economy--its "state of knowledge" relative to the developed country. For each value of κ there is an optimal value of π:

(15) $\pi^L = P(\kappa)$.

This is the *profit maximizing (PM)* curve. This is normally negatively sloped, so long as the marginal return to growth from increasing π diminishes as κ increases.[94]

There is thus a unique solution, as depicted in the figure: a steady state with a value of $\kappa = \kappa^* < 1$ (implying the persistence of a knowledge gap of a given size) with a value of π^L that is less than π^D. This is what we label as the normal situation, when it doesn't pay the developing country to close the knowledge gap, but it does pay it to deviate from static comparative advantage (and to do so persistently) so as not to fall too far behind—so that it can learn more effectively from the developed country advances in technology which are of benefit to all sectors of its economy. Even though the country would benefit from spillovers even if it didn't have an industrial sector, it would get fewer spillovers.

The infant never fully grows up, but to keep up with big brother, he has to continue to have industrial protection. There is a benefit to being the laggard: it is able to maintain the same rate of growth of the developed country by taking advantage of the knowledge that flows down from the developed country with a small fraction of its labor force allocated to the industrial sector. It can take *some* advantage of its comparative advantage in agriculture.

In the appendix, we describe other possible configurations which may emerge: situations where the infant fully catches up; where it is optimal to have no industrial policy, simply absorbing whatever knowledge trickles down to it; and where there can be multiple equilibria—countries can be trapped in a low level equilibrium marked by a high knowledge gap, but with a positive enough boost, can move into a better steady state equilibrium, with higher levels of consumption and a much smaller gap with the leading countries.

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[94] Because we postulate that the economy is in steady state (the knowledge gap is fixed), the analysis is greatly simplified. Along the first order condition $W_\pi = 0$, $d\pi/d\kappa = -W_{\pi\kappa}/W_{\pi\pi}$.
The denominator is always negative, so that the sign of $d\pi/d\kappa$ is the same as that of $W_{\pi\kappa}$, and the sign of $W_{\pi\kappa}$ is the same as that of $(f_{\pi\kappa}/f_\pi) - (f_\kappa/1 + f)$. We expect that an increase in κ reduces growth (when there is less catching up, there is less growth, *at a given level of* π), and that an increase in κ also reduces the *marginal* benefit of increasing π. In effect, we assume that the marginal effect dominates. But as we note in the appendix, if the knowledge gap is too large, the knowledge that accumulates in the developed country is less and less relevant to developing countries.

The full optimization problem is somewhat more complicated, because if the knowledge gap is closed, next year's optimization problem is different from this year's. The full optimization problem can be solved using standard techniques. The result is still that the optimal labor allocation π will depend on the state variable κ. The results described in the following paragraphs depend only the relationship between π and κ having the indicated properties.

Impact of industrial policies in advanced countries

The steady state equilibrium depends on whether the advanced country pursues an industrial policy (i.e. takes into account that its growth rate g can be affected by its labor allocation). If it does (and our previous analysis showed that normally it would want to do so), g* will be higher than it otherwise would have been, so π^L has to increase, at each κ, i.e. the SS curve, defined by (13), shifts up. This in turn means that (a) in steady state, the developing country will also have a higher growth rate; but (b) it will have to have a stronger industrial policy, i.e. a greater distortion in the static allocation of labor; and (c) the equilibrium gap between the developed and the less developed country will be larger. (See Figure 4).

3.3 Optimal Policies for Leaders and Followers

So far, we have assumed that there is a single policy (industrial policy) that can affect growth. But, of course, countries have at their disposal a large range of policies that might affect growth, as we saw in earlier sections. We generalize equation (8) describing the rate of growth of the economy to[95]

(8') $g = f(\pi, \kappa, \varsigma)$,

where ς is any growth enhancing measure,[96]

$$\partial g/\partial \varsigma > 0.$$

We assume further that there is a short run social cost of these measures beyond a certain level, ς* that maximizes short run utility. Thus, we write the short run (momentary) utility as

$$U^* (\pi, \varsigma)$$

with $\partial U^*/\partial \varsigma < 0$ for $\varsigma > \varsigma^*$.

The leader (the large, developed country) maximizes long term social welfare with respect to ς, taking into account the short run costs and the long run benefits. It immediately follows that the leader sets $\varsigma > \varsigma^*$.

The follower goes through a similar exercise, but for the follower, $\kappa < 1$ (in contrast to the leader, where $\kappa = 1$, by definition), and $\pi^L < \pi^D$. The marginal growth benefits of increasing ς will be affected by the growth cross elasticities between ς, κ, and π. Policies which are growth enhancing for the leader (for whom $\kappa = 1$) may not be growth enhancing for the followers, or may be much less so.

95 The growth functions of the two countries could themselves differ. Here, we argue that even if the growth functions are identical, policies will still differ. Note that, consistent with our earlier notation, we set κ for the developed country at unity.

96 It is of, course, possible that some measures increase growth over some range, and decrease growth over others. We ignore this possibility in this paper.

It follows that unless the growth equation (8') is separable between ς, on the one hand, and κ and π on the other,[97] the optimal value of ς for the leader will differ from that of the follower(s), even if they have the same preferences: *economic policies designed for advancing the technological frontier are different from those that optimize "catching up," borrowing technologies from others*

Assume, for instance, ς stands for "basic research" and that the level of basic research required to maintain a knowledge gap—given that knowledge is filtering down in any case—is less than that required for moving the frontier forward at the rate g*. Then the follower (the developing country) should do less research than the developed country.[98]

Sometimes, however, there has been an under appreciation of what is required to close the knowledge gap—or to prevent the knowledge gap from growing. At one time, the World Bank encouraged developing countries to devote essentially all of their educational resources to primary education, with very little allocated to university education. While well-intentioned, the effect of such policies was that the countries that followed them fell increasingly technologically behind. The 1998 World Development Report, *Knowledge for Development* [World Bank, 1998] helped bring about a reversal of that policy. If ς is interpreted as "university education," while $\varsigma^L < \varsigma^D$, it argued that still, $\varsigma^L > 0$.

There are active debates about the relative (and even absolute) role of different policies for both leaders and followers, e.g. concerning the role and design of pecuniary incentive structures, including intellectual property rights, the importance of openness and collaboration, and the impact of inequality and competition. Theoretical results appear to be heavily dependent on particular assumptions, and empirical results remain contingent and unsettled.

While this discussion shows that in some respects, leaders would do well to follow the Nordic model—consistent with the analysis of section II suggesting that the Nordic countries were in fact innovation leaders, or at least not the distant followers some have suggested-- and, with appropriate modification, so should followers, there are some dimensions in which markedly different policies might be appropriate. An intellectual property regime which is designed to move the frontier out as fast as possible may be markedly different from an intellectual property regime that is designed to close the gap between the technology at the frontier and technologies prevailing within a laggard country.[99]

If frontier research is more risky, policies that enable individuals within society to cope with those risks will be more important in frontier countries, unless risk aversion diminishes sufficiently with increases in income. If the winner-take-all processes that characterize the

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[97] That is, since the follower will always face a different value of κ and, in general, have a different value of π, in general, without separability, the optimal value of ς will differ.

[98] On the other hand, there may be less risk associated with the kinds of "research" required for catching up, and by itself, this would encourage investments in such kinds of research.

[99] Thus, the WIPO (World Intellectual Property Organization) General Assembly adopted a proposal from Brazil and Argentina on October 4, 2004 calling for a *developmentally oriented intellectual property regime,* as opposed the regime incorporated into the TRIPS agreement, which was widely seen as impeding access to knowledge, and thus development. See Dosi and Stiglitz (2014).

frontier countries leads to greater inequality, given imperfections of capital markets discussed in section I, it may be *more* important for a frontier country to have a strong public education system that guarantees access to education for all, if the human resources of that country are to be efficiently deployed. These observations suggest that a Nordic model may be even more relevant for the leader than the follower.

In short, while there may be some disagreement about "optimal" policies for innovation, it should be clear that those policies may be similar in some respect to, but differ markedly in others, from those which are conducive to enhancing imitation (catch up) within the frontier; and contrary to the assertion of Acemoglu *et al.* variants of the Nordic model may actually enhance well-being in both.

3.4 Extensions

The central model that we explored is one in which there are full spillovers across sectors, so that if the less developed country initially has a comparative advantage in agriculture/crafts, it always does. That means that if the country wants to have an industrial sector, it must *permanently* provide some protection. It is perhaps incorrect to say that the infant never grows up: productivity in manufacturing may increase enormously, and the gap between productivity in that sector in the developed and developing country may narrow markedly. But because of the assumption of full spillovers, *comparative* advantage never changes. This has one very important implication:

Even if it were true that infant industries sometimes never fully grow up, the support provided by the government to the industrial sector pays off: the economy is on a long- term faster growth trajectory than it otherwise would have had.

But a country like Korea represents the more typical story, where as it learns, productivity in the industrial sector increases faster than in agriculture, so much so that *eventually* the country's comparative advantage changes. That means that *eventually* government intervention to maintain a (relatively) large industrial sector --larger than would be the case under unfettered market forces-- is no longer required. But even after the country achieves some success in improving manufacturing capacities, it may still want to intervene, to produce *more* manufacturing goods than it otherwise would have produced, or more broadly, to encourage the expansion of those sectors with higher learning and innovation potential, and higher learning and innovation spillovers.

Of course, the uncoordinated equilibrium that emerges is not globally efficient. Because the leader does not take into account the benefits of the innovation that "trickle down" from it to the followers, it will engage in too little innovation, adopting policies that are less supportive than would be desirable from a global perspective. It may also undertake policies that excessively inhibit the flow of knowledge from itself to the followers. There is obviously a role for *global collective action*, for addressing the market/government failures that arise when each country pursues the policies directed solely at enhancing the well-being of its own citizens.

IV. Concluding Comments

This paper is an exercise in comparative economic systems, asking what kind of an economic system most enhances welfare, focusing especially on innovation and the production and dissemination of knowledge. Rather than beginning from the presumption that there is a single economic system that is best for all countries, it recognizes that different countries may be in markedly different situations: there are leaders and followers. What is optimal for a leader, trying to move the frontier ahead (and perhaps maximizing its innovation rents) may be different from that which is optimal for the follower, trying to take advantage of knowledge produced by others, trying to catch up, or at least not fall behind.

We have begun our analysis by a brief articulation of the multiple market failures that characterize innovation and the production and dissemination of knowledge. There is, for instance, no presumption that unfettered markets will be optimal, in any sense, in either the level or direction of investments in research. Quite the contrary: there is a presumption that there are government interventions that will enhance welfare.

Central to our analysis is the idea that the production and dissemination of knowledge is different from the production and dissemination of conventional goods; and the presumptions and understandings of what leads to good economic performance relevant for the latter may not be relevant for the former. Standard economic models assume that knowledge disseminates easily (and typically, costlessly) within and between countries. There is overwhelming evidence that there are large and persistent differences in productivity within and between countries, showing that this is not the case. That this is so has profound implications. It means, for instance, that reforms that improve the efficiency with which information/knowledge gets transmitted within and between countries can have a far more profound effect on standards of living than those that improve the allocative efficiency of the economy, especially when such reforms simultaneously impede the flow of knowledge.[100] Most importantly, it implies that simple injunctions for firms (countries) to become leaders, to move to the technological frontier, are of little relevance.

We have formulated a simple model in which countries can close the gap with the technological leader—but there is a cost to doing so, and the cost is sufficiently high that country may *choose* to remain a laggard.[101] Observed disparities in productivity may not just be the result of laziness or a lack of foresight, but of a recognition that the cost of closing the gap exceeds the benefit: there exists an international equilibrium, in which there are leaders and followers. But the follower, like the leader, has to recognize the pervasive market failures that arise, not just in moving the frontier out, but in catching up as well.

[100] As Greenwald and Stiglitz (2014) argue is often the case.

[101] The fact that there are a few countries, such as Korea, which have gone a long way in closing the knowledge/technological gap, is not necessarily inconsistent with the hypotheses put forward in this paper. Such countries may have underestimated the cost of closing the gap, may have unusually low time discount factors, or may face distinct circumstances in which the costs of closing the gap are unusually small.

Market failures affect both the supplies of inputs into innovation and the prices at which those inputs are available as well as the risk-adjusted private and social returns. We have explained how the Nordic model can be thought of as addressing in a fairly comprehensive way these market failures. Policies affecting education, social protection, especially of children, unions, public investments in technology and infrastructure, active labor market policies, industrial policies—all of these not only affect societal wellbeing directly, but innovation. We have argued that though there are some features of the American form of capitalism that are conducive to innovation, there are others that are not; and that while there may be questions about precisely how strong its economic performance has been, say in comparison to the Nordic countries, it is clear that what success it has attained can only partially be attributed to its markets and its form of cutthroat capitalism: some is a result of a historical accident, some can be attributed to its not-for-profit universities, some to strong government support.

Our analysis suggests that government policies in both the leader and the follower countries can play an important role in leading to more innovation, ensuring that the knowledge gap does not increase, and ensuring that innovations disseminate widely within the economy and that most citizens benefit. It is possible, in the absence of government policies, for innovations to lead most citizens to be worse off, even when the winners could have compensated the losers.

In democracies, whether governments adopt policies that facilitate innovation will depend on the consequences of innovation for most citizens. The Nordic model, by ensuring that more of its citizens benefit from innovation and growth, has created a virtuous circle: a political regime that supports policies that facilitate innovation and ensures that the benefits of the resulting growth are widely shared. [102]

[102] By the same token, as we have noted, some of the policies of the US that impede innovation are a result of political processes that reflect the political influence of special interests, like the financial sector.

Appendix A: Other Patterns of Equilibrium

In the text, we described the "normal" equilibrium where there is no convergence: there is a unique equilibrium in which the level of productivity of the follower grows at the same rate as that of the leader but there is a fixed gap. In this appendix, we briefly describe three other possible outcomes, one in which the follower catches up; on in which the follower undertakes no industrial policy, simply benefiting from the knowledge of the leader as it slowly filters down, and one in which there are multiple equilibria.

(a) *Catching up.* It is possible that the only steady state equilibrium is where $\kappa \geq 1$, i.e. eventually, the "L" country equals or surpasses the "D" country in productivity in the industrial sector. (Figure 5A). (Japan has surpassed the US in productivity in automobiles.) This might be the case where the "D" country has a higher rate of time preference ($\delta^D < \delta^L$) and/or a higher preference for agricultural goods ($\alpha_M^D << \alpha_M^L$).

In this case, in steady state, there are no spillovers--in the long run, the developing country becomes technologically superior in manufacturing. But even though it is technologically superior, its comparative advantage remains in agriculture. (This situation, while a conceptual possibility, is not very plausible. It is a consequence of our assumptions of full spillovers.)

(b) *The lazy laggard.* There is another possibility, depicted in Figure 5B, in which the spillovers from the advanced country flow sufficiently freely that the steady state curve intersects the horizontal axis at a high level of κ, i.e. even without industrial and trade policies, the backward country can keep up with the developed country, with only a modest gap. Denote that critical value of κ by κ_o. If at κ_o, the marginal return to learning (from creating an industrial sector) is small enough (i.e. f_π is small enough), then the $W_\pi = 0$ curve will hit the horizontal axis to the right of κ_o, implying that the steady state equilibrium entails $\pi = 0$, i.e. in steady state there is no industrial policy (though there will be in early stages of development, when κ is very small.) The country that is behind passively gains from the gradual spillovers as they transmit themselves across national boundaries.

(c) *Multiple equilibria.* There are other possibilities, which entail more fundamental changes in our underlying assumptions. We have assumed that the larger the knowledge gap, the greater the level of learning (at any level of production in the industrial sector), and the larger the marginal return to learning—i.e. the greater the incentives to distort production from that associated with short run comparative advantage. But when the knowledge gap is *too* large, it may be difficult to bridge the gap.[103] It is easier to learn about nearby-technologies than those

[103] That is, it may be the case that $f_2 > 0$ and $f_{12} > 0$, i.e. a country with a lower knowledge gap would have (at any given allocation of resources to the industrial sector) a higher rate of productivity growth and a higher marginal return to an increase in the industrial sector.

that are remote from one's own experience, so that spillovers may be larger to nearby technologies than to those that are more distant.[104]

Thus, while we normally expect that as the gap between the developed and less developed country narrows, the less developed country distorts its production less (i.e. its optimal value of π is smaller), it is possible that the opposite is true: if there is a very large gap, the knowledge base may be so low that the (marginal) benefits of learning are low. Then the optimal value of π may decrease as the knowledge gap increases, so that as illustrated Figure 5C, the welfare maximizing locus will be upward sloping for values below a critical level.[105] With both loci upward sloping, there may be multiple equilibria, a low level-large gap equilibrium, and another high level-low gap equilibrium. Not surprisingly, the high gap equilibrium is associated with a small industrial sector.[106] [107]

Appendix B: Other models of non-convergence

In this appendix, we discuss two deservedly influential papers which, like the model presented here but unlike Solow (1956) do not lead to convergence, even in the case of seemingly similar countries beginning with similar initial conditions. They differ, however, in certain critical respects: In Krugman (1981), the equilibrium entails no growth, while in Matsuyama(1992), divergences between the laggard country (countries) and the leaders grows without bound. By contrast, we have formulated a model in which there is, even in the long run, growth, but the disparities among countries are equilibrium disparities. There are several other critical differences among the models, and, as we suggest below, several of the critical results of these earlier papers may not be robust.

Krugman (1981): An unbalanced equilibrium. The key assumption in Krugman's model is the presence of external economies within manufacturing but limited geographically (to the country).[108] We follow Krugman in assuming in manufacturing a fixed coefficients technology, choosing units so that the output per unit capital is unity, each machine requires one unit of labor, there are two countries, each with a single unit of labor, and labor requirement per unit

[104] See Atkinson and Stiglitz (1969) and the literature to which that paper gave rise.
[105] This will be the case if the *marginal* return to a larger industrial sector actually diminishes as the knowledge gap increases beyond some point As an earlier footnote (footnote 15) made clear, the slope of the profit maximizing locus becomes positive even before that critical level of κ is reached.
[106] Moreover, as we noted in an earlier footnote, even in the "normal" case, the result that the curve giving the optimal value of π as a function of κ is downward sloping depended on assumptions concerning the sign of $(f_{\pi\kappa}/f_{\pi}) - (f_{\kappa}/1 + f)$.
[107] In models where there is not only learning by doing, but learning-to-learn (Stiglitz,1987c) and more advanced countries have a higher level of learning, no matter what the lagging country does, the gap between it and the developed country increases.
[108] In this sense, Krugman's analysis is parallel to the analysis here, focusing on *learning* spillovers. We assume that these spillovers are perfect within a country, but non-existent across boundaries.

of output of $a(K)$, where K is the size of the capital stock in the country[109] K is only used for manufacturing. . Under our assumptions, $0 \leq K \leq 1$ (i.e. K equals the fraction of the labor force working in manufacturing), $a(0)$ is the inverse of productivity in manufacturing when there is no manufacturing sector, $a(1)$ when all workers work in manufacturing, and $a'(K) < 0$.

One unit of labor produces one unit of agricultural goods. Food is taken as the numeraire, p is the price of manufactured goods in terms of food, w is the wage rate in terms of food. In a pure agricultural economy, $w = 1$. For simplicity, we assume that the share of wage income spent on food is $e(p)$. Initially, we will assume that capitalists save and invest all of their income, and that the rate of depreciation of capital goods is μ.

Krugman 's story is simple: the initial scarcity of capital leads to high profits, which are reinvested, leading to the expansion of the capital stock. But because of the external economies, investment in manufacturing is concentrated in one country. The focus is on the case where eventually, one country specializes in manufacturing, the other in agriculture, and the wage in the manufacturing country is driven up to ensure that profits are just sufficient to finance (gross) investment.[110]

Thus equilibrium is described by the pair of equations.

(A.1) $p - wa(1) = \mu$

(A.2) $1 = e(p)[1 + w]$

Profits in the manufacturing economy are equal to the value of sales (p) minus wage payments (the wage rate times labor requirement per unit output), and this just equals gross investment, and output in agriculture (which equals production in the country specializing in food) equals demand for food (which depends on total workers' income and the relative price). In the economy specializing in manufacturing, $w > 1$ if at $w = 1$,

$$e^{-1}(1/2) - a(1) > \mu$$

i.e. savings exceeds what is required to replace depreciating capital, so there will be excess demand for labor. Wages will be driven up until $w = w^* = [e^{-1}(1/(1 + w^*)) - \mu]/a(1) > 1$.

What is especially neat about this "unbalanced" equilibrium is that even though wages are lower in the other country, there is no incentive to move production, so long as labor costs are greater in the low wage country, i.e.

(A.3) $a(0) > a(1)w^* = e^{-1}(1/1 + w^*) - \mu$

[110] Our formulation differs slightly from Krugman's. He does not have depreciation.

[110] Our formulation differs slightly from Krugman's. He does not have depreciation.

Typically, however, if there are economies of scale, not all the "externalities" spillover fully to other firms, and if even an epsilon remains internal to the firm, the industry will be characterized as a natural monopoly.[111] It is implausible that a monopolist would not be aware of the effect of its behavior on the price. So long as $K < 1$, $w = 1$. Hence, the monopolist will choose K less than unity to ensure that the wage remains at unity, to

(A.4) $\max K\,[p - a(K) - \mu]$

where (assuming for simplicity that capitalists only consume manufactured goods)

(A.5) $2 - K = 2e(p)$

Or

(A.5') $p = e^{-1}(1 - K/2)$.

While there is still an unbalanced equilibrium, with GDP in the manufacturing economy markedly higher than in the other economy, wages in the two countries are the same.

But neither of the equilibria we have described so far is fully satisfactory. Workers in the low wage economy would realize the disadvantageous position they have been put in, and could impose trade barriers, unless the manufacturing economy shares its rents with them. The threat point of the low wage economy is easily defined: If it insists on autarky, its workers will still get a wage of w, but the price they will pay will now be

(A.6) $p^{**} = a(K) + \mu$

where

(A.7) $1 - K^{**} = e(a(K^{**})) + \mu)$.

If

(A.8) $a(K^{**}) < e^{-1}(1/1 + w^*)$

then autarky is better than being exploited by the manufacturing economy, even though autarky is socially inefficient. (This condition will be satisfied if most of the economies of scale are realized at small levels of production of the manufactured good.)

By the same token, the monopoly equilibrium will not survive if there is competition to be the monopolist, i.e. in a contestable equilibrium.[112] The two countries may compete to have the

[111] The fragility of the full spill over equilibrium has been emphasized by Greenwald and Stiglitz (2014).
[112] If there are even small sunk costs, then contestablity fails. See Stiglitz (1987a)

manufacturing monopoly located in their country, by offering to share the rents with the other country and keep prices at a competitive level, i.e.[113]

(A.9) $1 = e(p)(2 + p - a(1) - \mu)$.

In this case, again, while GDP may be "unbalanced," GNP is not—incomes are equal in the two countries.

The disparities in production are of the form that commonly arise in the presence of non-convexities. From a mathematical point of view, they are hardly surprising.[114] And often, such non-convexities become unimportant as the size of the economy grows. To see this, assume now that there are not 2 countries, but many countries, M. Let n be the fraction of the economies that engage in manufacturing. Manufacturing will move to low wage economies, and the global general equilibrium will be described by

(A.10) $(1 - n)M = e(p) M$

(A.11) $p - a(1) = \mu$

Or $p^* = \mu + a(1)$ and $1 - n^* = e(\mu + a(1))$

i.e. we can simply solve for the fraction of countries which specialize in manufacturing (agriculture.) Economies of scale result in specialization, but not in uneven development.

It is the non-convexities in *learning*, not in production, which play the central role in our analysis; in effect, it does not pay the laggard countries to pay the initial costs of catching up, given that they eventually will benefit from the leading countries' technologies as knowledge seeps down. This not only enables us to establish a growth equilibrium with non-convergence, but the non-convexity remains relevant even if there are large numbers of countries (unlike, as we have seen, the Krugman model, where the disparities in income disappear in a "large" world.)

Matsuyama (1992): Learning without spillovers. This paper is, in many ways, much closer in spirit to the theory developed here. In both, the pace of innovation is affected by the size of the manufacturing sector. The critical differences are: (a) In his model, the learning function is unaffected by the gap between the leader and the follower; the amount of learning does not depend on how much there is to learn; the presence of the gap variable plays a central role in establishing the equilibrium in our model; (b) In his model, there are no spill-overs from the manufacturing sector to the agricultural sector. This gives rise to the fundamental instability in

[113] Assuming the functions are such that efficiency requires that one country is devoted to manufacturing, the other to agriculture. We can easily derive the conditions under which this is so.
[114] With non-convexities, even utilitarian optima involve unequal incomes.

his system: countries which initially have a comparative advantage in manufacturing increase that advantage. In our model, for simplicity we assume full spillovers, so that there are no changes in comparative advantage over time.[115] (c) In his model, there is no role for policy; analyzing policy is the central motivation of our model.

The presence of spillovers (externalities) is one of the central features of our analysis. In the absence of such spillovers, so long as there is global competition, the benefits of learning by doing in one country are received by others, through lower prices of manufactured goods. Indeed, in the central case of unitary price elasticity demand functions, as productivity in the manufacturing sector increases, prices fall, and revenues remain the same. The economies growing faster in physical output do not grow faster in the value of their output. Again, while there is uneven development in outputs, there is not in incomes.

But with cross sector spillovers, as we have seen, this is no longer true. The countries with a larger manufacturing sector see their real incomes increase at a faster pace.

The passivity of government accounts for some of the striking results in Matsuyama's paper. He shows that in an open economy, an increase in agricultural productivity leads to lower growth, because production shifts away from the learning (manufacturing) sector as a result of the change in comparative advantage. But if the government can impose import restrictions (tariffs), it can unambiguously increase welfare—both incomes today and growth, as it can ensure that there is a higher level of manufacturing and food production.

Moreover, it if should turn out that it is optimal for the country to lower the share of industrial production, because of the presence of spillovers, there is still a steady state equilibrium in which the laggard country grows at the same rate as the leading country. The impact of the increase in agricultural productivity is *not* to lower the long-term growth rate, but only to increase the equilibrium gap in output between the laggard country and the leading country (though the gap in the intertemporal utility has actually been reduced.)

[115] In a more general "catch" up model, differences in comparative advantages would be reduced over time.

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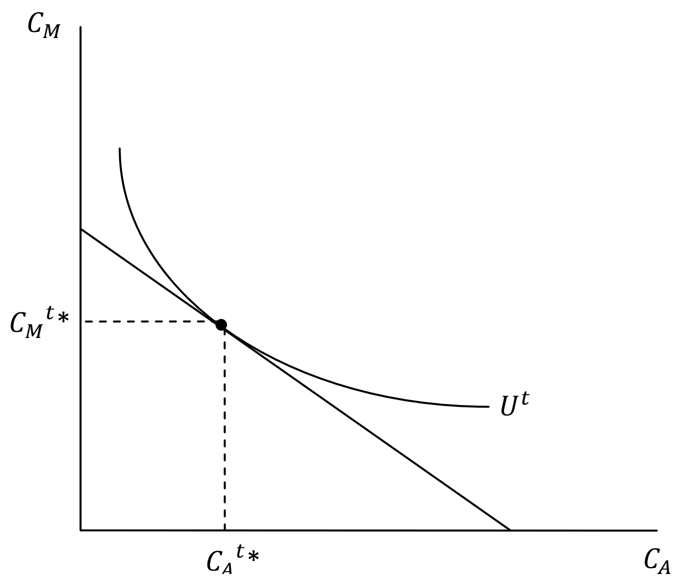
Figures



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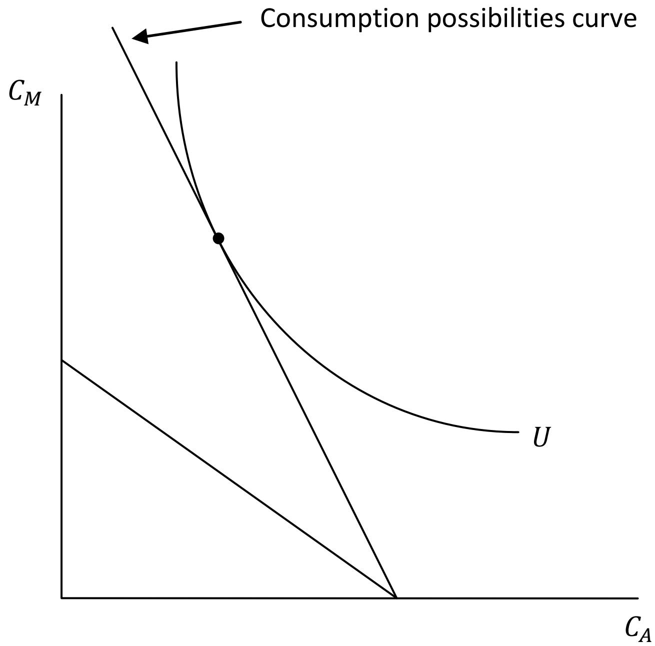

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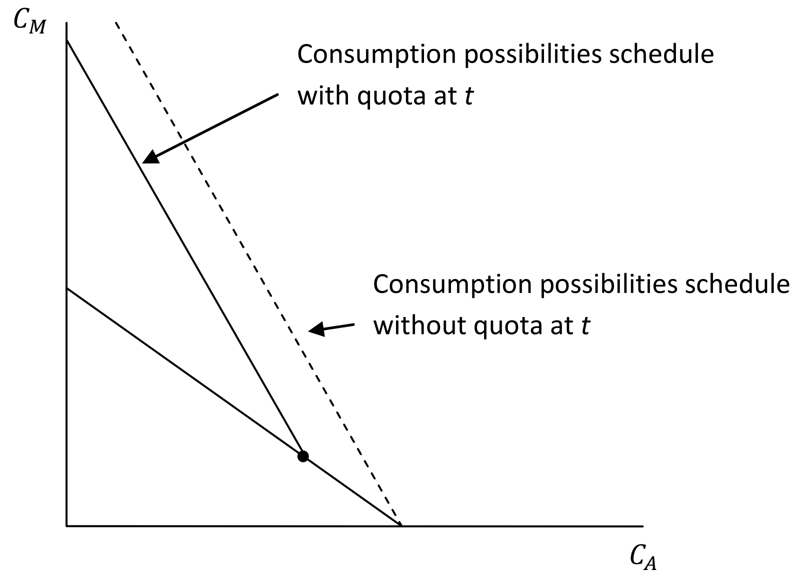
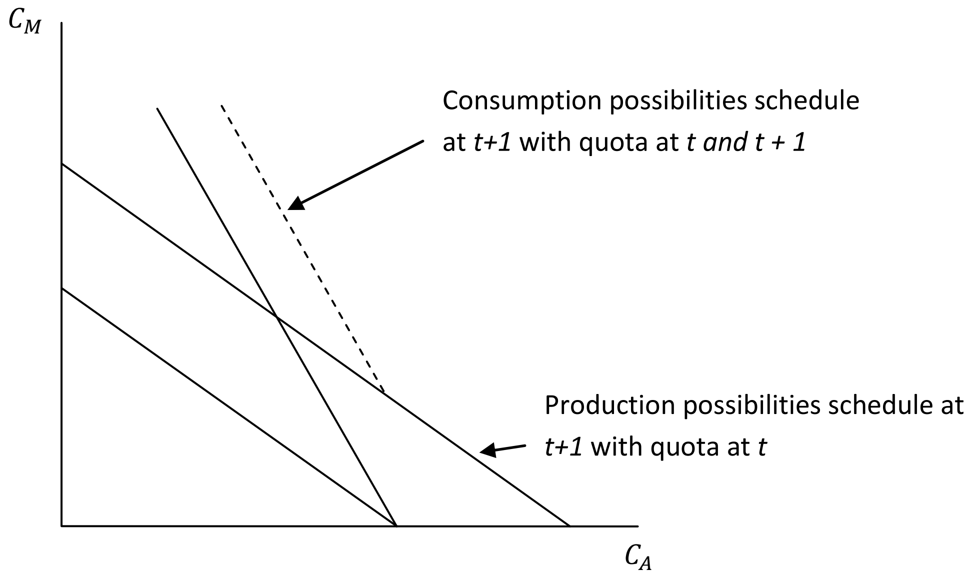

C_M
Consumption possibilities schedule
with quota at t
Consumption possibilities schedule
without quota at t
C_A

Figure 2A



C_M
Consumption possibilities schedule at *t+1* with quota at *t and t + 1*
Production possibilities schedule at *t+1* with quota at *t*
C_A

Figure 2B

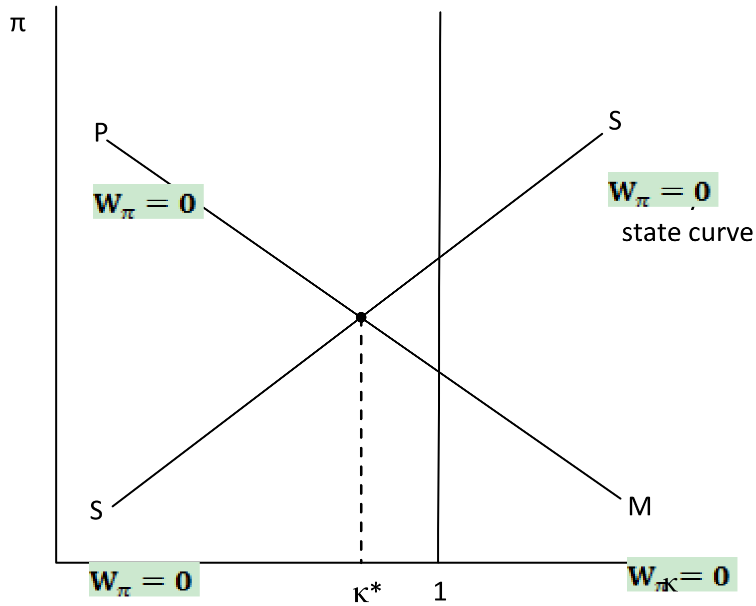

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Figure 3

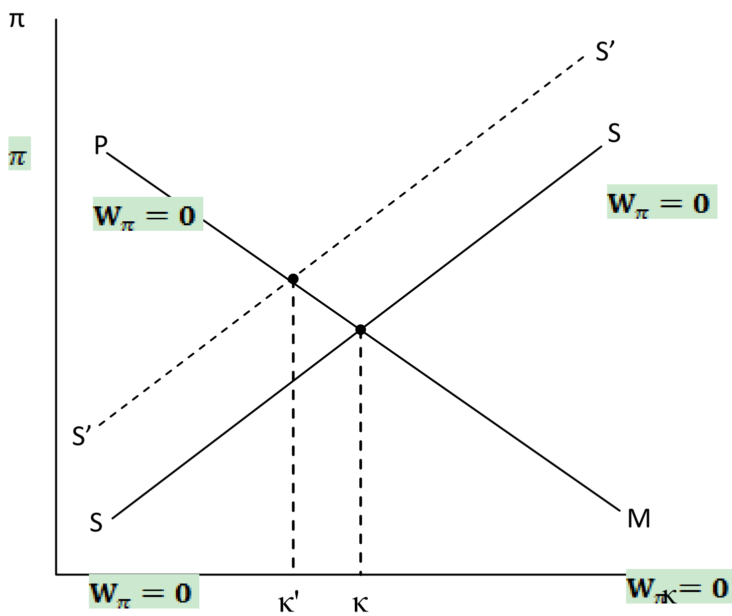

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Figure 4

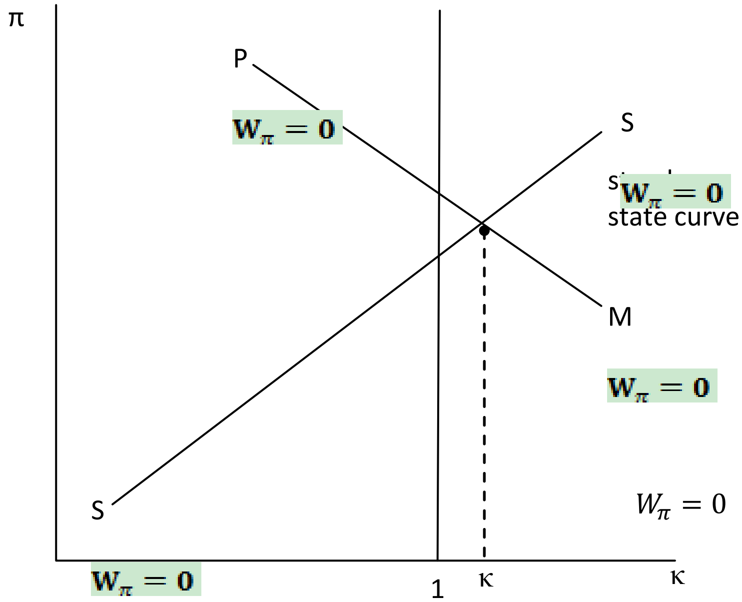

Figure 5A

$\mathbf{W}_\pi = \mathbf{0}$

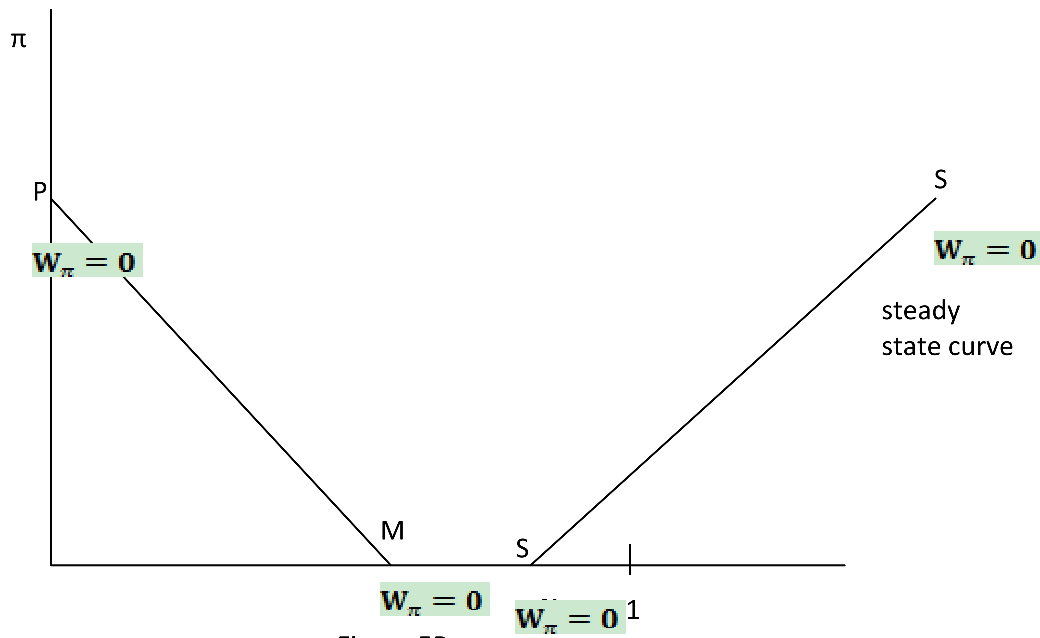

Figure 5B

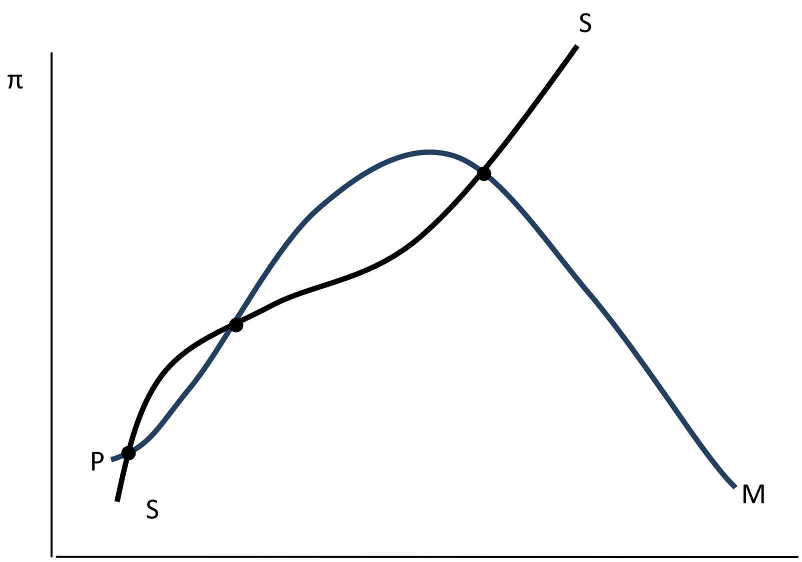

Figure 5C