Introduction

Economic growth has traditionally been attributed to the increase in national production arising from technological innovation. Nevertheless, the relationship between patents and economic growth remains uncertain. This relationship, which forms the focus of this book, is examined by means of a panel of 79 countries bridging the North–South divide for the period 1996–2013. Three groups of countries are identified by their model patent intensity as a proxy for their domestic innovation. The book's clustering empirics may ultimately question efficient growth generation by equal international patent policies.

In the past, developing countries were thought to be at an earlier phase along a linear path of historical technological catch-up by comparison with more developed countries. This course also underlined the neoclassical economics inclination toward "one-size-fits-all" patent policies for fostering innovation-based economic growth. These policies include initiatives by the World Intellectual Property Organization (WIPO), World Trade Organization (WTO) policies deriving from the Agreement on the Trade Related Aspects of Intellectual Property (TRIPS), and relevant innovation policies of the World Health Organization (WHO). This equal-country approach is also consistent with the Washington Consensus standard macroeconomic reform package for crisis-wracked developing countries promoted by the International Monetary Fund (IMF), the World Bank, and the United States Treasury Department. This neoclassical stance ultimately mirrors the constitutional legitimacy of the United Nations (UN)-level organs.

This book joins the ranks of endogenous growth dissenters who have challenged this hegemonic approach. Accordingly, it will be argued that patent harmonization across countries is not clearly necessary, empirically based, or otherwise adequate for the South. The clustering analysis presented in the book is also undertaken within the framework of "convergence" literature. This approach provides an additional and seminal insight known as "club convergence" that can help identify similarities and differences between countries based on generalized growth-related hypotheses. Club convergence over patent intensity and the concept of technological catch up are, of course, interrelated. As with other methodical taxonomies, no clear line runs between the two. As a result, a serious examination of this distinction demands the contextual divorcing of the convergence premise from issues relating to any one country's productivity performance. As a result, what is important for convergence analysis, as this book shows, is how countries perform over a model patent intensity relative to each other, as opposed to how a single country performs relative to its own historical technological catch-up.

Earlier accounts of the relationship between endogenous growth theory and club convergence mostly contributed to the understanding of convergence over salaries, educational level, Gross Domestic Product (GDP), and other macroeconomic income-related indications. Within the growth economics natural flow, convergence analysis may now be expanded into other fields, including patents and innovation.

Chapter 1 sets the framework for contemporary UN-level patent and innovation-related norm-setting. It highlights the fact that much of this process is still marred by regulatory inconsistency, underlying the need for a granular empirical and conceptual approach. Chapters 2–6 explain both how and why countries across the development divide differ in terms of patent intensity as a proxy for innovation-based economic growth. The book thus elaborates on the differences between the three patent clusters based on comparisons drawn over other World Bank and IMF country-group classifications, such as income level, geographic region, and economy type. This is followed by a characterization of the three country groups by core growth indicators, such as the type of institutions performing and financing Gross Domestic expenditure on Research and Development (GERD), GERD by type of research and development (R&D), human capital and human resources indicators, and spatial growth-related indicators.

Estimates of the patent intensity of selected countries and the three designated patent clusters as proxy of their comparable domestic innovation may yield valuable information for national and international policymakers, venture capitalist investors, and R&D managers, as well as for researchers in intellectual property, innovation and economic growth, and other fields.

1 Setting the Framework: Patenting and Economic Growth Policy

Introduction

Economists have traditionally perceived the patent system as a vital lever through which policy-making affects innovation-based economic growth.[1] Yet, across different countries the precise effect of patents remains uneven, for two fundamental reasons. These two reasons relate to the ambiguous effect of national patent laws upon their enforcement and to the ambiguity associated with the impact patenting rates have on national economic growth. First, much empirical ambiguity remains regarding the legal environment shaped by the presence and enforcement of patent laws. This ambiguity relates to such aspects as the impact of a patent rule of law on the incentive to invest in research and development, their ability to increase quotas of foreign direct investment (FDI), or their ability to promote other forms of technology absorption and diffusion in different countries.[2] If

[1] See, e.g., Richard Gilbert and Carl Shapiro, Optimal Patent Length and Breadth, *Rand Journal of Economics*, vol. 21, 106 (1990); Paul Klemperer, How Broad Should the Scope of Patent Protection Be?, *Rand Journal of Economics*, vol. 21, 113 (1990); Nancy Gallini, Patent Policy and Costly Imitation, *Rand Journal of Economics* vol. 23, 52 (1992).

[2] The scope of the present empirical ambiguity is rather startling. See, e.g., Yi Qian, Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment? A Cross-Country Analysis of Pharmaceutical Patent Protection, 1978–2002, *The Review of Economics and Statistics*, vol. 89(3) 436 (2007) (evaluating the effects of patent protection on pharmaceutical innovations for 26 advanced countries that established pharmaceutical patent laws during 1978–2002). In this seminal study, Qian finds that in countries with high levels of development, education, and economic freedom, patent laws indeed stimulate innovation. Ibid., at 436; José L. Groizard, Technology Trade, 45 *Journal of Development Studies* 1526 (2009) (using panel data for 80 countries for the period 1970, the author finds that FDI is higher for countries with stronger IPRs), at 11–13. On the other hand, Groizard identifies a negative relationship between IPRs and human capital indicators. Ibid.; Sunil Kanwar and Robert Evenson, Does Intellectual Property Protection Spur Technological Change?, 55 *Oxford Economic Papers* 235 (2003) (Lower IPRs can facilitate imitation, while, on the other hand, innovation in developing countries increases in proportion to greater IPR protection), at 236; Yongmin Chen and Thitima Puttitanun, Intellectual Property Rights and Innovation in Developing Countries, 78 *Journal of Development Economics* 474 (2005), at 489.

See also Rod Falvey, David Greenaway, and Zhihong Yu, who find evidence of a positive effect between IPR and economic growth for both low- and high-income countries, but not for middle-income ones. Extending the Melitz Model to Asymmetric Countries (University of Nottingham Research Paper Series, Research Paper 2006/07). Using panel data for 79 anything, intellectual property rights (IPRs) and patent law mostly seem to have fallen short in systematically predicting economic growth across countries, including developing ones.[3]

The second reason for this uncertainty relates to the effect of patenting rates on economic growth. This relationship, which forms the focus of this book, will be examined by means of a comparison of the impact of patent propensity rates crossed by R&D intensity across different countries (later to be defined as patent intensity) by way of an important (albeit not a sole) proxy for domestic innovation-based economic growth.[4]

Both the legal environment and patenting itself jointly affect the propensity to patent across countries. In other words, the realization that firms or countries differ in terms of their patent propensity rates acknowledges both the "capability factors" associated with the patent legal environment,[5] alongside "willingness

countries and four sub-periods (1975–1979, 1980–1984, 1985–1989, and 1990–1994), the authors conclude that the positive relationship between IPR and economic growth in low-income countries cannot be directly explained by the potential fostering of R&D and innovation.

For a negative correlation between tightening IPR and innovation, see, e.g., James Bessen and Eric Maskin, Sequential Innovation, Patents, and Imitation, Department of Economics, Massachusetts Institute of Technology working paper no. 00–01 (2000); Mariko Sakakibara and Lee Branstetter, Do Stronger Patents Induce More Innovation? Evidence from the 1988 Japanese Patent Law Reforms, NBER working paper 7066 (1999).

[3] See World Bank, Global Economic Prospects and the Developing Countries (vol. 12, 2002) ("At different times and in different regions of the world, countries have realized high rates of growth under varying degrees of IPRs protection") at 135. See also: Bruno van Pottelsberghe de la Potterie, The Quality Factor in Patent Systems, ECARES working paper 2010–027 (2010) (reviewing empirical studies which generally "lead to the conclusion that 'strong' patent systems have, at most, an ambiguous relationship with the rate of innovation"), at 7–8; Qian, Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment?, (note 2 above), ("The actual effect of IPR on innovation, however, remains one of the most controversial questions in the economics of technology"), at 436.

[4] The chapter focuses solely on the propensity to patent against the backdrop of other intellectual property regimes, which foster innovation, notably in developing countries. But see, e.g., Emmanuel Hassan, Ohid Yaqub and Stephanie Diepeveen, Intellectual Property and Developing Countries: A Review of the Literature, Rand Europe (2010) ("Several surveys carried out in developed countries have shown that other factors are much more effective than patents in enabling firms to profit from inventive efforts: trade secrecy, first-mover advantages and associated brand loyalty, the complexity of the learning curve and establishment of effective production, sales and marketing functions") (internal citations omitted), at 19 and sources therein.

[5] Capability factors relating to the patent legal environment include the cost of patenting: see e.g., Georg Graevenitz, Stefan Wagner and Dietmar Harhoff, Incidence and Growth of Patent Thickets: The Impact of Technological Opportunities and Complexity, *Journal of Industrial Economics* 61 (3), 521 (2013). Capability factors further include patent imitation and litigation costs. See, e.g., Hariolf Grupp and Ulrich Schmoch, Patent Statistics in the Age of Globalization: New Legal Procedures, New Analytical Methods, New Economic Interpretation, *Research Policy* 28, 377 (1999). Another capability factor is

factors"[6] associated with differing patent propensity rates even given comparable legal environments between countries.[7] This book focuses on the latter factors, assessing both how and why countries across the North–South divide differ in terms of their "patent intensity" as a proxy for innovation-based economic growth.

Our field of inquiry conveniently corresponds with the related work of economic geographer Andrés Rodríguez-Pose, explaining why, within the European Union's regional growth dynamics, peripheral and socioeconomically disadvantaged areas have consistently failed to "catch up" with the rest of the EU.[8] Rodríguez-Pose reports the presence of different "social filters" in different regions.[9] These filters provide a different "capacity to every region to assimilate and transform its own or foreign R&D related innovation into economic activity."[10] As a result, one finds "innovation

the lower capability to patent process innovation as opposed to product innovation: see, e.g., Erik Brouwer and Alfred Kleinknecht, Innovative Output, and a Firm's Propensity to Patent. An Exploration of CIS Microdata, *Research Policy* 28 (6), 615 (1999) (upholding that process innovations are generally less likely to be patented compared to product innovations); Anthony Arundel and Isabelle Kabla, What Percentage of Innovations are Patented? Empirical Estimates for European Firms, *Research Policy* 27(2), 127 (1988); Wesley M. Cohen, Akira Goto, Akiya Nagata, Richard R. Nelson, J. Walsh, R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States, *Research Policy* 31, 1349 (2002). See also the sources in note 6 below.

6 The pioneering work of Guellec and van Pottelsberghe has labeled willingness to patent factors as the potential of R&D collaborations with universities, research institutions, competitors or governments; geographical specificities, namely cluster effects among firms and countries; and technological specificities, namely new-to-the-firm/new-to-the-world innovation discrepancies. See Dominique Guellec and Bruno van Pottelsberghe de la Potterie, Applications, Grants and the Value of Patent, *Economic Letters* 69 (1), 109 (2000); Dominique Guellec and Bruno van Pottelsberghe de la Potterie, The Value of Patents and Filing Strategies: Countries and Technology Areas Patterns, *Economics of Innovation and New Technology* 11 (2), 133 (2002). As said, such archetypal willingness factors will be the focus of this book.

7 See Kuo-Feng Huang and Tsung-Chi Cheng, Determinants of Firms' Patenting or not Patenting Behaviors, *Journal of Engineering and Technology Management* vol. 36, 52 (2015) referencing business management theoretician Frederick Herzberg's Motivator-Hygiene theory on job productivity by differentiating capability factors (hygiene factors) and willingness factors (motivation factors). See Frederick Herzberg, Motivation-hygiene Theory, in Pugh, D. (ed.), Organization Theory (Penguin, 1966). Huang and Cheng distinguish capability factors to patent from willingness factors to patent (referring to patent propensity rates), which further leads them to question: why would a firm that is capable of patenting be unwilling to patent? (at 55). The intriguing interrelation between capability and willingness factors in patenting is still under-theorized and remains outside the scope of this book.

8 More generally, see Andrés Rodríguez-Pose, Innovation Prone and Innovation Averse Societies. *Economic Performance in Europe, Growth and Change* vol. 30 75 (1999); Riccardo Crescenzi and Andrés Rodríguez-Pose, Innovation and Regional Growth in the European Union (Springer, 2011).

9 Andrés Rodríguez-Pose, Innovation Prone and Innovation Averse Societies, Economic Performance in Europe, *Growth and Change* vol. 30 75 (1999), at 80.

10 Ibid.

prone" and "innovation averse" societies.[11] "Innovation prone" societies are "those capable of transforming a larger share of their own R&D into innovation and economic growth."[12] Conversely, "innovation averse" societies do not manage to transform their own R&D into innovation and economic growth to the same extent.[13] In a somewhat analogous manner, the book explains how, across the entire development divide, developing countries and notably emerging economies differ in their domestic innovation – heavily proxied by their patent intensity – from advanced economies, thereby characterizing what we may term "patent averse" and "patent prone" countries, respectively, based on their relative propensity to patent rates.

Developing countries led by emerging economies clearly differ in their propensity to attract FDI, trade, and technology.[14] Arguably, they also differ in terms of their ability to innovate and patent inventions. Traditional approaches conventionally depart from the familiar North–South dichotomy, or some variant thereof.[15] The differences in the economics of developing countries highlight, in particular, innovation asymmetries between Northern countries, which are deemed to generate innovative patentable products and technologies, and Southern countries, which are generally deemed to consume them.[16] This is reflected in a lower propensity to patent rate. This chapter substantiates the book's core theoretical and empirical argument in support of measuring patent intensity among countries by comparing patent propensity and R&D intensity rates between the groups of countries adjoining the developmental divide. In so doing, it contributes toward a theory that could replace the "one-size-fits-all" innovation-based economic growth equilibrium: a theory that examines multiple tentative equilibria across the archetypical development divide, as the empirics of this book later entail.

This chapter identifies this equal-country norm-setting as a fourfold challenge. Firstly, this norm refers to institutional aspects of fragmentation among UN-level agencies, including the WTO, over innovation and patent-related policies. Secondly, the dissonance in patenting and innovation-related norm-setting is explained by the present regulatory framework, which is designed to sustain transnational bargaining over trade and IP-related minimal standards and flexibilities. This bargaining posture is excessively based on national market size approximation, to the

[11] Ibid. [12] Ibid., at 82. [13] Ibid.

[14] More generally, see Daniel Benoliel and Bruno Salama, Toward an Intellectual Property Bargaining Theory: The Post-WTO Era. 32 University of Pennsylvania Journal of International Law. 265, (2010), at 312–364.

[15] See Paul Krugman, A Model of Innovation, Technology Transfer, and the World Distribution of Income, 87 *Journal of Political Economy*, 253 (1979), at 254–55.

[16] See Carlos M. Correa, *Intellectual Property Rights, the WTO and Developing Countries: The TRIPS Agreement and Policy Options* (Zed Books, 2000), at 11.

detriment of other, more subtle development-related criteria. Thirdly, this norm-setting challenge further entails the problematic trade-orientation of the Trade-Related Aspects of Intellectual Property (TRIPS) agreement, outweighing innovation-related considerations. Fourthly, it entails the superseding role of short-termed technical assistance and capacity-building policies at UN-level agencies, at the expense of longer-term and more cumulative development strategies.

Against the backdrop of the demise of the Washington Consensus and the gradual rise of endogenous economic growth theory, WIPO's blend of somewhat exogenous economic-related trade rules, fairly equal-country proprietary policies, and a broad development agenda demands empirical and conceptual clarity. Such clarity begs answers (provided in the following chapters) as to both *how* and *why* some countries are patent prone while others are patent averse as a proxy for their comparable domestic innovation.

1.1 Economic Growth, Patent Prone, and Patent Averse Countries

1.1.1 Patenting and Linear Innovation-Based Economic Growth

The initial argument concerning national economic growth through innovation emerged from Cambridge University economist Nicholas Kaldor in 1957. Kaldor theorized that differences in development stages across countries could be explained by differing rates in the adoption of technology.[17] The adoption of technology is often measured through patent statistics.[18] The underlying idea was that investment and learning were related, and that the rate at which they took place determined technical progress.[19]

Against the backdrop of serious doubts concerning the impact of R&D activity on economic growth, two core findings emerged, both of which regrettably focused primarily on developed countries. Firstly, a vast body of literature published in the late 1970s, particularly by economists Zvi

[17] Nicholas Kaldor, A Model of Economic Growth, 67 *Economic Journal* 591 (1957), at 595.

[18] Stanford University Professors Charles Jones and Paul Romer recently exemplified the usage of patent statistics over Kaldor's growth theory. See Charles I. Jones and Paul M. Romer, The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital 8 (National Bureau of Economic Research, Working Paper No. 15094, 2009) (Offering cross-country patent statistics for measuring international flows of ideas alongside trade and FDI as key facets for economic growth).

[19] Kaldor, supra note 17.

Griliches,[20] Jacques Mairesse,[21] and Bronwyn Hall,[22] established the relationship between R&D and firm-level productivity regarding the basic research.[23] Later writings corroborated these findings for firms located in high-tech industries in such advanced economies.[24] A second core finding followed. From an institutional perspective, the UN's approach has been that when there is a need for investing in R&D, this can most efficiently be made internationally, namely by Multinational Corporations (MNCs) considered best placed to orient the direction of the technological change amalgam.[25] Accordingly, it is

[20] Zvi Griliches, Issues in Assessing the Contribution of Research and Development to Productivity Growth, *Bell Journal of Economics* 10, 92 (1979); Zvi Griliches and J. Mairesse, Productivity and R&D at the Firm Level, in Zvi Griliches (ed.), *R&D, Patents and Productivity* (University of Chicago Press, 1984), 399; Zvi Griliches, Productivity, R&D and Basic Research at the Firm Level in the 1970s, *American Economic Review* 76(1), 141 (1986).

[21] See, e.g., Jacques Mairesse and Mohamed Sassenou, R&D and Productivity: A Survey of Econometric Studies at the Firm Level. *Science-Technology-Industry Review* 8, 317 (1991); Philippe Cuneo and Jacques Mairesse, Productivity and R&D at the Firm Level in French Manufacturing, in Zvi Griliches (ed.), *R&D, Patents and Productivity* (University of Chicago Press, 1984), 399.

[22] Bronwyn H. Hall and Jacques Mairesse, Exploring the Relationship between R&D and Productivity in French Manufacturing Firms, *Journal of Econometrics* 65, 263 (1995).

[23] For theoretical literature that incorporates basic research into R&D-driven growth models in closed economies, see, e.g., Lutz G. Arnold, Basic and Applied Research, *Finanzarchiv* vol. 54, 169 (1997); Guido Cozzi and Silvia Galli, Privatization of knowledge: Did the US get it right?'. MPRA Paper 29710 (2011); Guido Cozzi and Silvia Galli, Science-based R&D in Schumpeterian growth, *Scottish Journal of Political Economy* 56, 474 (2009); Guido Cozzi and Silvia Galli, Upstream innovation protection: Common law evolution and the dynamics of wage inequality, MPRA Paper 31902 (2011); Hans Gersbach, Gerhard Sorger and Christian Amon, Hierarchical growth: Basic and applied research, CER-ETH Working Papers 118, CER-ETH – Center of Economic Research at ETH Zürich (2009); Amnon J. Salter and Ben R. Martin, The Economic Benefits of Publicly Funded Basic Research: A Critical Review, *Research Policy* 30 (3), 509 (2001), at 509. For earlier discussion, see Daniel Benoliel, The International Patent Propensity Divide, *North Carolina Journal of Law and Technology* vol. 15(1) 49 (2013), at 53–60.

[24] As numerous empirical studies have shown, R&D activities are crucial to maintaining the competitiveness of firms. Additionally, within high-tech sectors corporate R&D investment may be more fruitful in terms of achieving productivity. See, e.g., Door Petra Andries, Julie Delanote, Sarah Demeulemeester, Machteld Hoskens, Nima Moshgbar, Kristof Van Criekingen and Laura Verheyden, (2009), O&O-Activiteiten van de Vlaamse bedrijven, in Koenraad Debackere and Reinhilde Veugelers (eds.), Vlaams Indicatorenboek Wetenschap, Technologie en Innovatie 2009 (Vlaamse Overheid, 2009), 53 (showing that approximately 80% of Flanders' total R&D expenditures have been conducted by firms in the high-tech segment).

[25] See, e.g., Frieder Meyer-Krahmer and Guido Reger, New Perspectives on the Innovation Strategies of Multinational Enterprises: Lessons for Technology Policy in Europe, *28 Research Policy* 751 (1999), at 752. But see Argentino Pessoa, R&D and Economic Growth: How Strong is the Link?, *Economics Letters*, vol. 107(2) 152 (May 2010) (examining the relationship between R&D outlays and economic growth in the OECD context, while doubting the effectiveness of an innovation policy that attempts to improve aggregate productivity only based on increasing R&D intensity), at 152. Pessoa explains that among

not surprising that there is a large number of scientific studies on this occurrence, or that several of these studies show an increasing internationalization of innovative activity (mainly R&D) by MNCs.[26] If meaningful patent intensity is to take place in developing countries, it will most probably be sought by the same MNCs that overwhelmingly internationalize R&D.

The growing emphasis on the internationalization of R&D by both growth theoreticians and succeeding policy-makers largely echoed another imperative theoretical breakthrough: Paul Romer's endogenous growth theory of 1990.[27] Romer found that economic growth is primarily the result of endogenous investments in industrial R&D in innovation by forward-looking, profit-seeking agents.[28]

In marked contrast to the neoclassical growth models formulated earlier by Robert Solow,[29] followed by David Cass[30] and Tjalling Koopmans,[31] whereby long-term economic growth depends on an archetypical exogenous process being a by-product of investment in machinery and equipment, Romer's hallmark economic growth insight seemingly

12 countries that experienced R&D intensity above the OECD average, only 3 (the United States, Finland, and South Korea) show a GDP growth rate higher than the OECD average. Pessoa further illustrates these intriguing findings for the cases of both Ireland and Sweden. He labels the Irish "Celtic Tiger" as presenting the highest rate of economic growth with low R&D intensity, and the "Swedish Paradox" illustrates an example where the highest R&D intensity coexists with a rate of output growth below the OECD average), at 153. These conclusions are, to date, still considered marginal in economic growth literature.

[26] See generally Organization for Economic Co-operation and Development, Compendium of Patent Statistics report (2008), at 28; Daniele Archibugi and Alberto Coco, The Globalization of Technology and the European Innovation System, in Manfred M. Fischer and Josef Fröhlich (eds.) *Knowledge, Complexity and Innovation Systems* 58 (Springer, 2001); Pari Patel and Modesto Vega, Patterns of Internationalization of Corporate Technology: Location vs. Home Country Advantages, 28 *Research Policy* 145 (1999); Alexander Gerybadze and Guido Reger, Globalization of R&D: Recent Changes in the Management of Innovation in Transnational Corporations, 28 *Research Policy* 251 (1999); Pari Patel, Localized Production of Technology for Global Markets, 19 *Cambridge Journal of Economics* 141 (1995) (offering evidence that there is no systematic evidence to suggest that widespread globalization of technological activities occurred in the 1980s).

[27] See Paul M. Romer, The Origins of Endogenous Growth, *8 Journal of Economic Perspectives* 3, 4–10 (1994); Paul M. Romer, *Endogenous Technological Change*, 98 *Journal of Political Economy* S71, S72 (1990) ("Technological change provides the incentive for continued capital accumulation, and together, capital accumulation and technological change account for much of the increase in output per hour worked)," at 72.

[28] Ibid.

[29] Robert M. Solow, A Contribution to the Theory of Economic Growth, *70 Quarterly Journal of Economics* 65, 68–73 (1956).

[30] David Cass, Optimum Growth in an Aggregative Model of Capital Accumulation, *32 The Review of Economic Studies* 233 (1965), at 233–40.

[31] Tjalling Koopmans, On the Concept of Optimal Economic Growth, in (Study Week on the) Econometric Approach to Development Planning (1965), at 226–28.

prevailed.[32] Though it has been challenged by competing economic models arguing for possible inaccuracies within US patent-based innovative markets, Romer's model has survived and continues to provide the foundation for overall R&D-related growth theory.[33] Henceforth, technological change, particularly through R&D expenditures, is regarded as a sine qua non that lies at the heart of both economic growth theory and policy.[34] Be that as it may, the comparative empirics of patent propensity

[32] Romer's economic growth theory was also said to result from investment in human capital and knowledge. Soon after, Romer's insight became widely popular. See Ben Fine, Endogenous Growth Theory: A Critical Assessment, 24 *Cambridge Journal of Economics* 245 (2000) ("Over the past three years, the number of chapters explicitly drawing upon [Romer's] endogenous growth theory almost certainly borders on a thousand"), at 246.

[33] The contributions by economists Aghion and Howitt and Grossman and Helpman were particularly effective in utilizing the increasing returns to scale of innovations to explain persistent global growth of output per capita over the past two centuries. See Philippe Aghion and Peter Howitt, *A Model of Growth Through Creative Destruction*, 60(2) *Econometrica* 323 (1992), at 327–29; Gene Grossman and Elhanan Helpman, *Innovation and Growth in the Global Economy 1–6* (MIT Press, 1991). For criticism of Romer's endogenous growth model, see Paul Segerstrom, Endogenous Growth Without Scale Effects, 88(5) *American Economic Review* 1290 (1998) (arguing that data does not support the claim that the rate of growth increases with the scale of the economy because patent statistics have been roughly constant even though R&D employment as an endogenous growth indication has risen sharply between the 1970s and 2000s and because a steady increase in R&D efforts has not led to any upward trend in US economic growth rates), at 1292–95; Charles Jones, Time Series Tests of Endogenous Growth Models, 110(2) *Quarterly Journal of Economics* 495 (1995) (developing an alternative model explaining why economic growth has not accelerated despite the substantial increase in R&D efforts), at 501–2.

[34] Romer, Endogenous Technological Change (note 27), at S72; Similarly, from a policy perspective, R&D is seen as the main driver of innovation, and R&D expenditure and intensity are two of the key indicators used to monitor resources devoted to science and technology worldwide. Governments are increasingly referring to international benchmarks when defining their science polices and allocating resources. See Eurostat – Statistics explained, Glossary: R&D intensity: http://ec.europa.eu/eurostat/statistics-explained/index.php/Main_Page.

But see Nathan Rosenberg and others who argue that many process innovations involve "grubby and pedestrian" incremental processes within the firm and are not captured by figures for R&D. See Nathan Rosenberg, *Inside the Black Box: Technology and Economics* (Cambridge University Press, 1982), at 12; Edward Dennison, *Accounting for Growth* (Harvard University Press, 1985) (suggesting that R&D accounts for only 20% of all technical progress); John R. Baldwin and Moreno Da Pont, *Innovation in Canadian Manufacturing Enterprises,* Ottawa: Statistics Canada, Micro Economic Analysis Division (1996) (explaining that certain firms do not engage in any formal R&D). There is also traditional methodological critique on the usage of R&D for innovation-based growth. See, e.g., Mark Crosby, Patents, Innovation and Growth, *The Economic Record*, 76 (234), 255 (2000) (The relationship between R&D and innovation outputs is likely to be time varying, possibly nonlinear, and is also likely to occur with uncertain lags), at 256; Zvi Griliches, Productivity Puzzles and R&D: Another Non-explanation, *Journal of Economic Perspectives*, vol. 2, 9 (1988) (explaining that R&D data are problematic because of problems of definition, and the treatment of time-lags, depreciation, and inflation), at 17–19. With the introduction of the unprecedented and