DYNREG
Dynamic Regions in a Knowledge-Driven Global Economy
Lessons and Policy Implications for the EU

WORKING PAPERS

Theoretical and Methodological Study on the Role of Public Policies in Fostering Innovation and Growth

Marc Schiffbauer

4 / 2006

DYNREG

**Dynamic Regions in a Knowledge – Driven Global Economy:
Lessons and Policy Implications for the EU**

Workpackage No. 1

Comprehensive theoretical and methodological framework

Theoretical and methodological study on the role of public policies in fostering innovation and growth

Authors

Marc Schiffbauer, ZEI and Bonn Graduate School of Economics, University of Bonn

universitätbonn
RHEINISCHE FRIEDRICH-WILHELMS-UNIVERSITÄT

UNIBONN Logo

European Union

Sixth Framework Programme

DYNREG

**Dynamic Regions an a Knowledge – Driven Global Economy:
Lessons and Policy Implications for the EU**

Workpackage No. 1

Theoretical and methodological study on the role public policies in fostering innovation and growth

Authors:

Marc Schiffbauer, ZEI and Bonn Graduate School of Economics, University of Bonn

Consortium Partners:

ESRI	**Economic and Social Research Institute (Co-odinator)**
UNIBONN	**University of Bonn, Center for European Integration Studies**
UTH	**University of Thessaly**
UB	**University Luigi Bocconi, Milan**
CIBAM	**Center for International Business and Management, Cambridge**
WUW	**University of Economics and Business Administration Vienna**
VUA	**Free University Amsterdam**
VUB	**Free University Brussels**
LSE	**London School of Economics**
ULEF	**University of Ljubljana**

"economies that adopt the formal rules of another economy will have very different performance characteristics than the first economy because of different informal norms and enforcement [with the implication that] transferring the formal political and economic rules of successful Western economies to third-world and Eastern European economies is not a sufficient condition for good economic performance." – North (1994, 8)

"Institutional 'copycatting' may have been useful for Poland, but it is much less clear that it was relevant or practical for Ukraine or Kyrgyzstan" – Rodrik (2005, 29)

1 Research questions

This survey outlines the literature on economic growth and development with respect to the following questions: (i) To what extend do public policies influence economic growth? (ii) Which policy mix might optimize a country's rate of growth and development?
Indeed, if we succeed in identifying key policies that foster economic growth, the implementation of optimal growth strategies could cut world poverty and affect income inequalities across countries.[1] However, we implicitly need to solve a closely related puzzle first in order to be prepared to define the scope of public policies: What are the key determinant of economic growth and development?
While the importance to identify the key determinants of economic growth is obvious, a unified theory that matches empirical facts is still missing. Instead, the emergence of endogenous growth theory since the early 90s induced a vast strand of literature covering numerous potential determinants of economic growth and development ranging from macroeconomic policies over trade and industrial policies to deep-seated institutional factors and initial conditions. Clearly, policymakers have direct control over some of these factors, but only limited (long-term) or no control over others.
If we have a closer look at the empirical part of the literature, the overall picture still remains puzzling. In particular, Summers (2003) suggests three main ingredients for growth: (i) economic integration through trade and investment, (ii) maintenance of sustainable government finances and sound money and (iii) an institutional environment in favor of contract enforcements and property rights. He concludes: "I would challenge anyone to identify a

[1] The poverty line is defined by 1 $ in purchasing power parities per day (static) by the Worldbank so that better growth strategies would reduce world poverty if the status quo is suboptimal. Moreover, Rodrik (2005) illustrates that disparities in income across countries account for the bulk of global disparities.

country that has done all three of these things and has not grown at a substantial rate" (Summers, 2003). Indeed, this policy mix appears to be intuitively appealing. Yet, Rodrik (2005) illustrates that corresponding inferences for policy implications are not generally consistent with empirical facts. Table 1 shows that Latin American countries experienced sustained growth during the 1960s and 1970s which represent periods of import substitution policies (high barriers to trade and capital flows) - e.g. El Salvador undertook tremendous reforms since 1989 in favor of macro stabilization, trade liberalization and private sector deregulations without achieving higher growth (see *Figure* 1). Contrarily, *Figure* 2 illustrates that economic growth took off in India in the early 1980s while economic reforms did not take place before 1991. Instead, the initial growth take-off was preceded by substantial public investments in infrastructure in the late 1970s and early 1980s as well as a gradual shift towards a more "business-friendly" policy environment at that time.[2] Table 2 denote that China, Vietnam, India and Uganda have experienced tremendous growth during the 1990s in the presence of major barriers to trade and capital flows.[3] Moreover, the index of overall property rights from the Frasier Institute of Economic Freedom reports for China a index number of 6.8 in 1985 and 4.9 in 2000 which is below the one of Mali, Iran, Panama or Romania.

Consequently, it appears that we need to take some care in isolating growth-enhancing policies and keep in mind to incorporate country specific conditions accurately. Nevertheless, recent advances in development accounting are pointing the way for future research. Caselli (2005) provides a comprehensive survey and various robustness checks of contributions in development accounting. He concludes that the fraction of the variance of income across countries that is explained by variations in factor accumulation (labor, physical and human capital) accounts exclusively for around 40% (upper bound). Thus, the bulk of international income differences is due to variations in total factor productivity (TFP). It follows that a successful theory needs to explain why some countries catch up in terms of productivity (TFP) while others lag behind.

In general, endogenous growth theories initiated by Romer (1990) and Aghion and Howitt (1992), where by endogenous we refer to models of endogenous technical change, are able to explain TFP-differences due to technical change across countries. These theories disclose new theoretical mechanisms for public policies to influence innovative activities and

[2] See Rodrik (2005) for a more detailed description of the growth take-off in India.

[3] In particular, China and Vietnam achieved sustained growth in the absence of trade liberalizations or enhancements of property rights since almost three decades.

TFP-growth - each policy which affects the productivity or cost structure of specialized intermediate producers impacts on the rate of technological progress in the economy.[4] This class of models was extended to distinguish between economies that adopt technologies developed elsewhere and innovating ones. Indeed, it is a well-founded stylized fact that almost all technologies are developed within a few advanced countries. *Figure* 5 and 6 support this finding. Moreover, *Figure* 7 exemplifies the importance of international technology diffusion (from the U.S.) in the Canadian pharmaceutical sector.[5] The theoretical work of Barro and Sala-i-Martin (1997) or Eeckhout and Jovanovic (2002) distinguishes between imitating (adopting) and innovating countries and predicts that a country's long-run growth rate depends exclusively on the rate of technical progress in few leading countries. The innovator and the imitator exhibit the same conditional growth rate in a balanced growth path. The corresponding income differences depend on the capacity of imitating countries to absorb foreign technologies. Barro and Sala-i-Martin (1997) view the security of property rights, taxation and infrastructure as the key determinants of a country's absorptive capacity. Some later models show that growth rates might even diverge if a country's stage of development is too low leading to "convergence clubs" of economies with similar stages of development.[6] Apart from political or institutional constraints to adopt innovative technologies, see e.g. Parente and Prescott (1999) and Acemoglu et al. (2002), the determinants of a country's absorptive capacity are seen as the key for its economic development and technological (TFP-) catch up.

Indeed, a closer look at some case studies supports the pivotal role of TFP-growth as an engine of overall growth in GDP per capita. Table 1 clearly indicates that variations in the growth rate of GDP per capita in Latin America from 1960 until 2000 are primarily due to variations in TFP-growth. The periods of high sustained growth in the 1960s and 1970s comply with periods of high TFP-growth, while the large decrease in GDP-growth in the 1980s is accompanied by a sharp drop in TFP-growth. Moreover, *Figure* 2 shows that growth in India is driven primarily by TFP-growth. More precisely, *Figure* 3 and 4 reveal that before 1980, states with a lot of manufacturing activity performed generally poorly, while thereafter, growth is driven primarily by manufacturing intensive states.[7] The catch

[4]In particular, this approach to economic growth concedes an important role to industrial policies discussed below.

[5]More generally, there is various empirical support in favor of the importance of international technology diffusion to determine a country's TFP-growth rate, see Keller (2004) for a comprehensive survey.

[6]See e.g. Basu and Weil (1998) or Acemoglu and Zilibotti (2001) for divergence in growth rates because of skill-biased technical change and Benhabid and Spiegel (2005) because of a lack of human capital.

[7]See Rodrik (2005) for a more detailed description of the growth take-off in India.

up in TFP of India's manufacturing sector, accompanied with increasing technical change in that sector, appears to support theories of technology diffusion and adoption of foreign technologies. *Figure* 5 illustrates that TFP-growth is also the primary source of China's 'growth-takeoff'. It also suggests that the enhancement of productivity may be linked to improvements in the provision of telecommunication infrastructure which also took off in the end of the 1970s. Consequently, we mainly focus on the role of public policies to foster economic growth via innovations and technological catch-up.

The rest of the paper is organized as follows. In section 2 we discuss theoretical and empirical approaches to isolate key mechanisms for innovation and growth that allow for a direct or indirect role of public policies. In particular, we analyze the literature with respect to the following questions: Whether and how does human capital facilitate the diffusion of technologies across countries? Are local complementarities between human capital - knowledge flows - important and what measures (e.g. brain gain policies) support them? Does the optimal composition of education change with the transitional path of an economy? What are the dynamics gains from trade liberalization - does trade convey technology spillovers? Whether and how trade policies influence the incentives to innovate? Under which circumstances do foreign direct investments (FDI) lead to technology transfers? What policy measures support such environments of knowledge flows via FDI? Do infrastructure investments influence the incentives to innovate and foster technological catch-up? Do macroeconomic policies/stability affect the composition of investments and hence innovations and long-run growth? What is the role of financial development in fostering the incentives to innovate or imitate - is there a compositional effect (e.g. credits vs. market-based system)? Whether and how industrial policies (e.g. deregulation of entry) impact on technological progress? Do R&D subsidies promote innovation and growth?

In section 3, we derive the corresponding open empirical hypothesis from the literature. Section 4 describes the feasible data sets which are necessary to analysis these hypothesis. In the subsequent section, we suggest a list of potential research papers resulting from the above analysis. Finally, we suggest the responsibilities for the research and the corresponding timetables in the last two sections.

2 Theoretical approaches and empirical evidence

In the following, we discuss theoretical approaches and the corresponding empirical support for several key determinants of innovation, growth and technology diffusion that are either directly or indirectly (institutional reforms) controlled by policymakers.

Human capital:

Initially, Lucas (1988) and Rebelo (1991) account for human capital as a productive input that accumulates knowledge by assuming the absence of diminishing returns for the combination of private and human capital. That is , the authors explicitly assume that human capital and technological knowledge are one and the same. Based on this (AK-) assumption they are able to show formally that an increase in human capital is growth-enhancing. Benhabib and Spiegel (1994) and Foster and Rosenzweig (1995) consider an alternative growth-channel of human capital: Human capital facilitates the adoption of foreign technologies. The policy implications of distinguishing between education as a factor of production or technology diffusion (TFP) are significant. In the former, the benefit of a rise in education is its marginal product, while in the latter it is the sum of its effect on all output levels in the future. Benhabib and Spiegel (1994) discriminate between both effects empirically. They estimate equations of the following type:

$$\Delta a_{i,t} = c + gh_{i,t} + m \left[\frac{h_{i,t} y_{max,t}}{y_{i,t}} \right] + \phi t + \theta i \tag{1}$$

where a refers to total factor productivity, h to human capital and y_{max}/y_i to the productivity-distance of country i with respect to the leader country. The authors detect positive estimates for the coefficient m which reflects that a country's capacity to absorb foreign technologies is increasing in its level of human capital. The same authors extend this idea in a later article to account for the possibility of a disadvantage in technological backwardness *à* la Howitt (2000). That is, Benhabid and Spiegel (2005) assume a tradeoff in relatively technological backwardness: On the one hand, there is an advantage of backwardness since the country can choose to adopt new technologies from a larger menu. On the other hand, it is harder to adopt more complex, skilled-biased technologies if the country lags behind the world technology frontier. It follows that technological laggards may converge or diverge in terms of productivity and growth depending on their level of human capital. In the empirical part of the article, the authors show that the predictions of the model based on the educational levels within countries match the growth performance of many emerging economies during the last 40 years quite well.

The positive link between human capital and growth raises the issue of policy interventions and the financing of education. Interventions are justified if social returns exceed private ones.[8] This is the case in Benhabib and Spiegel (1994) due to the positive social externality on technological progress. Yet, a number of studies do not confirm their results. Heckman and Klenow (1997) compare individual with cross-country Mincer wage regressions. If the latter outweigh the former, social returns exceed private. The authors find positive support for excessive social returns. Yet, when they control for technology differences across countries the rates become similar. Likewise, Topel (1999) shows that the social coefficient resembles the private if year-dummies are accounted for. Acemoglu and Angrist (1999) conduct an instrumental variable approach and can not approve deviations between social and private returns.[9] Yet, their results depend crucially on the validity of their instruments - individual education is instrumented by a dummy for the quarter of birth and average education is approximated by compulsory school attendance laws. Krueger and Lindahl (2001) provide robust micro-economic evidence for the existence of private returns, but assess weak macro-economic support for externalities on technical progress from the stock of human capital. In particular, its coefficient is not significant when restricting the regression to OECD countries.[10] Their results are contrary to Benhabib and Spiegel (1994). An attempt to reconcile both studies suggests that education matters only for technological catch-up, but not for frontier innovations.

A general critique which applies to all of these studies is the negligence of qualitative aspects of education. Yet, empirical examinations suffer from the scarcity of available qualitative measures of human capital since conventional proxies are typically based on quantitative measures of education, e.g. years of schooling. Still, several authors suggest empirical strategies to account for the quality of education. Barro (1991) apply student-teacher ratios across countries as a measure for quality. Yet, the evidence is weak since the ratio is

[8]Social rate of returns are typically measured as the effect of human capital on GDP, while private ones follow from Mincer wage regressions that estimate the individual return from an additional year of schooling.

[9]Similarly, Teulings and van Rens (2003) approve that private and social returns to education are equal in the short run.

[10]The authors argue that the assumption of a constant coefficient between initial education and growth across countries is flaw.

negatively related to the number of primary, but not secondary years of schooling. Klenow and Rodriguez-Clare (1997) and Bils and Klenow (2000) provide positive evidence that the human capital of the young generation (students) depends on the amount of human capital of the old generation (teacher). Finally, Hanushek and Kimko (2000) demonstrate the importance of the quality of human capital. They detect a strong causal relation running from the quality of the labor-force to economic growth. Their results are based on international measures of math and science test scores for 39 countries from Barro and Lee (1996*a*).[11] At the same time they find no evidence that public spending on schooling resources influences performance differences of students. Their findings support R&D based growth theories *à* la Romer (1990) where human capital affects the supply of technologies and knowledge transfers. Thus, the large social growth-externality from the quality of the labor force acknowledges the earlier results from Benhabib and Spiegel (1994). Still, the discussion shows that there appears to be a non-trivial mapping from (quality) measures of schooling to the quality of the labor-force.

A different strand of the literature focuses on strategic complementarities between human capital. Kremer (1993) assumes a special production function where production consists of different production processes. In each production process workers can make mistakes with a certain probability depending on their quality. Thus, it differs from the standard specification in the sense that the quality of workers can not be substituted by the quantity in each production process.[12] The specification yields strategic complementarities in human capital and hence multiple equilibria. Finally, some authors stress differences/persintencies in the world income distribution due to a complementarity between technology and skill (skill-biased technologies), e.g. Redding (1996), Basu and Weil (1998), Acemoglu and Zilibotti (2001) or Jovanovic (1996). This complementarity leads to imperfect technology diffusion and hence international income differences. Hence, it provides a microeconomic foundation for the Benhabib and Spiegel (1994)-approach. Moreover, it implies growth-effects due to improvements in human capital, higher protections of intellectual property rights and lower import tariffs. In general, strategic externalities in human capital exhibit a promising approach to refine our understanding of (local) knowledge interactions and hence the process

[11]Note that the authors identify implausibly large estimates since an increase in on standard deviation in the test scores enhances annual economic growth by more than 1%.

[12]He motivates the approach by the 'O-Ring' - a component of the Challenger space shuttle that costs a few cents but finally caused its explosion.

of technology diffusion.

Finally, a number of recent studies associate the composition of human capital and education with economic growth. In the models outlined above, primary, secondary and tertiary education are implicitly regarded as perfect substitutes. In particular, Acemoglu et al. (2002) and Aghion and Howitt (2005) argue that different stages of economic development require different skills. Thus, the closer a country gets to the world technology frontier, the more important is higher (tertiary) education to promote R&D. In contrast, imitation of foreign technologies requires basic (primary & secondary) education. Aghion and Howitt (2005) use this approach to explain productivity differences between the U.S. and the EU. In particular, 37.3% of the U.S. population between 25-64 have completed a higher education degree in 1999-2000, while only 23.8% of the EU population. Furthermore, educational expenditure on tertiary education amount for 3% of GDP in the U.S. against 1.4% in the EU. Vandenbussche et al. (2004) and Aghion, Boustan, Hoxby and Vandenbussche (2005) provide empirical evidence in favor of this hypothesis, whereas the former apply data for 22 OECD countries and the latter data for U.S. states. In both cases, they detect a positive interaction term between the distance to the world technological frontier (measured in TFP) and higher education, albeit it loses its significant if they control for country fixed effect in the former case. Likewise, Caspari et al. (2004) underline the empirical importance of the lack of tertiary education in Germany vs. the U.S. to explain growth differences between the two countries and Krueger and Kumar (2004) stress that skill-specific rather than general eduction in Europe vs. the U.S. causes a productivity gap. In general, this approach can be regarded as an application of a broader theoretical framework which suggest that different institutional frameworks are required for different stages of economic development as argued by Rodrik (2005).

Trade policies and partners:
The literature on trade and growth identifies three static gains from (completely) integrating in the world economy with respect to international trade in goods and factors:[13] (i) an improved allocation of input factors (e.g. capital and labor), (ii) higher productivity due to a specialization of production, (iii) increase in market size. The first effect is due to efficiency

[13]See Ventura (2005) for a unified approach to demonstrate these gains from trade under several market imperfections.

gains from reallocating factors from regions/industries in which they were abundant in autarky into those in which they were scarce. The second results from a specialization of production in products where a region's comparative (productivity) advantage is highest. The last captures the fact that fixed costs for the design of new specialized products need to be paid for only once, but can be sold in the entire (integrated) market. While all regions share the gains from the last two effects, the reallocation of factors might create losses for regions where factors are scarce. Ventura (2005) points out that the entry of large regions in the integrated economy might generate losses for countries with similar factor proportions because that region absorbs scarce factors. Consequently, trade liberalization in China or India might create negative externalities for economies with similar factor proportions in Latin America or Eastern Europe.[14] Nevertheless, it can be shown that an economic integration of the world economy leads to a Pareto-improvement for all countries if it is coupled with an appropriate (intra-regional) transfer scheme. The author infers a general prescription for development: 'open up and integrate in the world economy'.

The translation of static into dynamic gains depends on the scope of diminishing returns and market size effects. Ventura (2005) illustrates that economic integration features only level but not growth effects if diminishing returns to capital, which is the only state variable, are strong and market size effects are weak. Contrary, the framework results in persistent growth effects due to increasing/constant returns to capital if diminishing returns are weak relative to market size effects. Moreover, the author analyzes the consequences of several impediments to international trade. He shows that the gains from economic integration can be sustained completely if we exclusively allow for trade in goods and not factors as long as the factor prize equalization (FPE) holds - e.g. differences in factor proportions across regions are small relative to differences in factor proportions across industries. In addition, he characterizes the dynamics of the world income distribution accounting for deviations from FPE due to extreme factor proportions across regions, the existence of regions with insufficient high-productivity industries or the presence of transport costs (gradual globalization). In many cases, these deviations generate additional forces towards the stability of the world income distribution due to supplementary mechanics in favor of diminishing returns and the general prescription for development of 'opening up and integrate in the world economy' is sustained.[15]

[14]Contrary, gains from trade are larger for countries with different factor shares like the USA or EU.

[15]An exception is the friction of transport costs that apply only to intermediate goods. These entail potentially agglomeration effects across regions.

However, the dynamics described above exclusively focus on the evolution of the private capital stock over time. That is, the capital stock, possibly embedding technical knowledge, is the only state variable of the system. Yet, a complementary strand of the literature on trade and growth emphasizes the existence of dynamic gains from trade via transfers of embedded technologies.[16] Growth models of endogenous technical change provide a natural framework to study the effect of trade (in intermediates) on the incentives to innovate.[17] In this context, Rivera-Batiz and Romer (1991) study the effect of a liberalization of trade in goods in a symmetric two-country model. In this case, opening up to free trade does not imply permanent effects on the incentives to innovate (and hence growth) if the diffusion of knowledge is intra-national in scope. The reason is that the benefits as well as the (labor) costs of R&D increase by the same amount. Yet, Devereux and Lapham (1994) show that the outcome is different in the asymmetric case because the initially richer country carries out all research in equilibrium while the incentive to innovate is eliminated forever in the poorer one. Thus, the former specializes in research and the latter in manufacturing which augments the overall resources devoted to research in the richer country and the welfare in both countries (equally). In contrast, the rate of technical change and hence long-run growth increases in both cases if technology diffusion is international in scope. This results directly from the public good characteristics of knowledge - the combined stock of knowledge/technologies exerts a higher externality on future research. A more empirically founded framework constitute *product cycle models* which are based on the observation that new goods are invented in the *North* while the *South* imitates vintage goods.[18] Helpman (1993) analyzes the effect of intellectual property rights (IPR) in this framework. He demonstrates that tighter IPRs not necessarily improve the rate of innovation in the *North*, but unambiguously reduce the rate of imitation (and hence convergence) in the *South*. Finally, Acemoglu and Zilibotti (2001) argue that it the presence of skill-biased technical change as discussed above, the *South* has an incentive to protect IPRs in order to attract more suitable innovations.[19] It follows that a combination of trade opening and weak protection

[16]To capture these dynamics formally, one needs to introduce the stock of technologies as an additional, independent state variable.

[17]Grossman and Helpman (1995) provide a comprehensive survey of the early literature on trade and technology.

[18]Hence, these models suppose a slow diffusion of technologies across advanced and less developed countries.

[19]One might conclude that trade openness increases international income differences by aggravating the skill-biased in technologies in this case. Yet, general statements are difficult since they depend on the equalization of factor prizes (FPE) across countries which in turn depend on factor compositions, the

of IPRs in the *South* can impede their rate of growth (in the absence of FPE) as outlined by Gancia (2003). The discussion shows that the role of IPRs in innovation and growth is not obvious and that the dynamics between trade and growth (at least quantitatively) depend on the strength of international technology diffusion.[20]

A number of empirical studies verify the global dimension of technology spillovers. Yet, the diffusion process is far from perfect. Keller (2002*a*) finds that the geographic distance is an important determinant of the diffusion of technologies between countries.[21] Indeed, a number of studies also demonstrate the importance of international trade flows in order to explain spillovers of technologies. Thus, trade itself provides a mechanism for international technology diffusion. Coe and Helpman (1995) apply a cointegration analysis to investigate the effect of domestic and foreign R&D on domestic TFP. The econometric framework seems appropriate since conventional test indicate the presence of a unit root for both variables. In particular, they estimate the following specification for 22 OECD countries:

$$lnf_{ct} = \alpha_c + \beta^d lnS_{ct} + \beta^f lnS_{ct}^f + \epsilon_{ct} \qquad (2)$$

where S_{ct}^f is defined as the bilateral import-share weighted R&D stocks of the trade partners. The authors find large positive effects from import-weighted foreign R&D (β^f). Coe and Hoffmaister (1997) generalize these findings for a larger set of 77 advanced and developed countries. Keller (1998) relativizes these findings by demonstrating that the import shares in the construction of the foreign R&D variable are not essential to achieve their result. Yet, Keller (2002*b*) detects significant spillovers from foreign R&D to TFP via international trade using industry data for thirteen industries and eight countries. Overall, the impacts of foreign R&D from the same and different industries amount for 20% of the overall spillovers. Xu and Wang (1999) and Caselli and Coleman (2004) refine the link between trade and technology spillovers by focusing on trade in differentiated intermediate capital goods. The estimates for the effects of foreign R&D for domestic productivity increase in this case. Eaton and Kortum (2002) impose a more structural approach to estimate the importance of international trade for the transmission of technologies. They embed a Ricardian model

productivity of industries etc.

[20] Again, we stress that the impact of trade on growth is in general positive if FPE holds. If not, as is often the case in reality (compare wages across countries), Grossman and Helpman (1995) illustrate that opening up to trade can reduce economic growth in certain circumstances.

[21] He also isolates a common languages as an important component. This hints at a role of cultural factors (similarity) in the identification of global knowledge spillovers.

of trade in an endogenous Schumpetarian growth model of quality improving innovations. Based on a cross-section of 19 OECD countries, the authors find that an improvements in a country's technology raises the welfare of all other countries. Finally, Clerides et al. (1998) and Bernard and Jensen (1999) reject the hypothesis that exports of goods influence firm-level learning effects using case studies of three developing countries and the U.S. respectively.

The interrelations between trade and technological progress also provide a potential basis for trade policies. Note that the type of models outlined above imply two different sources of market imperfections: (i) a positive non-internalized externality of technologies on future research and (ii) market power in the intermediate goods sector. Grossman and Helpman (1995) demonstrate that trade policies as well as industrial policies in general can lead to second-best welfare benefits. Still, they stress that universal policy prescription are far from obvious due to complex general equilibrium effects that might counteract the original intensions. The authors consider an example in which the success of a tariff on an import-competing sector to foster innovations depends on whether the favored sector is a complement or substitute for the R&D sector in the general equilibrium production structure. That is, if the favored sector requires the same input factor (e.g. skilled labor), the equilibrium costs of this factor rise and R&D declines. However, some empirical case studies support the view that a mixture of active trade and industrial policies can enhance innovation and growth. In this regard, Rodrik (2005) describes the successful policy mix of tariff protection for traditional industries and export subsidies for innovative sectors in South Korea or Taiwan. We will discuss some of these aspects in greater detail in the section on industrial policy.

Finally, Baldwin and Forslid (2000) argue that trade liberalization influence the market structure in the R&D sector. More specifically, they illustrate that reduction in transport costs (i) reduce the value of intermediate firms by increase competition in R&D and (ii) improve financial intermediation by promoting asset trade. Both effects improve the incentives to invest in R&D in their framework.

Foreign direct investment:

Foreign direct investments (FDI) provide an additional potential transmission channel for the diffusion of technologies. The link is plausible since the sharing of knowledge among multinational parents and subsidiaries represents a natural channel through which technology can diffuse internationally. Moreover, foreign investors typically need to standardize their production process to local environments which facilitates the local adoption of technologies. In this regard, FDI appears to be superior to trade in order to convey technology spillovers.

In general, a potential foreign investor has a choice between direct investments and the licensing of a technology to a foreign firms. The latter approach prevent the operation in an unfamiliar business environment, but comes at the costs of moral hazard and the reliance on contract enforcements which seem to be severe in an international context. Indeed, *Figure* 8 suggests that most technology spillovers are due to indirect spillovers. Additionally, *Figure* 9 and 10 illustrate that FDI of the USA (the technological leader) as well as in the USA increases significantly during the 1990s respectively. Hence, we focus our analysis on FDI.

Grossman and Helpman (1995) emphasize two crucial theoretical aspects of the role of technologies in FDI. First, investors need to enter the market with superior technologies in order to be in a position to compete with locally owned firms in an unfamiliar business environment. Second, R&D is the type of firm level fixed costs that generates economies of scale and hence incentives for FDI. Thus, technological progress boost the incentives for FDI of the investor and the host country which hopes for larger productivity spillovers. In this regard, FDI is also a major policy issue. Keller (2004) denotes that governments spend large amounts of resources to attract FDI.[22]

The empirical evidence, however, is not that clear-cut. Recent surveys based on micro-level productivity studies concluded that there is no evidence for productivity spillover via FDI (Hanson (2001), Goerg and Greenaway (2002)). Aitken and Harrison (1999) confirms these results in a case study for Venezuela. Yet, the case studies of Larrain et al. (2000) and Liang (2003) reports tremendous knowledge spillovers from Intel's investments in Costa Rica and FDI for Chinese telecommunication firms, respectively. Branstetter (2001) and Singh (2003) exploit data on patent citations to investigate knowledge spillovers of FDI. The former detects positive spillovers from the investor to the host country for Japanese FDI in the USA

[22]The U.S. state of Alabama spent $ 230 million in 1994 to attract a new plant of Mercedes Benz. Likewise, the German state of Saxony spent a similar amount to attract a new plant of AMD in 2004.

as well as the other way around. The latter, even finds that foreign subsidiaries learn more from firms in the host country than vice versa for a panel of 10 OECD countries. These results are somewhat surprising. Yet, Keller (2004) underlines that they might be due to an endogeneity problem. Still, a number of studies provide robust empirical evidence in favor of technology transfers to the host country focussing on a more direct approach, e.g. Xu (2000), Griffith et al. (2003), Keller and Yeaple (2003). These studies, based on FDI-data for the U.S. or U.K., find that productivity growth in the host country is systematically higher in industries with more FDI. In particular, Keller and Yeaple (2003) estimate large quantitative effects in high-technology compared to low-technology sectors. Consequently, there exists various positive as well as negative evidence in favor of technology spillovers from FDI, whereas, apart from methodological issues, the difference depends on the country under study.[23]

In the following, we will see that theory can reconcile the conflicting empirical evidence in a number of ways. Rodriguez-Clare (1996) employs a static equilibrium model where productivity effects arise via the provision of high-quality intermediate inputs. He highlights a tradeoff for the host country: FDI increases the demand for intermediate goods and services of local suppliers while it suppresses local competitors (reducing the demand for local intermediates). Whether the net demand effect is positive depends on transportation costs and initial productivity differences in the model. Thus, the approach predicts that the productivity effect of FDI differs according to country-specific conditions.[24] Fosfuri et al. (2001) concentrate on productivity spillovers through labor training and turnover in the host country to justify FDI-spillovers. Indeed, Larrain et al. (2000) outline that Intel funded schools that taught local workers in Costa Rica. Several contributions suggest a number of additional factors that influence the existence of productivity spillovers from FDI. Blomström and Kokko (1998) and Peri and Urban (2006) emphasize the pivotal role of the absorptive capacity of the host country or the productivity gap between the home and the host country. That is, spillovers are larger if the technology gap is tighter which can be justified e.g. due to skill-biased technologies. The absorptive capacity usually refers to factors like the quality of institutions, human capital, regulations etc. These finding are analog

[23]Note that the results are spurious if additional effects of FDI are not accounted for. For example, Aitken and Harrison (1999) do not control for the effects of FDI on the market structure in Venezuela.

[24]Note however, that the author totaly abstracts from the possibility of long-run learning effects of firms in the host-country.

to the ones of imitator-innovator models described earlier. Antras and Helpman (2004) and Antras (2005) point out that technology transfers also depend crucially on the strategic decisions of the investor. The foreign investor might want to outsource or externalize a certain degree of knowledge to foreign affiliates or partners depending on firm-strategic considerations. This approach discloses the possibility for a number of supplementary determinants of technology spillovers from FDI. For example, the firm's 'entry'-strategy into the foreign market might change with the initial market structure in the host country. That is, the investor might prefer to enter the market with a more sophisticated production technology to escape from competition if the market structure in the host country is competitive.[25] In fact, Liang (2003) underlines the importance of this 'escape-competition effect' for FDI in the Chinese telecommunication sector. Finally, Eichgreen and Tong (2005) and Mercereau (2005) explore the competition of host countries in order to attract potential foreign investors, e.g. arising from the entry of new players like China or India. Summing up, the success of FDI for the host country depends on a number of complementary factors that pin down the probability for technology spillovers. Even though the literature examines some mechanisms for FDI-spillovers, substantial further research needs to be dome in order to isolate the key determinants of empirical differences across country, in particular with respect to supportive policy measures. In this regard, we agree with the final conclusion of Grossman and Helpman (1995, 66): "[to identify determinants of technology transfers]... we will need models that pay closer attention to how knowledge is transmitted within and between firms?"

Infrastructure:

A brief comparison of power generating capacities, telecommunication and transportation equipments across countries suggest immediately a close connection between the provision of infrastructure and a country's past economic performance. A substantial amount of empirical work confirms this correlation between infrastructure investments and economic growth across time (within 'a panel of' countries).[26] In fact, the prediction of a net positive growth effect of infrastructure investments constitutes a powerful growth strategy since policymakers exhibit direct control over infrastructure investments/subsidies. Yet, it is not surprising that episodes of high growth and economic activity comply with episodes

[25] This effect is suggested by Aghion and Howitt (2005) in a different framework.

[26] Gramlich (1994) or Holtz-Eakin and Schwartz (1994) survey the early literature.

of high expenditures for (public) infrastructure. Thus, the main empirical challenge is the identification of *cause and effects* between infrastructure investments and GDP-growth. Indeed, several recent empirical contributions report a positive causal relation for different regions and time periods. Fernald (1999) shows that the rise in road services substantially increased the productivity (TFP) across industry in the U.S. from 1953 to 1973.[27] The author employs an implicit test for endogeneity by showing that productivity growth is above average in vehicle intensive industries. Roeller and Waverman (2001) formulate a structural model for the supply and demand of telecommunication infrastructure to separate cause and effects on aggregate production.[28] They find large positive effects of telecommunication investments on economic growth in a panel of 21 OECD countries from 1970-90. Belaid (2004) confirms the results for a panel of 37 developing countries from 1985-2000. Finally, Calderón and Servén (2005) apply an (internal) instrumental variables approach to estimate a positive causal effect of different infrastructure measures on GDP-growth in a panel of 121 countries from 1960-2000. Besides, several empirical studies employ firm-level data on business costs to investigate the exact microeconomic functioning of infrastructure capital. In this regard, Holtz-Eakin and Schwartz (1994) and Morrison and Schwartz (1996) find robust empirical evidence for a negative relation between firm-level business costs and the provision of infrastructure capital in the economy. Moreover, Bougheas et al. (2000) detect a positive relation between infrastructure capital and the degree of specialization in intermediate production for the U.S. economy. The empirical evidence refers to a quite heterogenous set of countries, time periods or infrastructure variables. The impact on growth appears to be substantial in advanced as well as developing countries for certain periods.[29]

Most part of the theoretical literature suggests that the provision of infrastructure affects economic growth boosting private capital investments. This literature is substantially influenced by the work of Barro (1990) who incorporates productive public capital in an extended two sector *AK-growth model*. He assumes a (Cobb-Douglas) production function featuring constant returns to scale for the combination of private and infrastructure cap-

[27]He measures a rate of return of 100% before 1973 and a negative rate from 1973-89. To put it in the words of Fernald (1999): "the interstate highway system was very productive, but a second one would not be".

[28]The identification of cause and effects crucially hinges on the specification of demand and supply functions and congruence of price elasticities across the OECD countries.

[29]Roeller and Waverman (2001) and Belaid (2004) quantify similar elasticities of GDP with respect to telephones per worker for advance (0.45) and developing countries (0.5) for similar time periods using identical estimation techniques.

ital. Thus, he implicitly supposes that (broader) capital accumulation, which is studied by neoclassical theory, and technological knowledge, which is necessary to counteract diminishing returns, are one and the same. It follows that infrastructure or private capital investments feature not only level but also growth effects in the long-run. Yet, the growth effect of infrastructure is limited due to a financing by distortional taxes. Consequently, the author can derive an optimal level of infrastructure capital. In the literature this finding is referred to as the *Barro Curve*. It predicts that high saving rates and efficient tax systems sustain high economic growth. This approach has been generalized in several ways since - Turnovsky (1997) accounts for public capital which is subject to congestion, Kosempel (2004) for the case of finitely lived households, Turnovsky (2000) for an elastic labor supply and Ghosh and Mourmouras (2002) for an open-economy framework. An alternative approach is followed by Bougheas et al. (2000) who show that infrastructure investments increase an economy's degree of specialization.

The link between infrastructure and private capital accumulation may be appropriate to explain its growth-effect in less developed countries. Yet, it may not be adequate to explain recent growth performance in advanced countries. In a recent study, we argue that infrastructure reduces costly distortions between the final output and intermediate sector in a model of R&D based growth and hence enhances investments in R&D and innovations. This refinement is important at least for two reasons: (i) It relates long-run productivity/GDP-growth to the stock of infrastructure capital instead of its growth rate (as in the former literature). (ii) It comprises different policy implications than the existing models which are based on neoclassical inference. That is, we identify policies that influence the efficiency of the R&D sector (higher education, industrial and innovation policy, absorptive capacity), instead of neoclassical policies that influence the saving behavior, to determine the growth effect of infrastructure investments. In addition, we find positive empirical evidence in favor of a positive causal impact from (telecommunication) infrastructure investments on subsequent R&D investments in the business sector for 36 advanced countries from 1975-2000. This effect interacts positively with the amount of higher education, property rights and the initial R&D stock. In turn, we find no evidence that infrastructure investments influence private capital investments in our sample. The approach can easily be extended to an imitator-innovator framework, where the provision of infrastructure capital in the imitating country determines the probability of convergence and the stationary TFP-difference between the less developed and advanced country. So far, the empirical relation between infrastructure and productivity growth is studied by Fernald (1999), Bougheas et al. (2000) and Hulten et al. (2003) who analyze the impact of infrastructure on productivity and product specialization in the U.S. and India respectively. In fact, as we outlined above, Rodrik (2005) highlights the importance of initial infrastructure investments for TFP-growth in India since 1980. *Figure* 11 displays the TFP-growth and the change in the stock of paved roads (as % of total roads) and railroads in India from 1960-2000, which supports the author's view. The same analysis is carried out for China in *Figure* 12 for the stock of paved roads and telephone mainlines per worker. Finally, *Figure* 13 and 14 illustrate the accelerations of the infrastructure stocks and TFP for China from 1960-2000. Consequently, the figures suggest that the provision of infrastructure capital in connected to TFP-growth in these two major success stories in terms of economic growth during the last three decades.

Macroeconomic stability:
The appearance of endogenous growth theory challenges the traditional separation of business cycle and growth theory in the earlier literature. Conceptually, the notion of capital in endogenous growth theory is broader, e.g. capturing the accumulation of knowledge. Thus, short-run fluctuations in private capital entail externalities on the stock of knowledge/technologies and hence future investment opportunities and growth. The work of King et al. (1988) represents a prominent example for the integration of growth and business cycle theory. The authors incorporate endogenous growth in a real business cycle model in order to show that temporary shocks can induce permanent effects on output. It follows that national policies can induce long-run growth effects.[30]

The empirical literature has evolved predominantly in two distinct branches that separate the dynamics of low and high frequencies. An important exception reflects contribution of Ramey and Ramey (1995). The authors reveal a negative correlation between the overall volatility and the trend of GDP growth which is robust to the inclusion of the investment share of GDP. They apply cross section and (static) panel estimations for a sample of 92 as well as a subset of 24 OECD countries from 1960-1985. In addition, they are not able to find a robust empirical correlation between inflation and the share of aggregate investment. Furthermore, they show that most of the correlation between volatility and growth is due

[30] The same causation is predicted by business cycle models with investment irreversibilities; e.g. compare Aizenman and Marion (1993).

to variations in unexpected innovations to GDP-growth by considering deviations from a forecasting equation. Hence, their results suggest that uncertainty induced by nominal or real innovations links volatility and productivity growth. These findings are confirmed by study of Aghion, Marios, Banerjee and Manova (2005). The authors detect a negative causation from (exogenous) commodity price shocks to economic growth. Moreover, they illustrate that commodity price shocks reduce investments in R&D but not overall private investments. Hence, the transmission channel is via productivity growth and not factor accumulation.

Several studies analyze the direct impact of certain macro-policies on economic growth. Fisher (1993) focuses on the link between inflation and GDP-growth. He finds a negative empirical relationship between the two employing cross sectional and panel growth regressions for yearly data. The author also investigates the causal mechanism by splitting the sample into two sub-periods of mainly demand (1960-1972) or supply shocks (1973-1988). He argues that adverse supply shocks, which entail periods of high inflation and low growth, are the main source for the endogeneity of inflation, but finds no significant differences between the relation in both periods.[31] Several studies analyze nonlinear effects of inflation on growth.[32] Barro and Lee (1996*a*) applies low frequency data (10-year averages) and detects a negative relationship if annual inflation exceeds 20%. Similarly, Bruno and Easterly (1998) exclusively find a strong negative temporary correlation if inflation surpasses a specified value of 40% ("inflation crises"). Sarel (1996) endogenously determines a structural break in the inflation-growth relationship if the former exceeds 8%. Along the same lines, Sepehri and Moshiri (2004) estimate different structural breaks which vary from 5-15% depending on a country's stage of economic development. In contrast, Fisher (1993) uses splines, setting breakpoints at 15% and 40%, to test for non-linearities and finds that the negative correlation between inflation and TFP growth is, if anything, larger in low-inflation (OECD-)countries. In summary, most authors report evidence of a stronger negative relation in episodes of high inflation, albeit there exists a striking disagreement as to where that threshold is.

[31] The difficulty to identify a causal relation between inflation and growth is a general problem in the literature since appropriate instrumental variables for inflation barely exist. The most promising instrumental variable approach is due to Cukierman and Webb (1993) who incorporate measures of central bank independence as instrumental variables and detect negative correlations with economic growth.

[32] Intuitively, nonlinearities are appealing since there exist no economic advantages of excessive inflation. Thus, periods of extreme inflation arguably represent scenarios where authorities lost control over inflation dynamics and are expected to enforce counteracting policies. This reasoning also suggests that the degree of uncertainty is aggravated by the level of inflation.

Against this background, Easterly (2005) provides important insights with respect to the interpretation of these results. He underlines that the negative correlation between national policies (inflation, budget balance, real overvaluation, trade openness, and black market premium) and growth crucially depends on inflation-outliers, which represent episodes of low institutional quality. In particular, he illustrates that the explanatory power of national policies disappears if one controls for institutional measures such as geographic and ethno-linguistic variables.[33]

Fisher (1993) stresses three potential theoretical mechanisms to justify a link between inflation and growth: (i) a reduction in productivity growth because of distortions in the informational content of the price level due to aggregate uncertainty; (ii) a reduction in capital accumulation stemming from temporary hold up of investment decisions in the presence of aggregate uncertainty; (iii) inflation tax on returns from capital and R&D investment if investors must hold cash-in-advance. Aghion, Marios, Banerjee and Manova (2005) provide an alternative explanation. They show that volatility influences the composition of private investments. More specific, they distinguish between more productive but risky investments from secure but return-dominates ones. It follows that an increase in in the idiosyncratic risk of innovative investments induces a shift of private investments into return-dominated projects if financial markets are incomplete.[34] The investment composition effect provides a potential for national policies to affect innovative activities and hence aggregated TFP- and GDP-growth. That is, macroeconomic stability influences the quality of investments without changing its quantity - private capital accumulation. In this regard, Aghion and Howitt (2005) argue that the study of Easterly (2005) is based on average policies over time and abstracts from the effects of shocks and business cycles. Thus, he ignores the potential mechanism for macro-policies to influence economic growth through stabilizing the economy and improving the ability of producers to smooth out the effects of cycles and shocks. In fact, Aghion and Howitt (2005) find that counter-cyclical policies (e.g. primary budget deficit) increase economic growth using annual panel data on 17 OECD countries from 1965-2001.[35] The authors distinguish several macro-policies and reveal that counter-

[33]Easterly (2005) estimates cross section as well as dynamic panel growth regressions based on the general method of moments.

[34]In the empirical part, the authors are indeed able to identify a positive interaction term between volatility and financial development so that the negative effect of volatility declines in the degree of financial development.

[35]The set of countries exhibit sound institutions so that Easterly would have predicted no policy effect. In addition, Aghion and Howitt (2005) illustrate that the effect declines in the degree of financial development

cyclical public investments or direct firm subsidies are growth-enhancing while government consumption is not. Summing up, a negative relation between volatility and growth provides a mechanism for a growth-enhancing effect of (stabilizing) macro policies.

Financial development:

The degree of financial development of an economy has long been considered as an engine for economic growth and development. The theoretical literature provides several explanations that support this view. Acemolgu and Zilibotti (1997) emphasize that the possibility to diversify investment projects improves investment opportunity of firms. They assume that more productive investments are also riskier. Thus, the lower the opportunities for risk-sharing activities, the slower is the accumulation of capital. In addition, their model predicts that the uncertainty of a country's growth process is linked to its degree of financial development. That is, shocks impede economic growth when risk-sharing opportunities are low. However, in the absence of larger shocks, growth and in turn better financial institutions can still develop in these countries. It follows that "luck" determines to a certain extend the path of economic development in their world.[36] Among others, King and Levine (1993*a*) and Aghion, Marios, Banerjee and Manova (2005) formalize that the quality of private investments is related to the outside financing opportunities. Thus, financial intermediation promotes innovative activities and hence economic growth.

While most economist would agree that financial development is good for growth, there exists several alternative financial systems. Financial intermediation may be based on stock markets or credits. Numerous contributions to the literature from different backgrounds analyze implications of competing financial systems. The development of imitator-innovator growth models and the formalization of the process of technology adoption adds a new dimension to think about competing financial systems. That is, a market based system may be more adequate to finance investments in technologically developed, R&D based countries since stock markets are more appropriate to monitor the quality of products. However, producers in technological backward countries need to adopt/imitate foreign technologies in order to compete in the world market. This learning process takes time and delays the 'break-even' of investments. Moreover, firms in less developed countries do often not dispose of internal financing sources (to finance riskier projects in the presence of incomplete finan-

of an economy (negative interaction term).

[36] The fact that the variability of economic growth is higher in less developed economies is well documented by economic historians.

cial markets). Therefore, a financial system based on long-term relations between producers and investors may be more adequate. This reasoning already dates back to Gerschenkron (1962). It is an application of the idea that different stages of development require different institutions (appropriate institutions) which is outlined above.

There exists robust empirical evidence on the positive impact of financial development on long-run growth, e.g. King and Levine (1993*b*), Levine (1997). The degree of financial development is typically approximated by the amount of liquid liabilities, the amount of private credit relative to GDP or the value of private banks relative to central banks assets. These studies apply dynamic panel estimations based on a large number of advanced as well as less developed countries, whereby the heterogeneous sample is important to ensure the validity of the financial proxies. Levine, Loayza and Beck (2000*b*) apply an instrumental variable approach to identify a causal relation running from the degree of financial intermediation to economic growth. Moreover, they show that differences of financial developments across countries can be explained by differences in legal and accounting systems. Benhabid and Spiegel (2000) and Levine, Loayza and Beck (2000*a*) investigate whether the link between financial development and growth is due to improvements in private factor accumulations or productivity (TFP). The former detect positive evidence in favor of both transmission channels while the latter find larger (more robust) effects in favor of TFP-growth.

Industrial & Innovation policy:
Endogenous growth models are based on the assumption that current R&D entails a positive externality on future research. Likewise, most approaches account for the existence of monopoly rents from innovations that justify investments in R&D.[37] These market imperfections lead to inefficiencies in the decentralized equilibrium allocations which imply a potential role for public policies to influence innovations and growth. The general equilibrium welfare effects of such policies, however, may not be obvious ex ante as is underlined by Grossman and Helpman (1995). For example, an export subsidy in favor of an manufacturing sector, which is intensive in unskilled labor, induces a rise the equilibrium wage and hence a decline in the return to skilled labor in manufacturing. This enhances innovations since the R&D sector absorbs some of the released human capital from the manufacturing

[37] Hellwig and Irmen (2001) illustrate that endogenous technical change is still possible under perfect competition.

sector. Still, the equilibrium welfare effect also depends on resulting change in the output of the intermediate sector. Grossman and Helpman (1995) also stress that innovation policies may have an international transmission effect. For example, a permanent subsidy for R&D in one country might reduce R&D investments of the trade partner by rasing the costs of human capital in both countries via the equalization of factor prices. In the following, we analyze the equilibrium effects of policies that influence both sources of inefficiency: (i) the market structure in the intermediate sector and (ii) direct subsidies to R&D.

The standard model of endogenous technological change following Romer (1990) or Aghion and Howitt (1992) implies that an increase in product market competition between intermediate producers reduces expected future profits from innovations and hence the rate of technical change ('rent dissipation effect'). In addition, more intense competition lowers the expected durability of new innovations ('creative destruction') and hence the incentives to innovate in the quality ladder model *à* la Aghion and Howitt (1992). In contrast, Aghion et al. (2001) extend the basic framework to incorporate an 'escape competition effect'. They consider an ogopolistic intermediate sector where innovation enables a firm to brake away from intense competition for a certain period of time. It follows that an increase in product market competition involves an innovation-tradeoff: It reduces the static gains from imperfect competition, but enhances the incentive to innovate in order to escape from competition. The authors show that the first effect dominates if the ogopolistic firms are close technological rivals ('neck-and-neck'), while the second outweighs when one firm has a large technological lead. This results in an inverted U-relationship between the incentives to innovate and the intensity of product market competition. Again, this finding demonstrates the appropriateness of different policies in different stages of economic development: Little competition does not impede growth when firms are far from the world technology frontier, but matters if they catch up and compete with leading edge innovators.

Most empirical evidence suggest a positive relation between the degree of product market competition and (productivity) growth. Nickell (1996) applies several measures to approximate competition using firm level panel data of 147 stock market listed firms in the UK from 1975-1986. He detects a positive relation between TFP (-growth) and import penetration and a negative with higher concentration rates or higher rents. Blundell et al. (1999) reveal similar results from dynamic panel estimations of 340 UK-firms from 1972-1982. They find that less competitive industries induce fewer aggregate innovations using

the SPRU innovation data set to approximate innovations and concentration or import penetration data to approximate competition across sectors. Yet, they estimate a positive correlation between the market share and innovations within industries. Finally, Aghion, Bloom, Blundell, Griffith and Howitt (2005) provide positive empirical evidence in favor of the inverted U-relationship between patent rates and product market competition in a panel of manufacturing firms from 1973-1992.[38]
Aghion and Howitt (2005) formalize a similar positive relation between technical change and entry, exit or turnover rates. They illustrate that this link not only results from direct innovations of new entrants but also from an 'escape entry effect'. Likewise the 'escape competition effect', the threat of potential entrants augments the incumbents incentives to innovate. Again, the model implies that the 'escape entry effect' is stronger if a firm is closer to the technology frontier. Aghion, Burgess, Redding and Zilibotti (2005*a*) provide positive empirical evidence in favor of this hypothesis. In addition, Nicoletti and Scarpetta (2003) detect that productivity differences between Europe and the U.S. can be explained by higher entry costs and lower degree of turnover in Europe. Aghion, Burgess, Redding and Zilibotti (2005*b*) analyze the effect of entry deregulation in less developed countries. They employ panel data for Indian firms from 1980-1997 and find that policy reform have no influence on GDP-growth. Yet, the interaction term between entry deregulations and labor market regulations is positive which implies that entry affects growth in industries with less restrictive labor markets.[39]

In the original Romer (1990) model public subsidize for R&D enhance the rate of technical change. However, common wisdom suggests that there exist some natural limits for this growth-channel. In fact, Jones (1995) pinpoints that the number of resources devoted to R&D grew exponentially in advanced countries since 1950 without shifting the trend in growth. Therefore, Jones (1995) and Segerstrom (1998) introduce so called semi-endogenous growth models to match these empirical facts. In this class of models, long-run growth (in the stock of knowledge) can only be sustained if the level of R&D resources (the labor force) rises accordingly. It follows that R&D subsidies have no impact on long-run technical change and hence growth. Yet, Howitt (1999) extends the framework to show that long-run growth

[38]The authors measure the degree of competition by the Lerner-index as well as exogenous policy reforms. The degree of technical neck-and-neckness between firms is measured by the distance of a firm's TFP from the technology frontier.

[39]For positive evidence in favor of a positive relation between innovations and exit deregulations or turnover rates see Comin and Mulani (2005) and Fogel et al. (2005), respectively.

effects of R&D subsidies are still sustainable.[40] Finally, Segertrom (2000) generalizes the approach of Howitt (2000) and isolates a tradeoff in public R&D subsidies for innovation and growth. He also distinguishes between vertical and horizontal R&D, whereas the former reflects improvements in the quality of existing products and the latter increases number of intermediate goods (industries) in the economy. In addition, he assumes that the complexity of new innovations (need for resources) increases with the stock of knowledge. Thus, more resources (labor) must be devoted to R&D over time in order to sustain the rate of innovations. Segertrom (2000) shows that under these conditions R&D subsidies can never permanently increase horizontal and vertical innovation rates because they do not affect population growth (the resource pool). However, it is still possible that subsidies in favor of either the qualitative or the quantitative dimension impact on overall innovations and growth if the parameter constellation is such that one innovation channel is stronger. He highlights that in general one channel will be stronger so that onesided R&D subsidies might either promote or impede economic growth depending on the parameter values in both research sectors.[41] This study can explain the ambiguous empirical cross-country evidence of public R&D subsidies and demonstrates that policymakers may need some detailed knowledge about the bottlenecks of different research channels in their economy. Likewise, Nelson and Romer (1996) distinguish basic research by universities from practical innovations by industries. However, they assume that un-internalized social returns to R&D are so large that advanced countries still under-invests in R&D. More specifically, Nelson and Romer (1996) presume that basic research provides the pool for practical innovators to invent new products. In this regard, they stress that extreme onesided government subsidies might not be effective, in particular, when they involve a reduction in the budgets for the other type.

3 Hypotheses to be tested

The literature review underlines that public policies can influence innovations and growth in various ways. Yet, it also demonstrates that policy effects are often far from obvious ex ante. Instead, some detailed knowledge of the stage of developments or country-specific characteristics are necessary to achieve the desired outcomes. Still, the empirical growth

[40] He allows for horizontal and vertical R&D and links economic growth to the growth rate (not the level) of the population. His models is also in line with the Jones (1995) facts.

[41] The two research channels may be interpreted as basic research (horizontal) and learning-by-doing (vertical).

literature provides multiple examples for public policies which have promoted technological catch-up and sustainable growth. In the following, we use the recent theoretical insights outlined above to develop verifiable hypothesis that help to gain insights how and which public policies are appropriate to foster innovation and growth.

The literature on human capital and growth suggests that the level of human capital is a key input factor for R&D and the diffusion of knowledge (see above). Benhabid and Spiegel (1994, 2002) provide some empirical evidence in favor of this hypothesis based on educational measures. In contrast, Krueger and Lindahl (2001) do not find evidence for the R&D externality of human capital based on educational measures in a sub-set of OECD countries. We discussed above that more appropriate measures of human capital are available, which are based on qualitative test scores of the labor force. These have not been related to the diffusion of knowledge and technological catch up to test the Benhabib and Spiegel (1994) hypothesis, yet.
A positive relation between human capital and the diffusion of knowledge on a macroeconomic level does still not explain how the knowledge is transferred between agents or firms. The literature underlines the importance of local complementarities between human capital (and R&D). If technologies are directly transmitted via agents, the (global) mobility of labor affects regional stocks of knowledge/technologies. It follows that regional/national 'brain gain policies' provide an important policy tool to foster innovations and regional development. This hypothesis can be tested via surveys from corresponding agents.
Recent work of Aghion and Howitt (2005) suggests that tertiary education is more important for advanced (innovating) countries, while primary and secondary education is crucial for less developed (imitating) regions. Aghion, Boustan, Hoxby and Vandenbussche (2005) test this hypothesis in an international perspective employing a panel of 22 OECD countries. Their positive evidence is not robust to the inclusion of country fixed effects. It is straightforward to test this hypothesis for a larger set of more heterogeneous countries. In fact, the inclusion of non-OECD countries appears to be crucial to test for the importance of basic education for the adoption of foreign technologies.

Apart from the static gains of trade liberalizations, the literature emphasizes the dynamic gains from the diffusion of technologies via trade in goods. It follows that the technological progress of the trade partners impacts on the potential scope for technology spillovers. Indeed, a number of empirical studies affirm this hypothesis. These studies apply macro- and industry-level data from advances countries. In fact, the evidence in favor of this mechanism is more robust for industry data, see Keller (2002*b*). This underlines the importance of microeconomic data to test the hypothesis. Therefore, we apply firm-level data. In addition, we investigate the effect of trade (partners) on the adoption of foreign technologies in transition countries (new EU members) to compared our findings with the earlier results from advanced economies.

The literature provides ambiguous empirical evidence for the hypothesis that FDI creates growth-enhancing technology spillovers for the host country. Most studies focus on advanced countries and the few case studies for transition countries yield conflicting empirical evidence (Venezuela vs. Costa Rica, China). Theoretical models suggest that the link between FDI and growth depends crucially on the absorptive capacity of the host country and the investment strategy of the foreign investor. Thus, future research on the link between FDI and growth needs to isolate the empirical relevance of such complementary factors. The identification of the determinants of productivity spillovers from FDI help to understand the ambiguous empirical results across regions. Moreover, it enables policymakers to create an optimal economic environment (e.g. legislation, joint ventures) that maximizes the the gains from FDI for the host country.

Empirical studies illustrate that innovative infrastructure investments enhance economic growth. The theoretical and empirical contributions focus on private factor accumulation as the relevant growth-channel. We test if investments in telecommunication infrastructure stimulate factor accumulations, productivity growth or both using dynamic panel techniques for 36 countries from 1975-2004. A link between technical progress and the provision of infrastructure capital can be justified in a simple extension of basic R&D based endogenous growth models. The distinction between the effect on capital accumulation and R&D involves crucial policy implications (e.g. higher education, innovation policy vs. neoclassical inference). The framework can extended to examine the hypothesis that the provision of infrastructure capital in less developed countries improves their ability to catch-up with the world technology frontier (absorptive capacity).[42]

[42]We need to employ TFP-measures instead of R&D expenditures to approximate technical change since the latter is not available for a larger set of countries.

The classical dichotomy between the short- and long-run limits the long-run growth-impact of macroeconomic policies right from the start. However, endogenous growth theory provides a channel for short-run fluctuations to influence long-run growth. Thus, macro-policies that smooth the short-run variability of output augment long-run growth. Indeed, this view is supported by recent empirical studies. The investment composition effect, outlined above, suggests that the link is due to productivity effects instead of factor accumulation. Therefore, we investigate if macroeconomic volatility impedes innovation and hence growth.

The literature provides various theoretical and empirical support that financial development boosts innovation and growth. Still, financial development can be linked to different financial systems. Gerschenkron (1962) already argues that long-run relations between producers and financial investors (e.g. credit-based) might be more effective in technologically backward countries, while market-based might be preferable in advanced economies. We explore this hypothesis empirically using the amount of private credits or financial deposits to approximate a credit- (bank-) based system and the volume of stock market trade and the rate of stock market capitalization to measure the relative importance of a market-based financial system in an economy.

The framework of Aghion et al. (2001) and Aghion, Bloom, Blundell, Griffith and Howitt (2005) implies a tradeoff in product market competition for innovation, whereas the positive effect outweighs if the firm is closer to the (world) technology frontier. This non-linearity in the relation between competition and growth involves that the effect of product market regulations (industrial policy) depends on the stage of development of a country. It might very well be the case that 'excessive' product market deregulations impede economic growth in transition countries, but promote growth in advanced countries (EU). The effects must be analyzed separately in different countries since most of the existing empirical evidence stems from advanced countries (U.S., U.K.). Thus, we will test which industrial policies impact on innovation and growth in old and new EU member states.
The emergence of R&D based growth models induced a lively political and academical debate if R&D subsidies can boost innovation and growth. Recent endogenous growth theory provides conflicting predictions depending on the application of endogenous or so called semi-endogenous growth models (see above). Cross-country empirical evidence based on

macro-data also yields ambiguous results. The application of microeconomic data implies a more direct approach to examine the impact of R&D subsidies on the dynamics of innovation at the appropriate (firm-) level. Moreover, we focus on a sample of transition countries since these economies feature a large potential for technological catch-up. The results will help to discriminate between the conflicting theories and refine the determinants of successful R&D subsidies at the firm-level.

Finally, we emphasize that many determinants of innovation and growth, which can be influenced by public policies, are likely to be strategic complements or substitutes. That is, the provision of infrastructure, human capital and innovation policies are strategic complements if they are components of a country's absorptive capacity. Thus, improvements in human capital enhance growth-effects of infrastructure or R&D subsidies. In addition, the scarcity of one factor (e.g. infrastructure capital) might even block any potential growth-effects of FDI, trade or innovation policies. These interrelations need to be tested empirically by the inclusion of the corresponding interaction terms.

4 Data sets

Barro and Lee (1996*b*) provide an extensive panel database on measures of human capital.[43] The database includes various measures of different degrees of education and test scores in mathematics and science of the labor force in various countries. In addition, de la Fuente and Domenech (2002) construct an alternative database on human capital for fewer countries. They argue that their proxies incorporate less measurement errors than the Barro-Lee data-set.[44]

The Penn World Tables (PWT) and the World Bank (World Development Indicators - WDI) have published data on several measures of trade openness: The amount of imports relative to GDP, the amount of trade in goods to GDP. Additional proxies are available from Sachs and Warner (1995). Finally, Wacziarg and Welch (2003) presents extended (policy-) measures of openness and trade liberalization.

Panel data on FDI for various countries are available from the OECD and the WDI. The former also supply the the amount of R&D investments of foreign affiliates for several

[43]The updated version from 2001 is also available.

[44]The identification of the location of agents that transfer knowledge across regions and the corresponding brain-gain policies to attract them, will be based on literature research and internet searches.

OECD countries. The Bocconi University disposes of a firm level database on foreign investments in several Central and Eastern European countries. Moreover, the Amadeus database contains data of balance sheets at the firm level for almost all European countries. Finally, the Zephir-database contains M&A, IPO and venture capital deals with links to detailed financial company information. This database would allow to collect information on foreign investments undertaken in Latin America and Asian countries from 1997 onwards. Furthermore, the University of Ljubljana has access to CIS, trade and FDI firm-level data on Slovenian enterprises between 1996 and 2002.

The WDI-database contains information on social-cultural characteristics. Eurobarometer and Latinobarometro represent supplementary sources for institutional measures for the EU and Latin America. Institutional measures for (intellectual) property rights, law and order and economic freedom stem from various editions of the Fraser Institute's Economic Freedom.

Data on the following infrastructure measures for a large panel of countries are provided by the WDI-database and Calderón and Servén (2005): telephone and mobile phones mainlines per worker, road and railroad networks, ratio of paved roads to total roads, telephone mainlines waiting list, electrical power production and energy losses.

Approximations of the volatility of several indicators of economic performance or macro-policy variables can be easily constructed from the underlying series which are available for a large set of countries and time-periods.

Levine, Loyaza and Beck (2000) provide an extensive database on various measures of financial development for over 120 countries from 1970-2000. The database contains measures such as the amount of private credits issued by deposit money banks as % of GDP, the stock market value traded as % of GDP, the amount of deposits of the financial system, the amount of liquid liabilities to GDP, the ratio of deposit money bank vs. central bank assets or the stock market capitalization rate.

The OECD-STAN database and the UNIDO have published time-series for various countries of economic indicators on an industry level. Finally, the OECD, the ILO and the World Bank provide data for case studies in the automobile industry. In particular, the ILO data base contains up-to-date information on socio-economic variables from 200 countries.

5 Research papers

1.) Human capital and growth (ESRI)

2.) The emergence of ”brain gain policies” as a new strategy for regional development and innovation (WUW)

3.) Is openness a factor of competitiveness for the EU? (VUA)

4.) The impact of different types of knowledge transfer on innovation and productivity growth in new member states (FELU)

5.) The role of foreign firms in local economic development in CEECs (UNIBOC)

6.) Institutional quality and comparative advantage (UNIBOC)

7.) Infrastructure, growth and technological change (ZEI)

8.) Is macroeconomic volatility detrimental to innovation and growth? (ESRI)

9.) The role of institutions on growth: Different institutions for different stages of development? (ZEI)

10.) Clusters in India and CEECs. (CIBAM)

11.) Value capture and sustainable value creation from technological innovation: The role of business and public policy. (CIBAM)

12.) European industrial policy: Perspectives and recent trends. (CIBAM)

13.) The role of the government in the stimulation of R&D in dynamic growth regions. (VUA)

14.) The interdependency between EU and dynamic growth regions: The automobile industry case-study. (VUB)

15.) How efficient are public R&D subsidies in promoting firm's innovation and growth? (FELU)

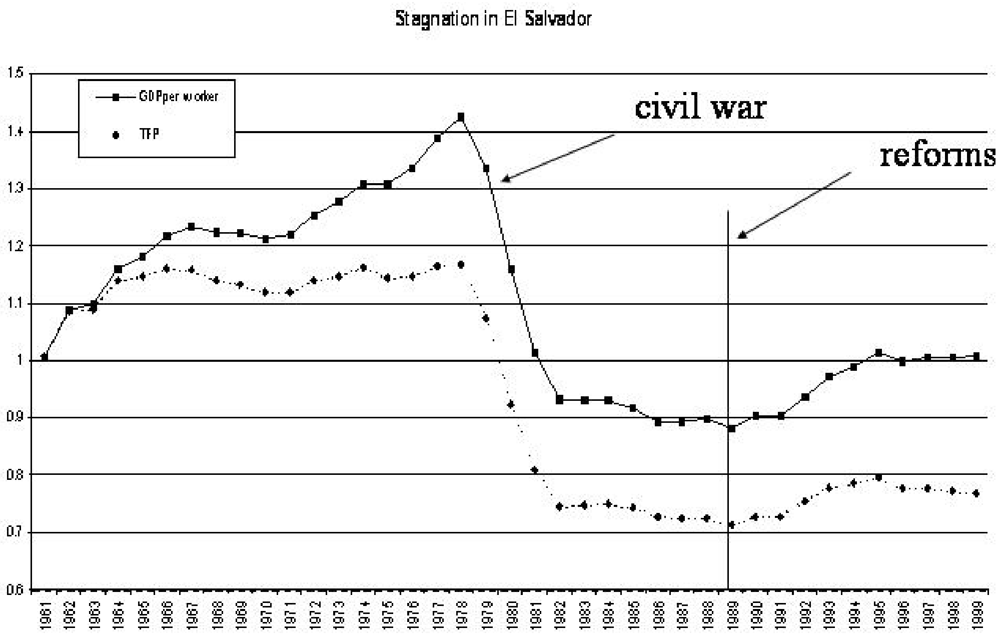
A Appendix

Table 1: Sources of growth in Latin America

Sources of Growth, Latin America, 1960-1999					
			Contribution of:		
	Output	Output per Worker	Physical Capital	Education	Factor Productivity
1960-70	5.72	2.88	0.83	0.31	1.74
1970-80	6.48	2.92	1.32	0.38	1.16
1980-90	1.47	-1.66	0.05	0.45	-2.12
1990-99	3.01	0.71	0.14	0.32	0.21

Source: Bosworth and Collins (2003)

Figure 1: El Salvador - failure of institutional reforms



Source: Rodrik 2005

Figure 2: India's growth takeoff

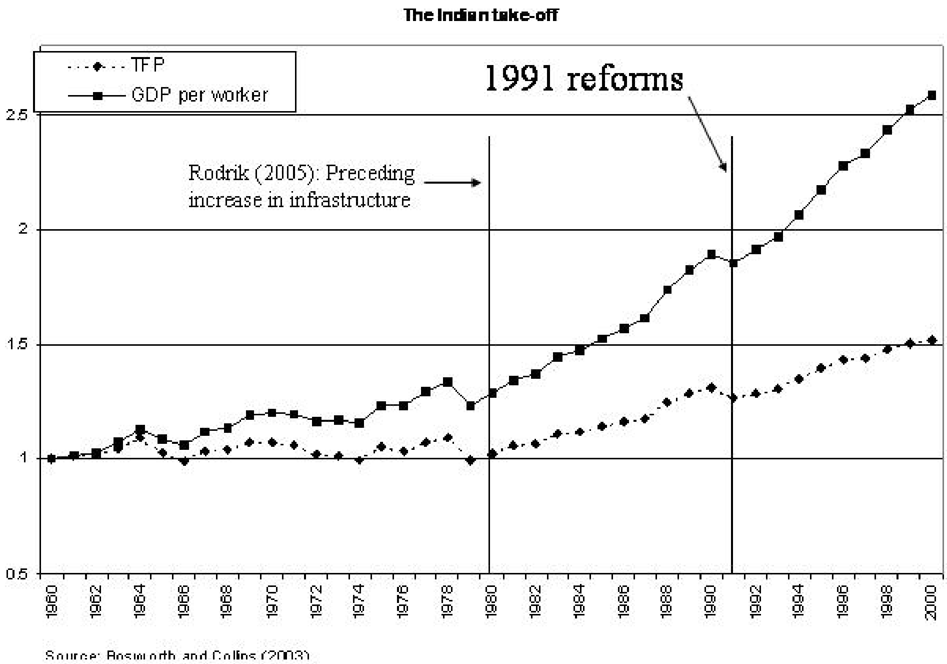
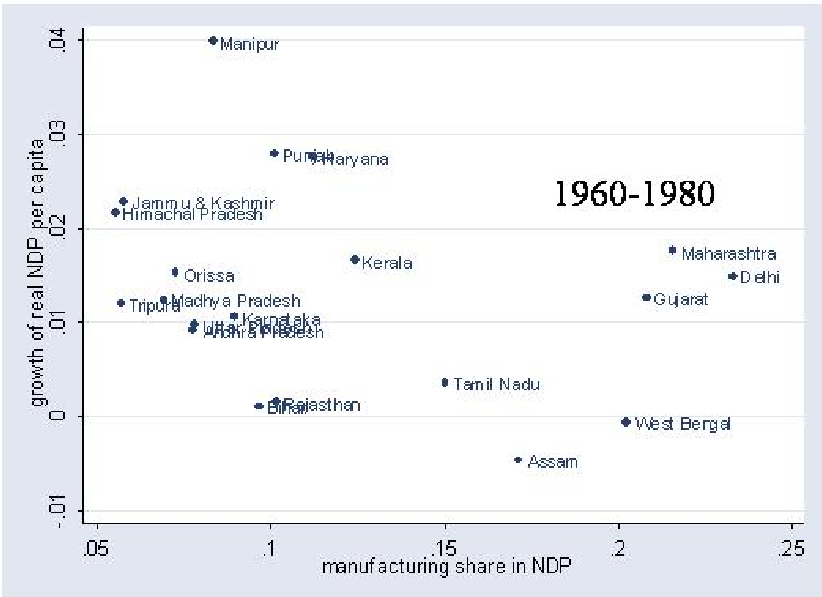


Figure 3: Growth and manufacturing across Indian states before 1980



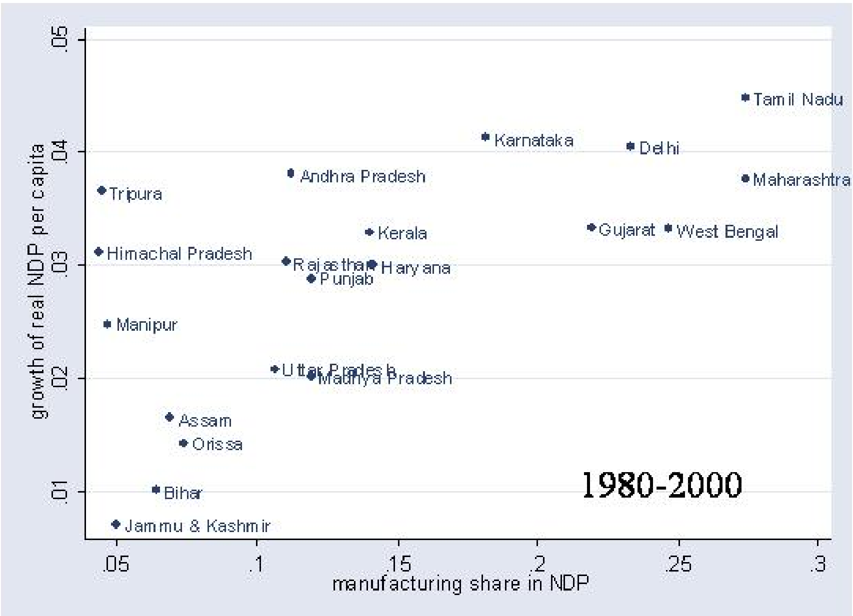
Source: Rodrik (2005)

Figure 4: Growth and manufacturing across Indian states after 1980

Table 2 - World Bank's 'Star Globalizers'

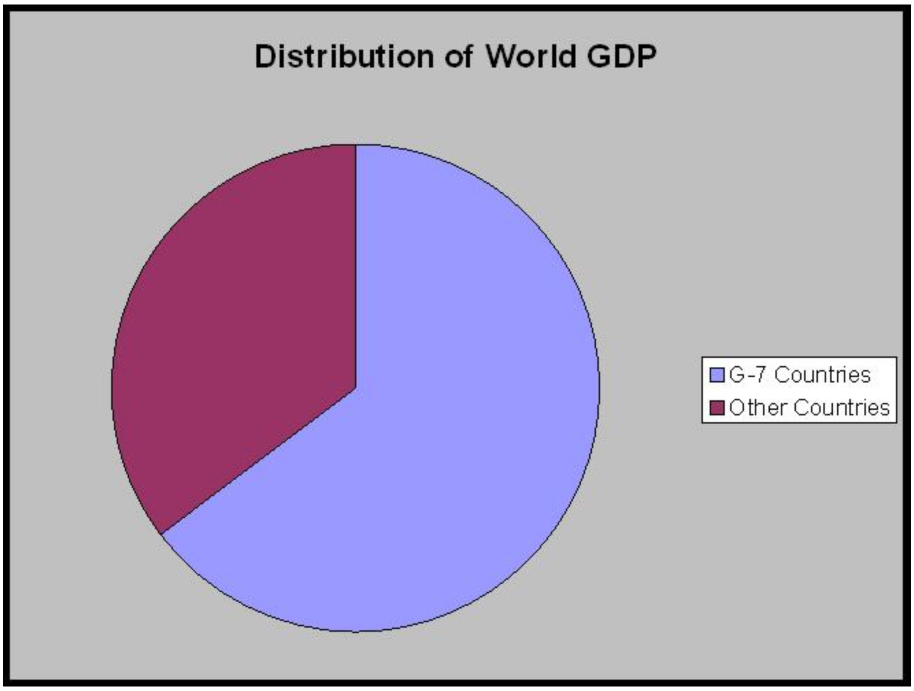
Country	Growth rate in the 1990s	Trade policies
China	7.1%	Average tariff rate 31.2%, national trade barriers, not a WTO member
Vietnam	5.1%	Tariffs range between 30 – 50%, national trade barriers and state trading, not a WTO member
India	3.3%	Tariffs average 50.5% (2. highest in the world)
Uganda	3.0%	Moderate reform

Source: Collier and Dollar (2001: 6)



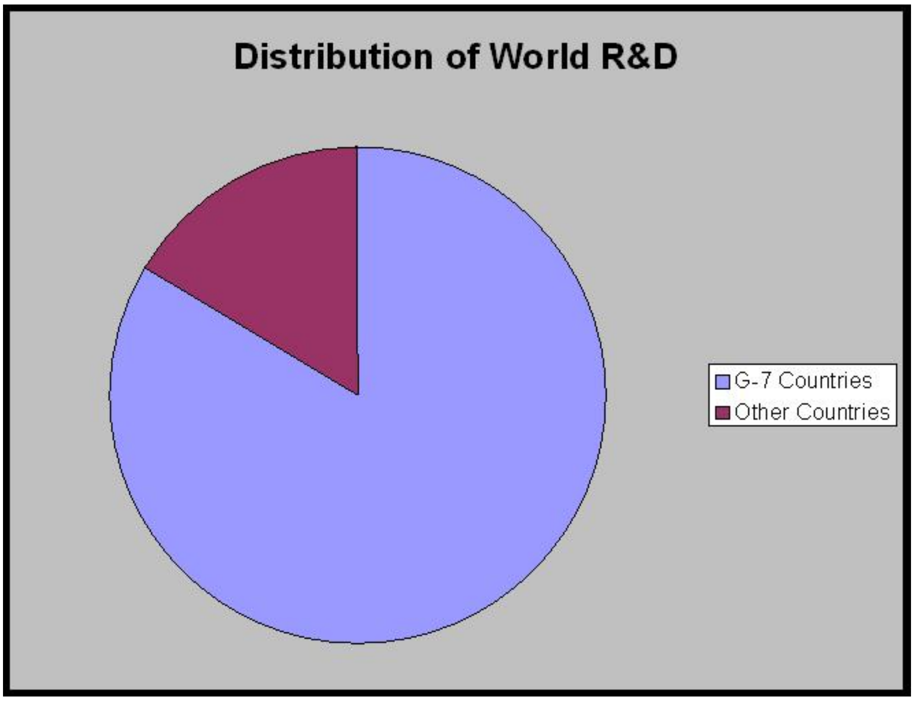
Source: Rodrik (2005)

Figure 5: Distribution of World's GDP



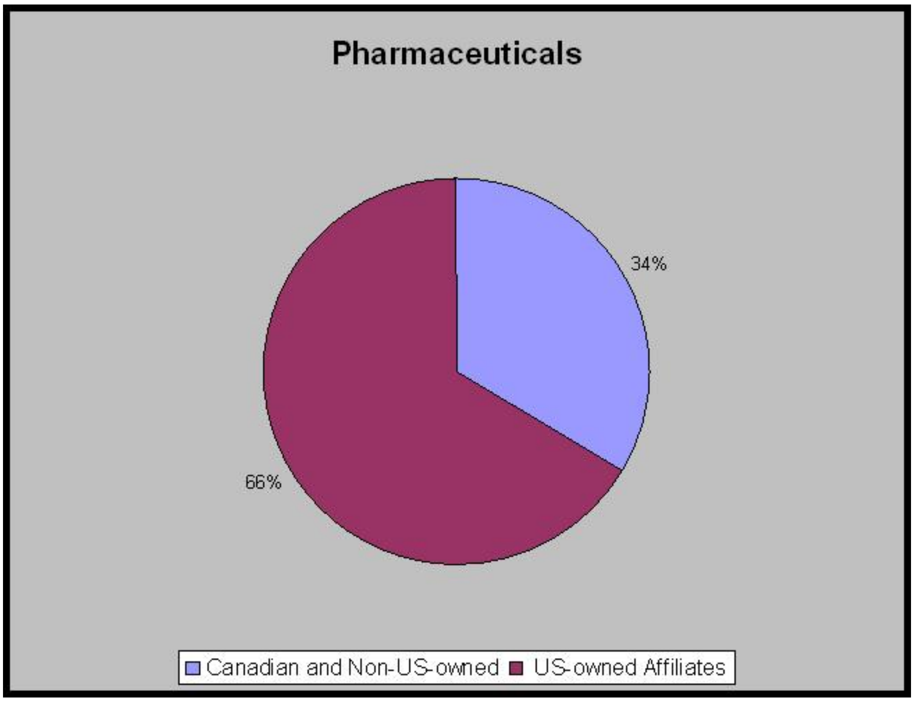
Source: Keller (2004)

Figure 6: Distribution of World's R&D



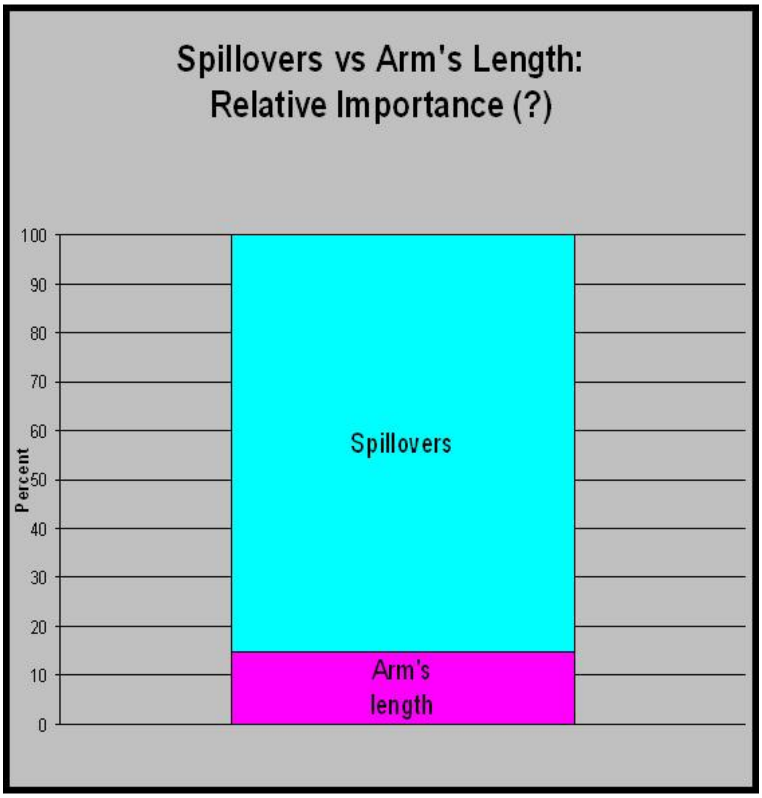
Source: Keller (2004)

Figure 7: Share of R&D investments of US-owned affiliates in Canada - pharmaceutical sector



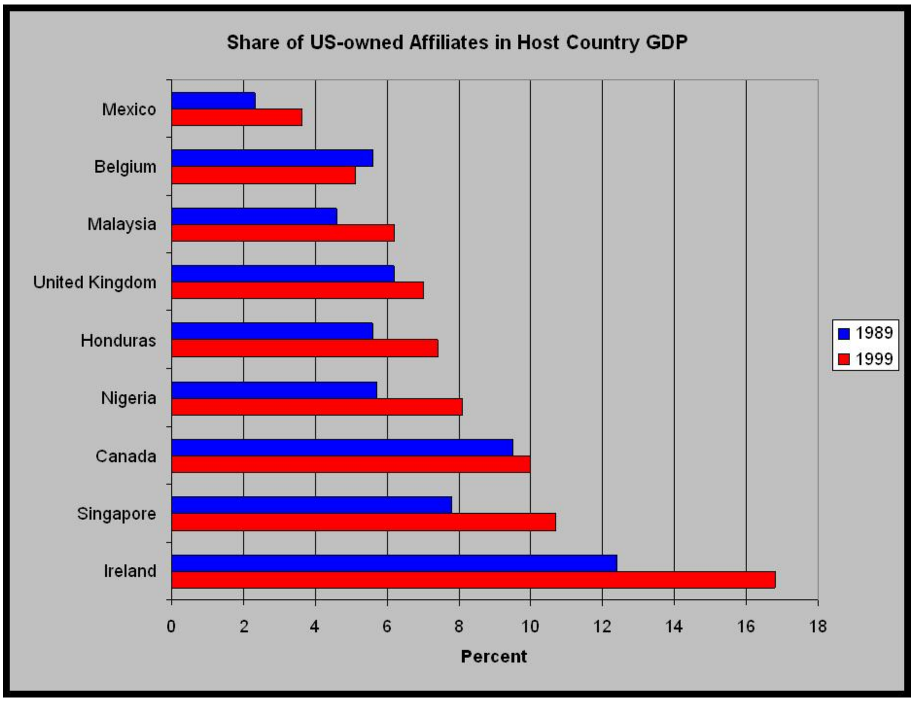
Source: Keller (2004)

Figure 8: Spillovers vs. arm's length technology licensing



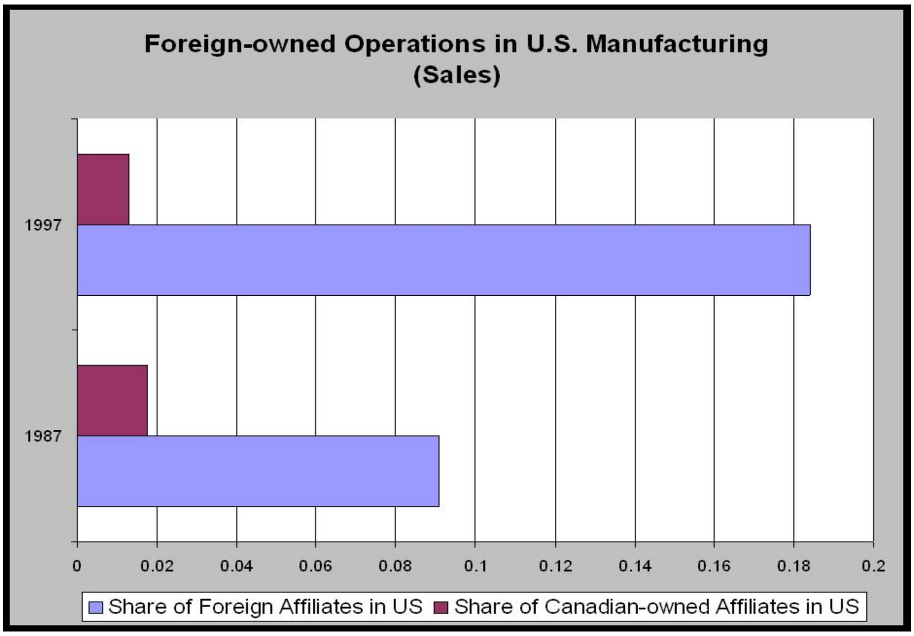
Source: Keller (2004)

Figure 9: Share of US-owned affiliates in host country



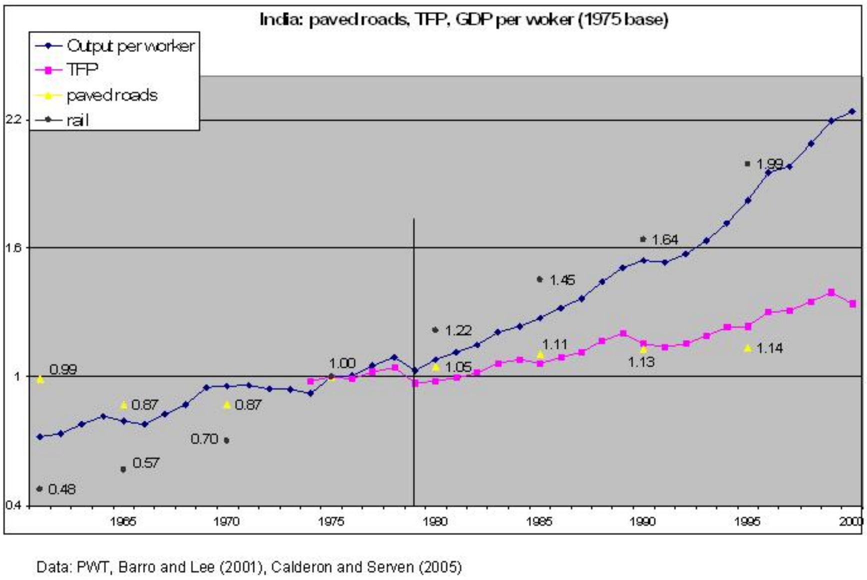
Source: Keller (2004)

Figure 10: Foreign-owned affiliates in the U.S.



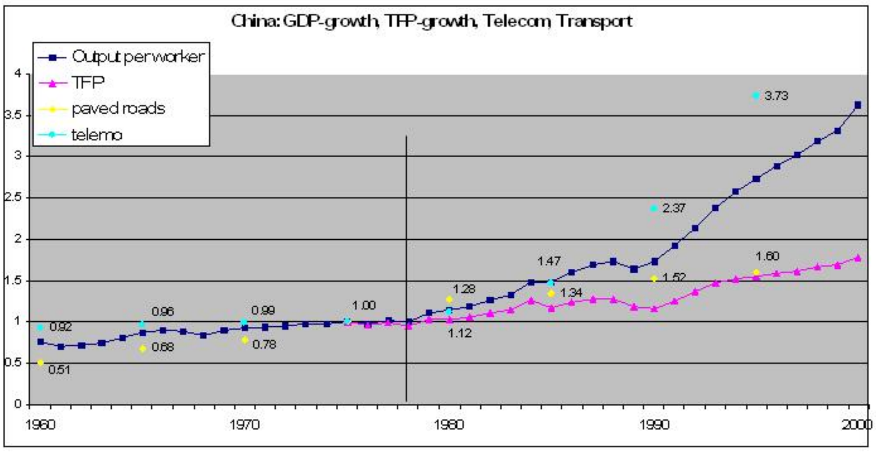
Source: Keller (2004)

Figure 11: India's 'growth-takeoff': The change in infrastructure stocks and TFP-growth



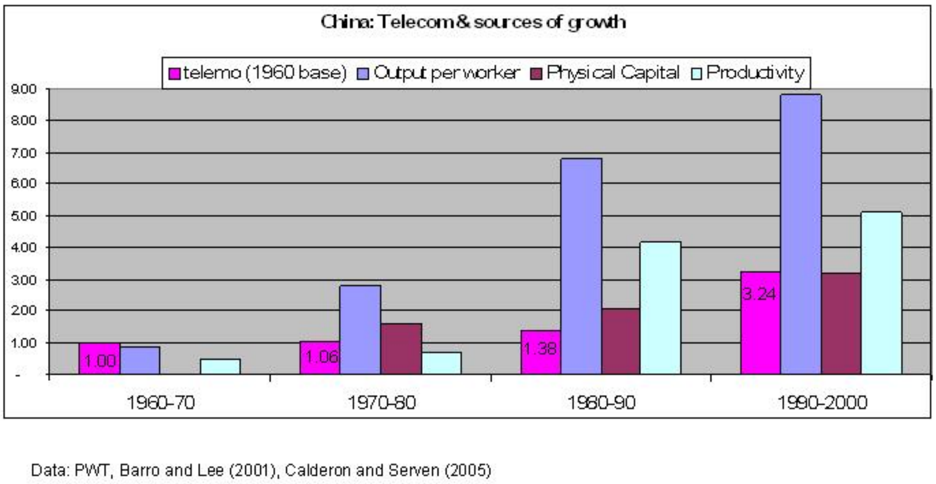
Data: PWT, Barro and Lee (2001), Calderón and Servén (2005)

Figure 12: China's 'growth-takeoff': The change in infrastructure stocks and TFP-growth



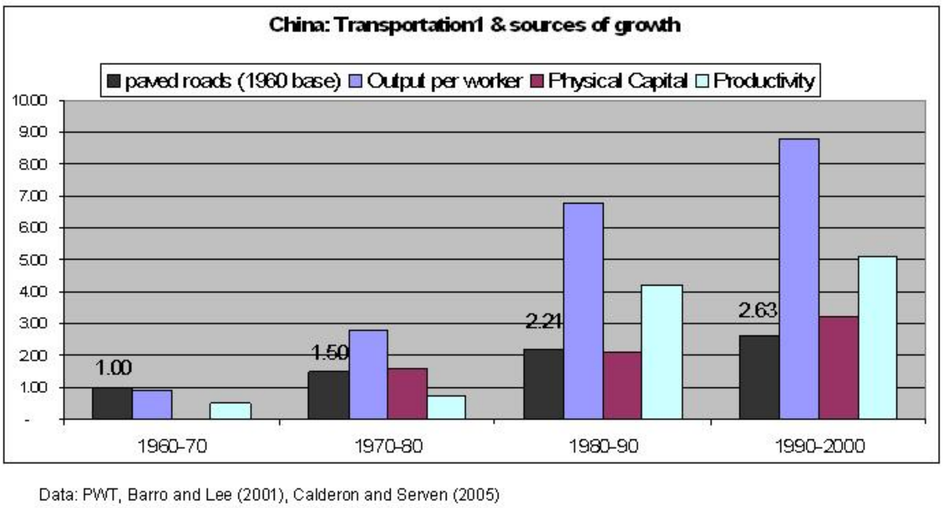
Data: PWT, Barro and Lee (2001), Calderón and Servén (2005)

Figure 13: Sources of growth in China - telephones mainlines per worker and TFP



Data: Bosworth and Collins (2003) and Calderón and Servén (2005)

Figure 14: Sources of growth in China - paved roads and TFP



Data: Bosworth and Collins (2003) and Calderón and Servén (2005)

References

Acemoglu, D. and F. Zilibotti (2001), 'Productivity differences', *Quarterly Journal of Economics* (116), 563–606.

Acemoglu, D. and J. Angrist (1999), 'How large are the social returns to education? evidence from compulsory schooling laws', *NBER working paper 7444* .

Acemoglu, Johnson and Robinson (2002), 'Reversal of fortune: Geography and institutions in the making of the modern world income distribution', *Quaterly Journal of Economics* **107**, 1231–1294.

Acemolgu, D. and F. Zilibotti (1997), 'Was prometheus unbounded by chance? risk, diversification, and growth', *Journal of Political Economy* **105**, 709–751.

Aghion, P., A. Marios, A. Banerjee and K. Manova (2005), Volatility and growth: Credit constraints and productivity-enhancing investment. mimeo Harvard-MIT.

Aghion, P., C. Harris, P. Howitt and J. Vickers (2001), 'Competition, imitation and growth with step-by-step innovation', *Review of Economic Studies* **68**, 467–492.

Aghion, P., L. Boustan, C. Hoxby and J. Vandenbussche (2005), 'Exploiting states mistakes to evaluate the impact of higher education on growth', *mimeo Harvard* .

Aghion, P., N. Bloom, R. Blundell, R. Griffith and P. Howitt (2005), 'Competition and innovation: An inverted-u relationship', *Quarterly Journal of Economics* **forthcoming**.

Aghion, P. and P. Howitt (1992), 'A model of growth through creative destruction', *Econometrica* **2**, 323–351.

Aghion, P. and P. Howitt (2005), 'Appropriate growth policy: A unifying framework', *Working Paper* .

Aghion, P., R. Burgess, S. Redding and F. Zilibotti (2005*a*), 'Entry liberalization and inequality in industrial performance', *Journal of the European Economic Association, Papers and Proceedings* .

Aghion, P., R. Burgess, S. Redding and F. Zilibotti (2005*b*), On the unequal effects of liberalization: Theory and evidence from indian delicensing data. mimeo LSE-Harvard-IIES.

Aitken, B. and A. Harrison (1999), 'Do domestic firms benefit from foreign direct investment? evidence from venezuela', *American Economic Review* (89), 605–618.

Aizenman, J. and N. Marion (1993), 'Policy uncertainty, persistence and growth', *Review of International Economics* **1**, 145–163.

Antras, P. (2005), 'Incomplete contracts and the product cycle', *American Economic Review* (September).

Antras, P. and E. Helpman (2004), 'Global sourcing', *Journal of Political Economy* (112), 552–80.

Baldwin, R. and R. Forslid (2000), 'Trade liberalization and endogenous growth. a q-theory approach', *Journal of International Economics* **53**, 497–517.

Barro, R. (1990), 'Government spending in a simple model of endogenous growth', *Journal of Political Economy* (98), 103–117.

Barro, R. (1991), 'Economic growth in a cross section of countries', *Quarterly Journal of Economics* (106), 407–43.

Barro, R. and J. Lee (1996*a*), 'International measures of schooling years and schooling quality', *American Economic Review* (86), 218–23.

Barro, R. and J. Lee (1996*b*), 'International measures of schooling years and schooling quality', *American Economic Review* (86), 218–223.

Barro and Sala-i-Martin (1997), 'Technology diffusion, convergence, and growth', *Journal of Economic Growth* **2**, 1–27.

Basu, S. and D. Weil (1998), 'Appropriate technology and growth', *Quarterly Journal of Economics* (113), 1025–1054.

Belaid, H. (2004), 'Telecommunication, infrastructure and economic development', *Working Paper* .

Benhabib, J. and M. Spiegel (1994), 'The role of human capital in economic development: Evidence from aggregate cross-country data', *Journal of Monetary Economics* **34**, 143–173.

Benhabid, J. and M. Spiegel (2000), 'The role of financial development in growth and investment', *Journal of Economic Growth* **58**(5), 341–360.

Benhabid, J. and M. Spiegel (2005), 'Human capital and technology diffusion', *Handbook of Economic Growth, P. Aghion and S. Durlauf eds.* (forthcoming).

Bernard, A. and B. Jensen (1999), 'Exceptional exporter performance: cause, effect, or both?', *Journal of International Economics* **47**, 1–25.

Bils, M. and P. Klenow (2000), 'Does schooling cause growth', *American Economic Review* (90), 1160–1183.

Blomström, M. and A. Kokko (1998), 'Multinational corporations and spillovers', *Journal of Economic Surveys* (12), 247–277.

Blundell, R., R. Griffith and J. Van Reenen (1999), 'Market share, market value and innovation in a panel of british manufacturing firms', *Review of Economic Studies* **66**, 529–554.

Bosworth, B. and S. Collins (2003), The empirics of growth: An update. Brookings Institutions, unpublished paper.

Bougheas, S., P. Demetriades and T. Mamuneas (2000), 'Infrastructure, specialization, and economic growth', *Canadian Journal of Economics* **33**(2), 506–522.

Branstetter, L. (2001), 'Is foreign direct investment a channel of knowledge spillovers? evidence from japan's fdi in the united states', *NBER Working Paper 8015* .

Bruno, M. and W. Easterly (1998), 'Inflation crises and long-run growth', *Journal of Monetary Economics* **41**, 3–26.

Calderón, C. and L. Servén (2005), The effects of infrastructure development on growth and income distribution. World Bank Working Paper, WPS3400.

Caselli and Coleman (2004), 'Importing technologies', *Journal of Monetary Economics* .

Caselli, F. (2005), 'The missing input: Accounting for cross-country income', *Handbook of Economic Growth, P. Aghion and S. Durlauf eds.* **forthcoming**.

Caspari, V., J. Rubart and G.Rehme (2004), 'Education, research and economic growth - some tests for the u.s. and germany', *Working Paper* .

Clerides, S., S. Lach and J. Tybout (1998), 'Is learning by exporting important? micro-dynamic evidence from colombia, mexico, and morocco', *Quarterly Journal of Economics* **113**, 903–948.

Coe, D. and A. Hoffmaister (1997), 'Are there international r&d spillovers among randomly matched trade partners? a response to keller', *IMF working paper 99-18, February* .

Coe, D. and E. Helpman (1995), 'International r&d spillovers', *European Economic Review* **39**, 859–887.

Comin, D. and S. Mulani (2005), A theory of growth and volatility at the aggregate and firm level. mimeo New York University.

Cukierman, A., P. Kalaitzidakis L. Summers and S. Webb (1993), 'Central bank independence, growth, investment, and real rates', *Carnegie-Rochester Conference Series on Public Policy* **39**, 95–140.

de la Fuente, A. and R. Domenech (2002), 'Human capital in growth regressions: How much di.erence does data quality make? an update and further results', *CEPR Discussion Papers No. 3587.* .

Devereux, M. and B. Lapham (1994), 'The stability of economic integration and endogenous growth', *Quarterly Journal of Economics* **109**, 299–305.

Easterly, W. (2005), 'National policies and economic growth: A reappraisal', *in: P. Aghion and S. Durlauf (eds.), Handbook of Economic Growth* .

Eaton, J. and S. Kortum (2002), 'Technology, geography, and trade', *Econometrica* **70**, 1741–79.

Eeckhout and Jovanovic (2002), 'Knowledge spillovers and inequality', *American Economic Review* **92**, 1290–1307.

Eichgreen, B. and H. Tong (2005), 'Is china's fdi coming at the expense of other countries?', *NBER Working Paper* .

Fernald, J. (1999), 'Roads to prosperity - assessing the link between public capital and productivity', *American Economic Review* **89**(3), 619–638.

Fisher, S. (1993), 'The role of macroeconomic factors in growth', *Journal of Monetary Economics* **32**, 485–512.

Fogel, K., R. Morck and Y. Bernard (2005), Corporate stability and economic growth: Is what's good for general motors good for america? mimeo University of Alberta.

Fosfuri, A., M. Motta and T. Ronde (2001), 'Foreign direct investment and spillovers through workers' mobility', *Journal of International Economics* (53), 205–222.

Foster, A. and M. Rosenzweig (1995), 'Learning by doing and learning fromothers: Human capital and technical change in agriculture', *Journal of Political Economy* **103**, 1176–1209.

Gancia, G. (2003), 'Globalization, divergence and stagnation', *IIES Seminar Paper 720* .

Gerschenkron, A. (1962), 'Economic backwardness in historical perspective', *Harvard University Press* .

Ghosh, S. and I. Mourmouras (2002), 'On public investment, long-run growth, and the real exchange rate', *Oxford Economic Papers* (54), 72–90.

Goerg, H. and D. Greenaway (2002), 'Much ado about nothing? do domestic firms really benefit from foreign direct investment?', *working paper, University of Nottingham, U.K., February.* .

Gramlich, E. (1994), 'Infrastructure investment: A review essay', *Journal of Economic Literature* (32), 1176–1196.

Griffith, R., S. Redding and H. Simpson (2003), 'Productivity convergence and foreign ownership at the establishment level', *CEPR Working Paper 3765, February* .

Grossman, G. and E. Helpman (1995), 'Technology and trade', *Chapter in Gene Grossman and Kenneth Rogoff (eds.) Handbook of International Economics Vol.3, North-Holland Publishers.* .

Hanson, G. (2001), 'Should countries promote foreign direct investment?', *G-24 Discussion Paper Series, United Nations, New York and Geneva* .

Hanushek, E. and D. Kimko (2000), 'Schooling, labor-force quality, and the growth of nations', *The American Economic Review* (90), 1184–1208.

Heckman, J. and P. Klenow (1997), 'Human capital policy', *University of Chicago mimeo* .

Hellwig, M. and A. Irmen (2001), 'Endogenous technical change in a competitive economy', *Journal of Economic Theory* (101), 1–39.

Helpman, E. (1993), 'Innovation, imitation and intellectual property rights', *Econometrica* **61**, 1247–1280.

Holtz-Eakin, D. and A. Schwartz (1994), 'Infrastructure in a structural model of economic growth', *NBER Working PaperNo. 4824* .

Howitt, P. (1999), 'Steady endogenous growth with population and r&d inputs growing', *Journal of Political Economy* (107), 715–730.

Howitt, P. (2000), 'Endogenous growth and cross-country income differences', *American Economic Review* (90), 829–46.

Hulten, C., E. Bennathan and S. Srinivasan (2003), Infrastructure, externalities, and economic development - a study of indian manufacturing industry. World Bank working paper.

Jones, C (1995), 'R&d-based models of economic growth', *Journal of Political Economy* (103), 759–784.

Jovanovic, B. (1996), 'The product cycle and inequality', *Working Paper* (106), 458–470.

Keller, W. (1998), 'Are international r&d spillovers trade related? analyzing spillovers among randomly matched trade partners', *European Economic Review* **42**, 1469–1481.

Keller, W. (2002*a*), 'Geographic localization of international technology diffusion', *American Economic Review* **92**, 120–142.

Keller, W. (2002*b*), 'Trade and the transmission of technology', *Journal of Economic Growth* **7**, 5–24.

Keller, W. (2004), 'International technology diffusion', *Journal of Economic Literature* .

Keller, W. and S. Yeaple (2003), 'Multinational enterprises, international trade, and productivity growth: Firm level evidence from the united states', *IMF Working Paper 248, December* .

King, R., C. Plosser and S. Rebelo (1988), 'Production, growth, and business cycles: Ii new directions', *Journal of Monetary Economics* **21**, 309–341.

King, R. and R. Levine (1993*a*), 'Finance and growth: Schumpeter might be right', *Quarterly Journal of Economics* **108**, 717–737.

King, R. and R. Levine (1993*b*), 'Finance, entrepreneurship, and growth: theory and evidence', *Journal of Monetary Economics* **32**, 513–542.

Klenow, P. and A. Rodriguez-Clare (1997), 'The neoclassical revival in growth economics: Has it gone too far?', *n: B.S. Bernanke, and J.J. Rotemberg, eds., NBER macroeconomics annual* pp. 73–103.

Kosempel, S. (2004), 'Finite lifetimes and government spending in an endogenous growth model', *Journal of Economics and Business* (56), 197–210.

Kremer, M. (1993), 'The o-ring theory of economic development', *Quarterly Journal of Economics* (108), 551–575.

Krueger, A. and M. Lindahl (2001), 'Education for growth: Why and for whom?', *Journal of Economic Literature* (39), 1101–1136.

Krueger, D. and K. Kumar (2004), 'Skill-specific rather than general education: A reason for us-europe growth differences', *Journal of Economic Growth* **9**, 167–207.

Larrain, B., F. Lopez-Calva and A. Rodriguez-Claré (2000), 'Intel: A case study of foreign direct investment in central america', *Working Paper No.58, Center for International Development, Harvard University, December* .

Levine, R. (1997), 'Financial development and economic growth: views and agenda', *Journal of Economic Literature* **35**, 688–726.

Levine, R., N. Loayza and T. Beck (2000*a*), 'Finance and the sources of growth', *Journal of Financial Economics* **58**, 261–300.

Levine, R., N. Loayza and T. Beck (2000*b*), 'Financial intermediation and growth: causality and causes', *Journal of Monetary Economics* **forthcoming**.

Levine, R., N. Loyaza and T. Beck (2000), 'Financial intermediation and growth: Causality and causes', *Journal of Monetary Economics* (46), 31–77.

Liang, G. (2003), 'Foreign investment, competition and innovation: The emergent system of innovation in china's telecom equipment industry', *Communications & Strategies* (52), 115–138.

Lucas, R. (1988), 'On the mechanics of economic development', *Journal of Monetary Economics* **22**, 3–42.

Mercereau, B. (2005), 'Fdi flows to asia: Did the dragon crowd out the tigers?', *IMF Working Paper No. 05-189* .

Morrison, C. and A. Schwartz (1996), 'State infrastructure and productive performance', *American Economic Review* (86), 1095–1111.

Nelson, R. and P. Romer (1996), 'Science, economic growth and public policy', *Working Paper* .

Nickell, S. (1996), 'Competition and corporate performance', *Journal of Political Economy* **104**, 724–746.

Nicoletti, G. and S. Scarpetta (2003), 'Regulation, productivity and growth', *Economic Policy* **36**, 11–72.

Parente and Prescott (1999), 'Monopoly rights: A barrier to riches', *American Economic Review* **89**, 1216–1233.

Peri, G. and D. Urban (2006), 'Catching-up to foreign technology? evidence on the veblen-gerschenkron effect of foreign investments', *NBER Working Paper 10903* .

Ramey, G. and V. Ramey (1995), 'Cross-country evidence on the link between volatility and growth', *American Economic Review* **85**, 1138–1151.

Rebelo (1991), 'Long-run policy analysis and long-run growth', *Journal of Political Economy* **99**, 500–521.

Redding (1996), 'Low-skill, low-quality trap: Strategic complementarities between human capital and r&d', *Economic Journal* (106), 458–470.

Rivera-Batiz, L. and P. Romer (1991), 'Economic integration and endoge-nous growth', *Quarterly Journal of Economics* **106**, 531–55.

Rodriguez-Clare, A. (1996), 'Multinationals, linkages, and economic development', *American Economic Review* (86), 852–873.

Rodrik, D. (2005), 'Growth strategies', *Handbook of Economic Growth, P. Aghion and S. Durlauf eds.* **forthcoming**.

Roeller, L. and L. Waverman (2001), 'Telecommunications infrastructure and economic development - a simultaneous approach', *American Economic Review* **91**(4), 909–923.

Romer, P. (1990), 'Increasing returns and long-run growth', *Journal of Political Economy* **5**, 71–102.

Sarel, M. (1996), 'Nonlinear effects of inflation on economic growth', *IMF Staff Papers* **43**, 199–215.

Segerstrom, P. (1998), 'Endogenous growth without scale effects', *American Economic Review* (88), 1290–1310.

Segertrom, P. (2000), 'The long-run growth effects of r&d subsidies', *Journal of Economic Growth* **5**, 277–305.

Sepehri, A. and S. Moshiri (2004), 'Inflation-growth profiles across countries: Evidence from developing and developed countries', *International Review of Applied Economics* **18**, 191–207.

Singh, J. (2003), 'Knowledge diffusion and multinational firms: Evidence using patent citation data', *working paper, Graduate School of Business Administration and Department of Economics, Harvard University* .

Summers, L. (2003), *Godkin Lectures*, Cambridge, MA: John F. Kennedy School of Government, Harvard University.

Teulings, C. and T. van Rens (2003), 'Education, growth and income inequality', *CEPR Discussion Paper 3863* .

Topel, R. (1999), 'Labor markets and economic growth', *In O. Ashenfelter and D. Card (eds.), Handbook of Labor Economics, North Holland.* .

Turnovsky, S. (1997), 'Productive government expenditure in a stochastically growing economy', *Macroeconomic Dynamics* (3), 615–639.

Turnovsky, S. (2000), 'Fiscal policy, elastic labor supply, and endogenous growth', *Journal of Monetary Economics* (45), 185–210.

Vandenbussche, J., P. Aghion and C. Meghir (2004), 'Growth, distance to frontier and the composition of human capital', *mimeo Harvard-UCL* .

Ventura, J. (2005), 'A global view of economic growth', *Handbook of Economic Growth, P. Aghion and S. Durlauf eds.* (forthcoming).

Wacziarg, R. and K. Welch (2003), Trade liberalization and growth: New evidence. Working Paper.

Xu, B. (2000), 'Multinational enterprises, technology diffusion, and host country productivity growth', *Journal of Development Economics* (62), 477–493.

Xu, B. and J. Wang (1999), 'Capital goods trade and r&d spillovers in the oecd', *Canadian Journal of Economics* **32**, 1258–1274.