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## The case for technology policy: A tentative evaluation

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# Kieler Arbeitspapiere

# Kiel Working Papers

Kiel Working Paper No. 714

**The Case for Technology Policy.  
A Tentative Evaluation**

by  
Karl-Heinz Paqué

December 1995



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## *Abstract*

*This paper is a tentative summary and appraisal of the main theoretical arguments and empirical evidence for/against an industrial policy in support of high-tech industries. The paper reviews arguments based on endogenous growth theory and strategic trade theory and surveys the most relevant pieces of empirical evidence, notably on external learning effects and international rent-shifting. The author concludes that there is no solid empirical basis for sector-specific technology policies, but that one might make a sensible case for non-discriminatory government support to knowledge creation by private firms, e.g., through a generous tax treatment of private spending on research and development.*

*Keywords (Classification System, Journal of Economic Literature):*

- O Economic Development, Technological Change, and Growth*
- O 3 Technological Change*
- O 30 General*
- O 31 Innovation and Invention: Processes and Incentives*

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## 1. Analytical Benchmarks

To a large extent, international frictions in markets for high-tech products are the consequence of some form of unilateral state intervention. Using a large variety of instruments, many governments grant support to specific branches of economic activity whose growth is deemed to be beneficial or even crucial for the long-term performance of the national economy. The policy toolbox ranges from overt protectionism and subsidisation to more covert barriers to market entry such as discrimination in public procurement, product standards and distributional networks. Whatever their specific shape may be, the instruments are usually part of a more or less coherent growth strategy that is well summed up under the terms "technology policy" or "industrial policy".<sup>1</sup>

Many of the more popular arguments for technology policies in high-tech markets can easily be refuted with standard economic reasoning and are therefore no serious candidates for further scrutiny.<sup>2</sup> The more powerful case for technology policy - and the one that is most likely to dominate future debate on trade frictions in high-tech markets - comes from two modern strands of economic research that are both analytically important and politically relevant: endogenous growth theory and strategic trade theory.

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<sup>1</sup> We use these terms interchangeably in the following paragraphs, with both terms describing a government policy that grants support to a (specific) high-tech industry.

<sup>2</sup> A standard undergraduate textbook on international trade - Krugman, P., M. Obstfeldt, *International Economics: Theory and Policy*. 3rd edition, New York 1994, pp. 278-81 - does an excellent job in refuting some common errors and misapprehensions.

## 1.1. Endogenous Growth Theory

Some strands of endogenous growth theory - notably the pioneering work by Grossman, Helpman [1991] and Rivera-Batiz, Romer [1991a, 1991b] -<sup>3</sup> have focused on the link between international trade integration and the concomitant changes of sectoral specialisation patterns on one side and the long-run growth prospects of a country on the other. This work contains a vast array of rather complex analytical insights that may also be of interest for selected questions of economic policy. With some courageous simplifications, the policy gist of the work - as far as it is relevant for technology policy in advanced economies - may be summarised as follows.<sup>4</sup>

International trade patterns in (free) high-tech markets are determined by comparative advantages. More than in other markets, however, these comparative advantages may be affected by the resources that different economies devote to industrial research, i.e. to investment into the creation of new knowledge. But not each and every piece of new industrial knowledge does affect trade patterns; whether it does depends, most importantly, on the subsequent diffusion of this knowledge, i.e., in economists' jargon, on the degree of localisation of technological spillovers. In this respect, two polar cases deserve attention as conceptual benchmarks: knowledge as a global good and knowledge as a national good.

If the spillovers are essentially global, i.e. if competitors in all relevant countries have access to any addition to the (common) knowledge pool wherever it comes from, there will be no lasting effects of national research efforts on trade patterns, and one is back

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<sup>3</sup> Grossman, G. M., E. Helpman, *Innovation and Growth in the Global Economy*. Cambridge Mass. 1991; Rivera-Batiz, L. A., P. M. Romer, "Economic Integration and Endogenous Growth", in: *Quarterly Journal of Economics*, Vol. 106 (1991) pp. 531-556, and "International Trade with Endogenous Technological Change", in: *European Economic Review*, Vol.35 (1991), pp. 971-1004.

<sup>4</sup> A detailed survey of results is given by Stolpe, M., *Technology and the Dynamics of Specialization in Open Economies*. Kiel Studies 271. Tübingen 1995, Section B. IV, pp. 41-47.

at standard explanations of trade in terms of national endowments with ordinary production factors, notably labour, human capital and physical capital. In these circumstances, national technology policy makes little economic sense because what it helps to create in terms of new knowledge will easily diffuse outside the country without giving domestic producers a viable and persistent advantage over foreign competitors.

If, on the other hand, knowledge spillovers remain geographically concentrated and thus essentially national in scope, then a cumulative process of what may be called 'national learning' may set in and drive a widening competitive wedge between the respective national industry and the rest of the world: in the extreme, a country starting with a tiny and accidental technological lead may eventually dominate the relevant world market because it profits - alone and persistently - from its own knowledge creation, which allows it to lower costs, to raise quality levels and to introduce new products and production processes. In these circumstances, a national technology policy may well have a powerful rationale: if private producers do not make the socially optimal decisions - in economists' jargon: if there is a market failure - government may step in to initiate the virtuous high-tech growth circle.

Is the market likely to fail? Among the cases of potential market failure that have been identified in the literature, two stand out in importance, one focusing on positive externalities of private R&D-spending, the other on negative ones. The argument on positive externalities recognises a tendency towards private *underinvestment* in R&D due to any positive spillover contributions to the (national) stock of knowledge that cannot be appropriated in a private calculus of profit maximisation. The government is then called upon to raise the level of research effort in the industry at hand.

The one on negative externalities identifies a tendency towards *overinvestment* due to inefficient parallel research: with a limited common pool of potential discoveries and innovations at any point in time, a successful innovation is likely to reduce the



prospective commercial value of research efforts by other firms, a form of negative (pecuniary) externality that is not properly taken into account by private agents.<sup>5</sup> The government may then be called upon to reduce, or better: to bundle and focus the research efforts so as to ensure a maximum expected social rate of return and a minimum deadweight loss.

Which instruments of intervention should the government use? In the case of positive externalities, the modern theories of endogenous growth recommend public support directly of R&D-activities rather than general protectionist measures for the respective industrial branch, say, in the form of production subsidies or tariffs. This is in line with the more traditional welfare analysis of externalities in trade theory<sup>6</sup>, though the underlying rationale of the result is somewhat different: while traditional theory wants the government to avoid static allocative losses, the modern theory wants it to avoid a (growth-hindering) resource competition for skilled labour that may be used both in manufacturing and in research. E.g., production subsidies or tariff protection for the production of a high-tech good may induce highly qualified engineering personnel to move from research into production, thus increasing the cost of R&D and reducing the country's potential for growth.

A similar argument for direct intervention applies for the case of negative externalities, though it has not yet been spelled out in detail in the literature: if a 'bundling' of R&D-efforts is required to reduce inefficient parallel research, it should be done by allowing firms to cooperate so as to rationalise and co-ordinate some of their research investment, possibly under government auspices and encouragement.

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<sup>5</sup> This (pecuniary) externality is a typical result of models of (Schumpeterian) creative destruction as pioneered by Aghion, P., P. Howitt, "A Model of Growth through Creative Destruction", in: *Econometrica*, Vol. 60 (1992), pp. 323-351.

<sup>6</sup> See, e.g., the classical statement by Cordon, M. *Trade Policy and Economic Welfare*, Oxford 1974, pp. 257-264.

## 1.2. Strategic Trade Theory

Some modern strands of trade theory - beginning with the pioneering work by Brander, Spencer [1983, 1985] and Dixit, Kyle [1985] <sup>7</sup> have focused on the international rivalry for monopoly rents in world markets that operate under conditions of highly imperfect competition, usually involving only very few producers from different countries. This rivalry can have the characteristic that possibly accidental initial advantages of one firm lead to high monopoly profits because potential competitors are deterred from market entry by high start-up costs and/or the narrowness of the prospective market.

Once again, the details of the relevant theoretical models are complex, but the case for government intervention in the form of so-called strategic trade policy is simple and straightforward: by granting a temporary subsidy to a newcomer, the government may turn potential competitors into actual ones, thus breaking up a (quasi-)monopolistic market position of the dominant foreign producer(s) and shifting at least some of the monopoly rents from one country to the other. If, in the end, national subsidy costs are lower than the gain in rents, then the active policy stance pays off from a national point of view.

Note that, in the technology policy debate, the case for a strategic trade policy does hardly come neatly separated from arguments based on endogenous growth theory. E.g., the case for the European Union's long-standing effort to break up the American quasi-monopoly in the world market for commercial aircraft has been consistently justified on two grounds: shifting rents across the Atlantic *and* laying the ground for the expansion of a high-tech industry that was regarded as greatly beneficial in terms

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<sup>7</sup> Brander, J. A., B. J. Spencer, "International R&D Rivalry and Industrial Strategy", in: *Review of Economic Studies*, Vol. 50 (1983), pp. 707-722, and "Export Subsidies and International Market Share Rivalry", in: *Journal of International Economics*, Vol. 16 (1985), pp. 83-100; Dixit, A. K., A.S. Kyle, "The Use of Protection and Subsidies for Entry Promotion and Deterrence", in: *American Economic Review*, Vol. 75 (1985), pp. 139-152.

of internal and external learning processes for future economic growth in Europe. In fact, the American lead in aircraft and related technologies was widely identified as being the consequence of a costly learning process that any prospective European competitor would still have to go through.

## 2. Empirical Evidence

What do we know about the prospects for a successful technology policy in actual reality? Or more specifically: What do we know about the extent to which there are cumulative processes of external learning that are geographically concentrated? And what do we know about the extent to which there are monopoly rents to be shifted around internationally? It may not come as a surprise that any serious economist can hardly avoid to answer all of these questions with: very little. Our current ignorance simply reflects the enormous problems of empirically isolating and measuring the relevant phenomena, not to speak of identifying causal relationships.

To be sure, there is a large literature of individual case studies, in which selected high tech branches or markets are picked to demonstrate the success or failure of particular government measures. In the context of the bilateral trade disputes between the United States and Japan, some of these studies have received considerable public attention, notably the book by Tyson [1992].<sup>8</sup> These studies suffer from major methodological deficiencies: despite their wealth of information and interpretation, they offer neither a theory-based empirical account of the diffusion of knowledge or the shifting of rents nor a reasonably specified counterfactual scenario that would allow to pin down with some conceptual precision to what extent government intervention in fact altered the path of economic history.

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<sup>8</sup> Tyson, L. D., *Who's Bashing Whom? Trade Conflict in High-technology Industries*. Washington D.C. 1992. See also, most recently, Cohen, S., P.-H. Chin, *Tipping the Balance: Trade Conflicts and the Necessity of Managed Competition in Strategic Industries*. Berkeley/Kiel 1995 (mimeo).

The example of Japanese industrial policies is notorious in this respect.<sup>9</sup> To qualify as a valuable piece of economic analysis, it is *not* sufficient to demonstrate that there was some intervention in some industrial branch and that producers in this branch were increasingly successful in world markets; it has rather to be shown that the relevant path of events was sufficiently different from what could have been expected on the basis of factor endowments and learning processes that went on anyway, independently of government action.

It is an a priori open question whether the remarkable world market penetration that Japanese industry achieved in the mass production of cameras, automobiles and semiconductors was the 'natural crop' of the specific engineering skills that the Japanese education and training system tends to provide (like, say, the German or the Swiss one) or whether it was the 'artificial consequence' of smart technology policy initiatives, or part of both. To come closer to an answer, one would have to study carefully the dynamics of comparative advantages over time and across countries, testing for elements of path dependence and hysteresis in specialisation patterns of production and trade,<sup>10</sup> and linking this to government interventions. Clearly, the case studies available so far fall well short of this standard.

Apart from the more descriptive case studies, however, there is a small but growing literature that makes a serious econometric attempt at identifying phenomena that are relevant for technology policy making. In the following paragraphs, we will provide a brief review of important recent pieces of empirical analysis - first of those concerning

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<sup>9</sup> On Japanese industrial policies in the relevant periods, see Yamamura, K. "Caveat Emptor: The Industrial Policy of Japan", in: Krugman, P. (ed.), *Strategic Trade Policy and the New International Economics*. Cambridge Mass. 1986.

<sup>10</sup> An econometric step in this direction has been made by Stolpe, M., *Technology and the Dynamics of Specialization in Open Economies*. Kiel Studies 271. Tübingen 1995, Chapters 3 and 4.

external learning effects and growth, and second of those concerning rent-shifting through strategic trade policy.<sup>11</sup>

## 2.1. External Learning and Growth

There has been a large number of studies over the last three decades which, in one way or another, try to measure and quantify spillover effects of R&D. While many of them are flawed and subject to a variety of reservations, they do on the whole support the view that R&D-spillovers are positive and quantitatively important.<sup>12</sup> We shall strictly focus on those (relatively few and recent) studies that investigate the regional and sectoral incidence of learning effects and externalities, which is the core issue for the design of technology policies.

### 2.1.1. The Case of the Semiconductor Industry

In recent years, the semiconductor industry has been at centre stage of the technology policy debate, not least because it is widely regarded as a strategic industry in the sense that the production of semiconductors involves strong learning effects (and thus cost reductions) over time and that semiconductors are used as high-tech inputs in virtually all branches of any modern economy.<sup>13</sup> Irwin, Klenow [1994a]<sup>14</sup> deliver the

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<sup>11</sup> For a more extensive survey, see Paqué, K.-H., "Technologie, Wissen und Wirtschaftspolitik - Zur Rolle des Staates in Theorien des endogenen Wachstums", in: *Die Weltwirtschaft* 3, 1995, pp. 237-253.

<sup>12</sup> This is also the conclusion of the most comprehensive survey of this literature to date: Griliches, Zvi, "The Search for R&D Spillovers", in: *Scandinavian Journal of Economics*, Vol. 94 (1992), Supplement, pp. 24-47.

<sup>13</sup> See T. F. Bresnahan, M. Trajtenberg, *General Purpose Technologies: "Engines of Growth"?* NBER Working Paper No. 4148, National Bureau of Economic Research, Cambridge Mass., August 1992; and E. Helpman, M. Trajtenberg, *A Time to Sow and a Time to Reap: Growth Based on General Purpose Technologies*. NBER Working Paper No. 4854, National Bureau of Economic Research, Cambridge Mass., September 1994, who provide a rigorous analysis of the link between economic growth and the expansion of what they call "general purpose technologies", i.e. technologies that are "extremely pervasive" in the sense of being used as inputs by a wide range of sectors of an economy.

<sup>14</sup> Irwin, D. A., P. J. Klenow, "Learning-By-Doing Spillovers in the Semiconductor Industry", in: *Journal of Political Economy*, Vol. 102 (1994), pp. 1200-1227.

first serious econometric attempt to estimate the actual magnitude of internal and external learning effects as well as the geographic concentration of externalities for the semiconductor industry.

On the basis of a large set of quarterly data for the period 1974-92 and for roughly 30 semiconductor producers in the United States, Europe and East Asia (Japan and South Korea), the study provides estimates of how strongly the product price depends on past production of semiconductors (i) in the firm itself, (ii) in the country where the firm is located, and (iii) in the world as a whole. In the absence of cost data, the product price is taken as a proxy for 'dynamic' marginal production cost<sup>15</sup>, i.e. the marginal cost that takes into account the discounted value of all future cost reductions due to production experience; cumulative past production is taken as a proxy for the cumulative production experience and thus for the level of technical knowledge, i.e. the stage of the learning process. Also, an explicit distinction is made between cumulative experience within a production line - i.e., within the current generation of memory chips - and the experience with earlier production lines, i.e. with older memory chip generations.

The results of Irwin, Klenow [1994a] are remarkable and important. They find strong learning effects *within* each chip generation - on average a 20 percent cost reduction with a doubling of output over time. However, they find no significant learning effects between chip generations: any new quality stage of technological development in the form of a new generation of memory chips begins with a level playing field. They also find rather powerful externalities: additional output (and thus additional experience) of other firms leads to a cost reduction of roughly one third of a corresponding output increase of the firm itself. What they do not find, however, is a significant difference between *international* and *intranational* externalities: knowledge spillovers - as far as

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<sup>15</sup> Strictly speaking, it is an 'adjusted' product price that is used: Irwin, Klenow, op. cit., pp. 1212-1213 assume Cournot-competition and adjust the price accordingly, thus taking account of changing monopolistic mark-ups over the product cycle.

they exist - appear to be undisturbed by national borders. Also, the authors of the study do *not* find any significant difference in the structural parameters of learning and external effects between Japanese and other firms.

All in all, these results cast serious doubt on whether the popular idea that there are powerful first-mover advantages for early market entrants is really compatible with the empirical record of the semiconductor industry. Prima facie, the simple observation that Japanese semiconductor producers - after a prolonged period of spectacular world market penetration - lost again world market shares to American competitors by the late 1980s, seems to point in the same direction. However, the interpretation of this fact is complicated by two major policy shifts that may have influenced the course of events, namely the conclusion of two US-Japanese semiconductor trade agreements, which brought some protectionist relief to American producers, and the establishing of SEMATECH, the joint industry-government research consortium in the American semiconductor industry.

With respect to the trade agreements, there is by now a broad consensus that they came too late - the first in 1986 - to prevent a fundamental restructuring of American industry away from the mass production of DRAMS<sup>16</sup> to more profitable market segments (e.g., design intensive chips). With the benefit of hindsight, one can say that this turned out to be a blessing because of the rising tide of competitive pressures from South Korean producers that forcefully entered the DRAM market and undermined the dominating Japanese position.<sup>17</sup>

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<sup>16</sup> Dynamic Random Access Memory Chips.

<sup>17</sup> On the genesis and the details of the American-Japanese semiconductor agreement, see Irwin, D. A., *Trade Politics and the Semiconductor Industry*, NBER Working Paper No. 4745, National Bureau of Economic Research, Cambridge Mass., May 1994, pp. 69-71; for a summary of opinions, Maitland, I., "Who Won the Industrial Policy Debate?" in: *Business & The Contemporary World*, 1, 1995, pp. 83-95, notably pp. 88-89.

With respect to the economic impact of SEMATECH, there has been a first econometric attempt at estimation, again by Irwin, Klenow [1994b]<sup>18</sup>. Using data on American semiconductor firms, i.e. on those which were members of SEMATECH in the relevant period and those which were not (and which, statistically, form a control group), the authors estimate the effects of the consortium on the members' R&D-spending, profitability, investment and productivity. Their results turn out to be conclusive only for the effect on R&D-spending: they indicate that SEMATECH has *reduced* R&D-spending by roughly 300 million US-Dollars per year. In terms of the two alternative theoretical interpretations of technology policy presented above<sup>19</sup>, this supports the view that SEMATECH has served as an instrument to focus and bundle research, i.e. to reduce inefficient parallel efforts, rather than to expand the research scope into ranges that would otherwise not have been profitable to explore by private member firms.<sup>20</sup>

While SEMATECH may thus have helped firms to coordinate their research efforts efficiently, there is by now broad agreement that this piece of positive technology policy can hardly be made responsible for the bulk of the recovery of the American semiconductor industry.<sup>21</sup> Instead, the timely restructuring of the industry appears to have done by itself the major part of the work. In view of the econometric evidence about the powerful international diffusion of technological knowledge in this high tech

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<sup>18</sup> Irwin, D. A., Klenow, P. J., *High Tech R&D Subsidies: Estimating the Effects of SEMATECH*. NBER Working Paper No. 4974. National Bureau of Economic Research, Cambridge Mass., December 1994.

<sup>19</sup> See Section 1.1. above.

<sup>20</sup> Irwin, Klenow [1994b] speak of support for the 'sharing hypothesis' against the 'commitment hypothesis'.

<sup>21</sup> See, i.a., the assessment in THE ECONOMIST of April 2nd 1994, "Uncle Sam's Helping Hand" (pp. 91-93).



industry, one should not be surprised to see one country's producers recover quite successfully even from rather deep adjustment crises.<sup>22</sup>

### 2.1.2. Knowledge Diffusion: International and Interregional

Coe, Helpman [1993]<sup>23</sup> attempt to quantify international knowledge spillovers between industrial economies.<sup>24</sup> On the basis of annual data for the period 1971-1990 and 22 mostly OECD-countries, they estimate how strongly total factor productivity in any country depends on the 'research capital stock' (i) in this country itself and (ii) in all other countries. The domestic 'research capital stock' is defined as total national R&D-expenditure, accumulated over time using a certain rate of 'knowledge depreciation'; the total foreign research capital is calculated as a weighted average of all other countries, with the weights being bilateral import quota, i.e. - roughly speaking - the degree of trade integration.

The authors find that total factor productivity in a country depends strongly on the domestic research capital: according to their estimates, a one-percent increase of the research capital stock leads to a 0.25-percent productivity increase. They also find that foreign research capital matters as well, but that it matters comparatively more for smaller countries than for large ones. In fact, for small highly-integrated economies,

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<sup>22</sup> It is most unfortunate that no methodologically comparable studies are available for evaluating specific technology policies of other countries, notably those of Japan and the European Union. This is so because, to our knowledge, no data are available that would allow to set up control groups of firms that are not covered by the relevant policy and to quantify the effect of government intervention against this background. Thus the many available accounts of European technology policy - e.g. Klodt, H., *Wettlauf um die Zukunft*. Kieler Studien No. 206. Tübingen 1988; Klodt, H., et al., *Forschungspolitik unter EG-Kontrolle*. Kieler Studien No. 220. Tübingen 1988; and, more recently, Klodt, H., J. Stehn et. al, *Strukturpolitik der EG*. Kieler Studien No. 249. Tübingen 1992, pp. 98-114 and 152-160 - have to remain largely descriptive and interpretative.

<sup>23</sup> Coe, D. T., E. Helpman, *International R&D Spillovers*. NBER Working Paper No. 4444. National Bureau of Economic Research, Cambridge Mass., August 1993.

<sup>24</sup> A methodologically comparable study that focuses, however, on spillovers from rich to poor countries is Coe, D.T., E. Helpman, A. W. Hoffmaister, *North-South R&D Spillovers*. CEPR Discussion Paper No. 1133. Centre for Economic Policy Research, London, February 1995.

research efforts in the main trading-partner countries appear to matter at least as much as corresponding efforts at home. Apparently, trade between advanced economies - and with it international capital movements - appear to be powerful channels for transmitting technological knowledge across borders, a result which tends to support the estimates and message of Irwin, Klenow [1994a] in the narrower context of the semiconductor industry.

On interregional knowledge spillovers, there are two major studies that are directly relevant for the policy questions at hand. Jaffe, Trajtenberg, Henderson [1993]<sup>25</sup> exploit the geographic information contained in U.S.-patent statistics to draw econometric inferences on the extent to which the diffusion of knowledge remains localised after an innovation has been made in some place of the country. The central piece of information on which they build their econometrics is the geographic pattern of patent citations to be found in new patent applications, which can serve as a kind of road map to track knowledge spillovers.

While the methodology is rich and complex in detail<sup>26</sup>, the results are rather clear-cut. First of all, they point towards quite strong localisation effects, with the degree of localisation being higher for patents of private firms than for those of universities, which is plausible because purely academic research results are likely to be circulated more openly than the knowledge created in private research laboratories. Second, for any patent, localisation tends to decline over time, but very slowly so: even a decade after a patent is granted, the geographic diffusion pattern remains little changed for all practical purposes. And third, the high degree of *geographic* localisation is *not*

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<sup>25</sup> Jaffe, A. B., M. Trajtenberg, R. Henderson, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations", in: *Quarterly Journal of Economics*, Vol. 108 (1993), pp. 577-598.

<sup>26</sup> See Jaffe, Trajtenberg, Henderson, op. cit., pp. 580-585. The main methodological problem is to separate genuine spillovers from correlations that are due to a pre-existing pattern of geographic concentration of technology-relevant activities.

matched by a corresponding degree of *sectoral* localisation: whatever the grouping of patents into technological or industrial segments, there is always a remarkably high share of citations that refer to patents in very different fields. This casts some doubt on the common assumption that cumulative learning processes *within* a well-defined high-tech industry are a valid rationale for technology policy.

This last result has received independent support from another strand of research on interregional knowledge spillovers, which applies ideas of endogenous growth theory to the study of urban agglomerations. In a major contribution on the economic determinants of city growth, Glaeser et al. [1992]<sup>27</sup> test two competing hypotheses, one identifying knowledge spillovers *within* an industry, the other one spillovers *between* industries as the driving force of output and employment growth. Using a large data set on the structure of industry for 170 metropolitan areas in the United States for the time 1956-87, the authors estimate to what extent the long-term growth of a city industry was positively or negatively correlated with a number of characteristics of local industry structure, most importantly the degree of specialisation (i) of the respective industry and (ii) of the rest of the urban economy.

The results are again rather clearcut: other things being equal, an industry tends to grow faster in cities where it is still underrepresented and where the rest of the urban economy has a low degree of industrial specialisation. Hence, as in the research on patent knowledge diffusion, an empirical case can be made for inter-industrial rather than intra-industrial spillovers dominating the picture.<sup>28</sup>

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<sup>27</sup> Glaeser, E. L., H. D. Kallal, A. Scheinkman, A. Shleifer, "Growth in Cities", in: *Journal of Political Economy*, Vol. 100 (1992), pp. 1126-1152.

<sup>28</sup> Note, however, that - by not specifying any proxy variable for the state of 'knowledge' - the methodology used by Glaeser et al. [1992] may be subject to the criticism that it does not allow to discriminate between technological externalities and mere pecuniary externalities, which work through the price mechanism and do less easily qualify as a rationale for technology policy. - The same problem plagues another strand of research which tries to identify intersectoral external effects by examining the input-output relationships between industries and estimating to what

## 2.2. Strategic Trade Policy: The Aircraft Industry

Rent-shifting in high-tech markets through deliberate government intervention has been an explicit aim of policy in one particular branch of economic activity: the aircraft industry. Naturally, it has been this industry and in particular the economics of the European launching of Airbus as a competitor of Boeing that was subjected to empirical analysis, notably by Baldwin, Krugman [1988] and Klepper [1990, 1994].<sup>29</sup> For a number of reasons ranging from the duopolistic market structure to simple lack of data, all these empirical studies consist of model calibration and simulation rather than econometric estimation of theory-based parameters.<sup>30</sup> This is why all results must be interpreted with utmost caution because they depend crucially on the models' assumptions and imputed parameters.

The policy-relevant core of these studies consists in answering the following double question: to what extent and for what economic reason did the subsidised market entry of Airbus - and thus the transformation of the aircraft market from a (prospective) monopoly of Boeing into a transatlantic duopoly - lead to a redistribution of producer and consumer surplus in the United States, in Europe and in the rest of the world?

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extent the productivity in one industry is affected by output changes in other industries. By this token, Caballero, R. J., R. K. Lyons, "The Case for External Effects", in: Cukierman, A. (ed.), *Political Economy, Growth, and Business Cycles*. Cambridge Mass. 1992, pp. 117-139, find sizeable externalities, but it remains unclear of what kind. - On these methodological problems in detail, see Stolpe, M., *Technology and the Dynamics of Specialization in Open Economies*. Kiel Studies 271. Tübingen 1995, Section B. V, pp. 51-54.

<sup>29</sup> Baldwin, R., P. R. Krugman, "Industrial Policy and International Competition in Wide-Bodied Jet Aircraft", in: Baldwin, R. (ed.), *Trade Policy Issues and Empirical Analysis*. Chicago 1988; Klepper, G., "Entry into the Market for Large Transport Aircraft", in: *European Economic Review*, Vol. 34 (1990), pp. 775-803; "Industrial Policy in the Transport Aircraft Industry", in: Krugman, P., A. Smith (eds.), *Empirical Studies of Strategic Trade Policy*. Chicago, London 1994, pp. 101-126. - A methodologically comparable analysis of the market for small-sized aircraft is provided by Baldwin, R., H. Flam, "Strategic Trade Policies in the Market for 30-40 Seat Commuter Aircraft", in: *Weltwirtschaftliches Archiv/Review of World-Economics*, Vol. 125 (1989), pp. 484-500.

<sup>30</sup> On the specific methodological problems in this field of empirical research, see Krugman, P., "Introduction", in: Krugman, P., A. Smith, op. cit., pp. 4-5.

Despite considerable methodological differences, the answers to these questions do not differ greatly between the relevant studies.

Briefly summarised, the answers read as follows. The market entry and continued market presence of Airbus has led or will lead to a loss of producer surplus in the United States due to the reduction of (monopoly) profits and a gain of consumer surplus all over the world due to lower aircraft prices. However, European 'consumers/taxpayers' are likely to end up worse off because the additional tax burden may well overcompensate the gain in consumer surplus. Also, world welfare as a whole is likely to be reduced because the loss of producer surplus in the United States may well overcompensate the world-wide gains in consumer surplus (net of the tax burden), a result which reflects the enormous importance of economies of scale in the aircraft industry: given very sharp cost reductions through learning effects, the socially optimal outcome for the world as a whole may simply be a monopoly.

The central conclusion from these results is that, in economic terms, the European Airbus venture is better interpreted as a world-wide anti-monopoly policy rather than a transatlantic rent-shifting: European consumers/taxpayers foot the bill of breaking an American monopoly to the unambiguous advantage of consumers in the rest of the world.<sup>31</sup> Whether one likes this policy or not, it has very little to do with the idea of a genuine strategic trade policy that postulates a national interest in rent-shifting as the

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<sup>31</sup> Note, however, that this result holds only if Boeing had in fact become a monopoly without the subsidised market entry of Airbus. Yet this is an open question because Boeing's inner-American competitor McDonnell Douglas might have remained in the market in this case. A model calibration by Klepper (1990, 1994), which explicitly puts the actual Airbus entry against a duopoly with equal market shares of Boeing and McDonnell Douglas, yields the counterintuitive result that a duopoly Boeing/Airbus leaves Boeing with *higher* profits than the duopoly Boeing/McDonnell Douglas because the latter involves more equal market shares and thus forces Boeing further up the average cost curve. Whatever one may think of this peculiar result - it depends crucially on the imputed market share of McDonnell Douglas, which is purely speculative - the Airbus venture does lose its anti-monopoly rationale once it is assumed that there be no monopoly in the counterfactual scenario anyway.

normative basis for government intervention, and not an altruistic policy stance vis-à-vis the rest of the world.

Needless to say that one may put forward other arguments for fostering a European aircraft industry as an important high-tech branch, but these usually lead into the realm of technological spillovers (see Section 2.1. above). To our knowledge, there have been no systematic empirical assessments of the aircraft industry with respect to technological externalities. Casual observations - e.g. the apparent failure of Germany's Daimler-Benz to profit from so-called synergy effects between aircraft and motor car production<sup>32</sup> - suggest that these effects have been grossly overestimated in the past and have lured some firms into a path of diversification that turned out to be unprofitable in the longer run.

There is a more general conclusion to be drawn from the empirical studies on rent-shifting that goes well beyond the aircraft market. Obviously, the aircraft industry is almost a textbook case for an industry with strong economies of scale and, consequently, very few commercial players and fat monopoly margins: if even in this industry it is very hard to channel rents into the pockets of producers in the intervening country, how can one ever arrive at a powerful case for government intervention on these grounds in other industries that are much further away from the conditions of a natural monopoly? One may suspect that the chances to do so are small at best.

### **3. Technology Policy: Some Cautious Conclusions**

Despite the vast uncharted territories that still await future research - notably in the field of econometrically scrutinising the various dimensions of knowledge diffusion - some preliminary conclusions may be drawn from the available evidence surveyed above.

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<sup>32</sup> See, e.g., THE ECONOMIST of May 20th, 1995, "Schrempp Cocktail" (p. 70), of November 18th, 1995, "A Tale of Two Conglomerates" (p. 20) and "Dismantling Daimler" (p. 79).

(i) Knowledge spillovers appear to be a pervasive feature of modern economies that is likely to be of great importance for economic growth. There is still much less clarity about how the knowledge diffusion actually works, although there are some patches of relevant evidence: studies on the *interregional* diffusion process point to strong localisation effects in terms of geography, but not in terms of sectors of economic activity; in turn, studies on *international* diffusion point to powerful spillovers across national borders, be it on a macroeconomic level or for a selected important high-tech industry, namely semiconductors. The apparent contradiction between the empirical results from interregional and international studies may have its cause in a genuine 'globalisation' of knowledge flows: it is not implausible to suspect that the leading high-tech centres in different countries may be better linked in terms of communication than the high-tech centres and the periphery in one single (large) country.

(ii) The aim of shifting monopoly rents between countries does not make by itself a case for government intervention. The one instant where it was obviously relevant - the aircraft industry - is history since Airbus is by now an established competitor of the former (quasi-)monopolist Boeing. Whether the launching of Airbus was a policy success depends on the criteria used. Be that as it may, no comparably structured high-tech branch, where fat monopoly profits accrue in just one country, is in sight in the near future.

(iii) The actual record of government intervention in high tech industries is very hard to evaluate because, usually, no sensible counterfactual scenario can be made available. However, there is one important case where such a scenario has been at least tentatively constructed: SEMATECH. The relevant analysis of SEMATECH indicates that the consortium helped to reduce - arguably inefficient - parallel research, thus pointing to a positive role of the government as an agent that bundles and focuses rather than expands research efforts.

Back to the basic question: Is there a theoretically sound and empirically supported rationale for government intervention in high-tech markets? Given the extent of our ignorance of the precise determinants and structure of knowledge flows, it is hard to avoid the conclusion that a government in an advanced economy has exactly the same information problem as the empirical economist in tracing the relevant knowledge flows. Hence a fine-structured industrial policy targeted at selected high-tech industries can hardly be recommended.<sup>33</sup> On the other hand, the observed regional localisation of knowledge spillovers may suggest that a 'technology policy' aimed at generally supporting the (otherwise suboptimal) growth of high-tech agglomerations, can make economic sense. The problem is, of course, how this should be done with a minimum risk of incurring deadweight losses for taxpayers and consumers. Some reasonable guidelines may read as follows.

1. In selecting instruments of government intervention, one should aim at supporting R&D itself and not output or trade because output subsidies and trade policies do invariably have undesirable allocative side effects, not to speak of the potential for political frictions that may come to the fore once countries engage in protectionist warfare in high-tech markets.
2. When choosing R&D for government support, one should consider whether the apparent market failure cannot be corrected through what may be called 'government coordination' rather than through subsidies. Finding an economically efficient level and structure of industry research by jointly launching particularly large and risky projects or by weeding out costly parallel research is eventually in the interest of all firms concerned; and at least in high-tech markets that are characterised by (not too wide) oligopolies, firms may be ready to cooperate in

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<sup>33</sup> This is an almost commonplace conclusion among economists. See, e.g., the policy conclusions by one of the main advocates of endogenous growth theory: Grossman, G. M., "Promoting New Industrial Activities: A Survey of Recent Arguments and Evidence", in: OECD Economic Studies, Vol. 14 (1990), pp. 117-119.



research. Hence the government may simply serve as a positively neutral agent that creates the necessary credibility, commitment and mutual trust among the private parties so as to make the joint venture possible at all. With the benefit of hindsight, SEMATEC may in fact be interpreted in this way, given its apparently successful record and its decision in 1994 to continue its operation into the second half of the 1990s, but to renounce on government money, which had previously made up about half of its funds.

Of course, even such a modest government role does create problems. First, it requires a precise definition in anti-trust law under which pre-competitive circumstances a R&D-joint venture does not fall under the ban on collusions. In practice, any exemption clause will be abused to some extent so that the likely damage of abuse will have to be put onto the debit account of any (government-sponsored) co-operation. Second, it requires a decision to what extent foreign firms are permitted to participate. Again, there is a conflict: on one side, the very rationale of technology policy is to foster national high-tech agglomerations, and not the ones in other countries; on the other hand, the participation of foreign firms may be the only feasible way to tap a foreign stock of knowledge that may be crucial to obtain or preserve the competitive edge of domestic industry. Even if foreign firms were excluded from participating in a government-sponsored co-operation, however, they may acquire the relevant knowledge by taking over a firm that does participate.<sup>34</sup> In practice, this can hardly be avoided unless a government is prepared to make very serious inroads into the freedom of capital movements.

3. If an element of subsidisation is to be added to the package of government R&D-support, it should be done in a non-discriminatory fashion. This means - roughly

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<sup>34</sup> The history of SEMATEC is telling in this respect. See *THE ECONOMIST* of April 2nd, 1994, "Uncle Sam's Helping Hand" (p. 93).

speaking - that any dollar or DM spent on R&D should be subsidised at the same rate, no matter in which branch of economic activity it is invested. This of course means that high-tech branches with high ratios of R&D-spending to value added receive a higher subsidy per unit of value added; but this 'discrimination' is perfectly compatible with the externality-based logic of the subsidy because they are also the branches whose output is likely to be the furthest below the social optimum. In practice, a favourable tax treatment of R&D may be the most appropriate tool to achieve this task.

Of course, one may wonder whether most industrialised countries - including the United States and Germany - do not already have an implicit R&D-subsidy implemented in their tax codes, though maybe for reasons that have nothing to do with a conscious and deliberate effort to support R&D. An implicit R&D-subsidy can be recognised in two distinct elements of the tax code.<sup>35</sup> First, labour costs incurred in R&D can be deducted as current expenditure like labour costs incurred in production, although they are economically more like an investment in future knowledge creation and thus, in a neutral tax code, would have to be treated like an investment in physical capital, which can only be deducted over time according to some schedule of depreciation. Second, the value of the knowledge output that is not sold in the market for patents and licences but kept for exclusive use in the company, is not counted as an asset for tax purposes. This amounts to a positive discrimination of the knowledge stock vis-à-vis that part of the physical capital stock that is produced by the firm itself. While these tax rules may not be optimal from an economic perspective, they do constitute a considerable element of R&D-support and maybe a starting-point for a "non-mercantilistic technology policy".

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<sup>35</sup> For details, see Stolpe, M. "Industriepolitik aus Sicht der neuen Wachstumstheorie", in: *Die Weltwirtschaft*, 1993, 3, pp. 369-370.

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