# Patterns of technological progress and corporate innovation

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May 2010

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## Contents

# 1 Abstract

The bulk of the global innovative effort takes place in 5 countries: USA, Japan and China as leaders, with France and United Kingdom as immediate followers, which all display, on the long run, a negative marginal value added on innovation. The present paper attempts to answer the following question: why does most of innovative activity takes place in markets apparently hostile to innovation, i.e. giving back negative marginal value added on innovation ? A model is introduced in which any market may be represented as a Selten's extensive game, subgames of which are played as Harsanyi's games with imperfect information, by a temporarily finite and changing set of players. The firms' innovative activity is a Nash's dynamic equilibrium in which innovating is rational though suboptimal, without premium on innovation being a real economic profit. The model is the theoretical framework for the study of six cases: Ford Motor, General Motors, Honda, Chevron, Akzo Nobel and IBM, which allow to conclude that firms do innovation either because they have to or because this is their comparative advantage and they can do it in an exceptionally efficient way. As economic growth is grounded in efficient business patterns and in some countries those business patterns shape themselves in the context of a strong exogenous pressure on innovation. This leads to the development of economies which, regardless its pace of economic growth and balance of payments, come to a point when marginal value added on innovation is negative. At this point, however, incentives to innovate do not disappear and firms continue to apply the same business patterns and thus do create scientific input which gives back negative marginal real output. This pattern of global technological progress seem to be quite durable, with financial markets that allow to compensate, by successful financial placements, the downturns of innovative projects.

# 2 Introduction

The present economic crisis, as all crises, gives way to questions about the future economic order and the prospects for global economic growth. One of the questions concerns technological progress. The declarations of Barack Obama about the new gear for the American economy coming from new technologies bring forth two main questions: a) what is the pace, intensity and geographical pattern of technological progress in the global economy, both from the input and the output point of view ? b) what are the patterns of behaviour of business firms, the necessary transformers of scientific invention into economic growth, vis a vis scientific progress and technological change ?

The present paper attempts to answer those questions on the grounds of available information on patentable innovation and aggregate accounts in thirteen countries – Canada, Denmark, Finland, France, Japan, Netherlands, Norway, Sweden, UK, USA, India, China and Brasil – as well as information about innovative effort and financial performance of 6 global corporations: Ford Motor, General Motors, Honda, Chevron, Akzo Nobel and IBM.

# 3 The macroeconomic context

## 3.1 Scientific input to real economy

Technological progress consists both in creating scientific inventions and in using them as input for creation of wealth in the real economy. Therefore the first important issue is how to measure the scientific input. Ideas and discoveries are not exactly countable, as both their appearance and effects are difficult to define precisely. On the other hand the number of patent applications filled is frequently used as the aggregate measure of the number of scientific inventions bearing important economic consequences ( see for example: Jaffe et al. 1982; Frantzen 2000; Holmen, Jacobsson 1998; Eaton, Kortum 1999; Rensman, Kuper 1999). Of course, many inventions are not patentable or it is not profitable to patent them, For example in oil & gas drilling business, where most innovations are so strongly site – specific that the probability of imitation is negligible but, on the other hand, the fact of publishing the description of those innovations could bring, for a firm, the risk of uncovering too many cards to the competitors. In the same way there are strong differences among countries as for the quality of their local intellectual property protection regimes. Scientific input appears at different peers of the value chain of the economy, however on the long run most scientific input to industry ends up as modifications or creation of final goods in the consumer markets. In these markets global marketing success strongly depends on patenting. On the other hand patenting is essential to global technology diffusion and spillover. At first sight patents seem to be a barrier to technology spillover as it assumes legal protection of inventions. However, on the long run patenting plays the same role as any legally regulated procedure – it is a way of communicating and solving complex problems in broad social systems. As a matter of fact, an invention is more likely to spillover when patented – all the actors of the process are in a clear situation then, with equally clear transaction costs and opportunities for economic rent. Non – patented inventions, on the contrary, are much harder to diffuse as there is very few legal ways to do it. Thus research and development activity that ends up in a patent procedure can be considered as a complete process of technological development, with maximum value added, compared to those R&D projects which remain outside the patenting regime. Therefore patentable ( and patented ) innovation is essential to economic development and in this paper the number of patent applications filled by applicants domestic to the given country is considered as the aggregate measure of scientific input to the real economy of this country.

Currently the bulk of the global innovative effort, measured with the number of patent applications, seems to take place in 5 countries: USA, Japan and China as leaders, with France and United Kingdom as immediate followers ( see Table 1). Among those five, Japan alone represents about one half of the world's scientific input. Japan and United States account for more than 80% of it. Therefore the first fact important for the present study is that the global scientific input is actually not as global as it could seem ( Germany is not included in the table due to the fact that it's unification in the post communist period makes comparisons difficult. At present the German economy represents some 60 000 domestic patent applications per year.). Furthermore, among those five four are developed countries, with one challenger – China – coming along at pace that has been particularly accelerated during the last two decades. Surprisingly enough India and Brasil, usually mentioned with China as other dominant emerging markets, come with less than one tenth each of the number of domestic patent applications. Among the thirteen countries subject to the present analysis only five – Canada, Finland, Japan, USA and China – have significantly increased their scientific input whilst other developed countries - Denmark, France, Netherlands, Norway, Sweden and United Kingdom – have witnessed an important downsizing of their innovative activity.

*Table 1 - Total number of domestic patent applications filled in selected countries, since 1950 until 2007.*

| | Total number of domestic patent applications filled | | |
|---|---|---|---|
| | **1950 - 1970** | **1971 - 1990** | **1991 - 2007** |
| Canada | 30 588 | 41 974 | 64 292 |
| Denmark | 20 081 | 19 172 | 25 531 |
| Finland | 14 601 | 29 488 | 36 785 |
| France | 248 019 | 243 486 | 227 930 |
| Japan | 986 175 | 3 962 044 | 5 968 371 |
| Netherlands | 51 372 | 40 247 | 36 333 |
| Norway | 23 729 | 16 626 | 19 607 |
| Sweden | 89 221 | 80 484 | 59 250 |
| UK | 447 909 | 413 901 | 327 197 |
| USA | 1 335 210 | 1 336 832 | 2 597 648 |
| India | 16 018 | 22 712 | 43 100 |
| China | 16 000* | 81 007 | 690 965 |
| Brasil | 24 789 | 46 840 | 51 428 |

Source: World Intellectual Property Organization ( WWW.wipo.org ); * For the period 1950 – 1970 the data for China is author's own estimate. WIPO does not provide the corresponding information

The size of the scientific input to economy is significantly influenced by the ability of the labour force to produce innovation. Some authors tend to state that the overall equilibrium between the research and development activity and real production is determined by the percentage of the labour force able to produce innovation (Eaton, Kortum 1999). The volume of scientific input is one thing, the relative ability to do so is another. If we consider the average annual number of domestic patent applications per 1000 people employed (Table 2 ), a significant disparity among the developed countries appears, similar to that occurring for the size of scientific input. The size of scientific input to real economy in the given country seems to depend strongly upon the relative division of labour between the R&D sector on one hand and the sector of production on the other hand, just as stated by the "golden rule of research" by Edmund S. Phelps ( 1964). There, two different paths of economic development seem to appear. The first one, represented by Finland, Japan, USA and China, may be called "R&D oriented". On the long run these countries display a constant growth both of scientific input and of the relative propensity of the workforce to perform it. Others, like United Kingdom, France, Sweden, India or Brasil, are definitely not oriented in that way. Their scientific input and the relative ability of the workforce to innovate are declining or staying quite even over the last six decades.

*Table 2 - Average number of domestic patent applications per 1000 people employed.*

| | **Average number of domestic patent applications per 1000 people employed** | | |
|---|---|---|---|
| | **1950 - 1970** | **1971 - 1990** | **1991 – 2007** |
| Canada | 0,2565 | 0,1952 | 0,2562 |
| Denmark | 0,4291 | 0,3746 | 0,5515 |
| Finland | 0,3093 | 0,6186 | 0,9662 |
| France | 0,5852 | 0,5546 | 0,5614 |
| Japan | 0,8886 | 3,3179 | 5,3747 |
| Netherlands | 0,5278 | 0,3424 | 0,2756 |
| Norway | 0,7913 | 0,4355 | 0,5128 |
| Sweden | 1,1478 | 0,9616 | 0,8206 |
| UK | 0,8498 | 0,8307 | 0,7159 |
| USA | 0,9092 | 0,6643 | 1,1219 |
| India | 0,0051 | 0,0048 | 0,0066 |
| China | 0,0020 | 0,0081 | 0,0549 |
| Brasil | 0,0367 | 0,0456 | 0,0378 |

source: author's, on the grounds of data from World Intellectual Property Organization ( WWW.wipo.org ) and from The Conference Board and Groningen Growth and Development Centre, Total Economy Database, January 2010 (http://www.conference-board.org/economics/database.cfm )

## 3.2 The real output from the scientific input

At the macroeconomic level innovation is supposed to bring two basic kinds of real returns: a) higher productivity b) higher product. The first kind relies on the assumption that scientific input leads to more efficient technologies and those, in turn, bring a more efficient usage of labour ( see for example: Romer 1986; Grossman, Helpman 1993). The second relates the fact that successful innovation leads to creation of new product markets ( Schumpeter 1976) and to investment in new plant and equipment ( Phelps 1964; Tobin 1961, 1969, 1971), and, consequently to a greater output from the given outlays of production factors, as well as to a greater value added by the whole economy. The Table 3 shows average labour productivity, per hour worked, for 11 out of the set of 13 countries that were taken into account for the computation of scientific input: Canada, Denmark, Finland, France, Japan, Netherlands, Norway, Sweden, UK, USA, India, China, Brasil . In all eleven countries productivity displays a steady growth on the long run, whilst, as it was previously pointed out, the productivity of the same economies in terms of scientific input tends rather to lower, with rare exceptions.

*Table 3 - Average labour productivity per hour worked in 2009 US$*

| | Average labour productivity per hour worked in 2009 US$ | | |
|---|---|---|---|
| | 1950 - 1970 | 1971 - 1990 | 1991 - 2007 |
| Canada | $23,86 | $33,68 | $42,78 |
| Denmark | $17,80 | $31,11 | $45,37 |
| Finland | $11,53 | $23,40 | $39,95 |
| France | $14,32 | $31,45 | $48,99 |
| Japan | $8,23 | $20,49 | $34,28 |
| Netherlands | $17,58 | $37,14 | $52,58 |
| Norway | $20,04 | $41,15 | $69,23 |
| Sweden | $20,57 | $32,67 | $43,23 |
| UK | $14,45 | $24,69 | $40,88 |
| USA | $23,54 | $35,33 | $47,18 |
| India | n.a | n.a. | n.a. |
| China | n.a | n.a. | n.a. |
| Brasil | $4,46 | $8,43 | $10,12 |

Source: The Conference Board Total Economy Database, January 2010, http://www.conference-board.org/economics/database.cfm

The value added by the national economy as a result of the scientific input can be estimated, on the long run, as average real GDP per domestic patent application, which is computed in the Table 4, for the same set of 13 countries that previously. The rationale behind this average is twofold. Firstly, every patentable innovation has to end up as some product or technology and, consequently, as consumption, investment, government spending or exports. Secondly, patentable innovation contributes to move outwards the technological frontier of the national economy and thus to maximize, temporarily, its aggregate value added. The ratio has to be applied to long periods of time, as the full transformation of scientific input into real output takes several years. Therefore, on the long run the ratio of GDP per domestic patent application is the average value added per unit of scientific input and represents the most broadly seen economic output from scientific input. As for the 13 countries in question, the average differs significantly among them, the differences tend to widen in time and they are not easily explainable by previously mentioned factors: labour productivity, R&D productivity or the size of scientific input. Moreover, they are hardly possible to explain by other macroeconomic variables, as GDP per capita or the pace of its growth. The average is computed for three different periods of time which allows marginal analysis. Over the whole span of observation – from 1950 to 2007 - marginal GDP per patent application is positive, excepted Japan, which had lost 20% of its initial economic profits from patentable innovation. In the same interval of time the champions of marginal value added on innovation are, respectively: Brasil, Netherlands, Norway and Sweden, which all had increased the value added in question about fourfold. If two consecutive marginal values are computed, the first one for 1971 – 1990 in relation to 1950 – 1970 and the second one for 1991 – 2007 in relation to 1971 – 1990, a different picture appears drawn. Whilst the first marginal is positive for almost all countries ( excepted Japan, as usual), the second one is negative for: Canada, Denmark, Japan, USA and China. Marginal values for the period of 1991 – 2007 seem to be inversely proportional to the volume of scientific input. Countries displaying the highest scientific input tend to witness a decreasing ability to produce real output from it. Of course, it could be stated that there are secondary gains from innovation, resulting from its diffusion across global markets. An invention made and patented in United States can bring payoffs through its commercialisation in foreign markets (see for example: Eaton, Kortum 1999). If such was the case, countries with negative marginal GDP per patent application should be those with a significantly positive balance of payments. This is not the rule at all. Then secondary effects of such a positive balance of payments should be captured, on the long run, in the pace of economic growth, and, consequently, in a positive marginal GDP per patent application. Therefore, diffusion of innovation does not explain why, on the long run, the bulk of the world's innovative effort takes place in markets which, at least at first sight, have been giving a negative return on innovation.

*Table 4 - Average GDP per domestic patent application ( USD PPP, 2007).*

| | **Average GDP per domestic patent application ( USD PPP, 2007)** | | |
|---|---|---|---|
| | **1950 - 1970** | **1971 - 1990** | **1991 - 2007** |
| Canada | $175 640 776,04 | $290 160 451,59 | $275 040 004,98 |
| Denmark | $66 101 104,84 | $123 520 847,15 | $115 773 750,36 |
| Finland | $58 750 614,87 | $63 919 180,53 | $66 875 987,02 |
| France | $46 111 772,14 | $98 505 039,74 | $130 038 794,23 |
| Japan | $13 501 330,56 | $12 932 500,34 | $10 839 609,89 |
| Netherlands | $64 228 212,60 | $164 162 113,53 | $247 016 417,26 |
| Norway | $46 808 555,59 | $135 478 887,23 | $172 287 689,90 |
| Sweden | $23 881 867,05 | $47 635 609,13 | $79 490 074,34 |
| UK | $32 235 796,11 | $54 454 519,05 | $89 482 609,00 |
| USA | $49 522 463,74 | $95 027 896,56 | $75 848 094,95 |
| India | $468 617 623,01 | $658 695 854,50 | $827 356 749,90 |
| China | $140 640 040,74 | $301 769 448,87 | $199 093 604,29 |
| Brasil | $117 013 151,70 | $417 099 155,52 | $499 806 012,23 |

source: author's

There seem to be a country – specific pattern as for both the production of scientific input to real economy and the subsequent real output from it, and, in the same time, in all the thirteen countries studied both patenting and further economic usage of scientific inventions relies mainly on the business sector ( maybe with a slight exception of France, which has a very strong public research sector, though intrinsically linked with big corporations like Dassault or Elf). Therefore it is worth studying to what extent and in what ways the differences among countries can be explained by microeconomic factors, namely by individual strategies of business firms. In this respect a model is introduced further below and comparative case studies are conducted on the grounds of it.

# 4 The microeconomic inquiry

## 4.1 Theoretical background

Firms tend to innovate when they earn some kind of innovation premium due to market novelty or to the increase of productivity ( Arrow 1962; Barzel 1968; Kamien and Schwartz 1982; Scherer 1967; Loury 1979). This premium tends to diminish as more and more firms innovate in the same markets. Innovation brings, among others, a greater diversity of goods offered to consumers. There might exist a contradiction, however, between the optimal diversity of products from the point of view of the consumer, on one hand and the same kind of diversity considered from the producer's point of view ( Spence 1976; Dixit – Stiglitz 1977). Some economist point out, right in the lines of the Schumpeterian tradition, that innovative activity is essentially a reaction to external pressures and an act of absorption of some exogenous scientific input rather than autonomous creation. Both reaction and absorption are greatly influenced by the imperative to imitate other market players (Katz, Shapiro 1985; Farrel, Saloner 1985; Abrahamson, Rosenkopf 1990, 1993). From this point of view strategies of firms vis a vis innovation may be rational though suboptimal, as imitation plays a more and more important role. Besides, it is possible that once set on its tracks with an initial input of capital, the R&D function plays its own games and although internal to business organizations becomes autonomous in terms of goals and development paths (Phelps 1964; Barzel 1968). Besides, any kind of outlays of factors of production have to be considered in the context of alternative cost, should the latter be the simplest benchmark in the form of purely financial investment ( Jensen 1993, 1999). The financial peer is even more justified as firms can enter into possession of results of research or even of ongoing research projects through mergers and acquisitions (Sudarsanam 2003).

Three questions arise in the light of macroeconomic data. Firstly, why does most of innovative activity take place in markets apparently hostile to innovation, i.e. giving back negative marginal value added on innovation ? Secondly, what characteristics of markets or businesses can lead to such a negative macroeconomic response to scientific input ? Thirdly, what patterns of firms' behaviour can yield an important innovative effort in presence of such hostile environment ? Two hypotheses arise about firms' innovative activity as the conventional "premium – on – innovation" explanation is becoming doubtful: a) firms innovate because they have to, under the pressure of product markets as well as their broad social environment b) firms innovate simply because they can, because the R&D sector, that have been developing for decades, is now quite autonomous and generates a constant input of scientific discoveries, impossible to ignore. Both hypotheses sum up to a more general one, that firms' innovative activity is a Nash's dynamic equilibrium (Nash 1950a; Nash 1950b; Nash 1951; Nash 1953) in which innovating is rational though suboptimal, without premium on innovation being a real economic profit ( Waśniewski 2009).

## 4.2 The model

Any market may be represented as a Selten's extensive game (1975), subgames of which are played as Harsanyi's games with imperfect information (1953; 1966; 1967; 1968) , by a temporarily finite and changing set of players. In each of those subgames each player (*i*) applies at the moment *t* a strategy *S(i;t)* as shown in Equation 1.

*Equation 1*

$$S(i;t)=[MA(i;t);R(i;t)]$$

-where *S(i;t)* is the strategy applied by the player *i* at the moment *t*, *MA(i;t)* is the set of modalities of action and *R(i;t)* is the set of results.

Strategies *S(i;t)* are real Nash's strategies in the sense that they aim at maximizing a complex set of pure, unicriterial strategies. The managers of a firm might undertake to maximize: a) scale of activity b) profitability c) short - term accumulation of capital d) long – term value for shareholders and by the same means the long – term ability of a firm to accumulate capital. Of course, it is arguable whether short – term accumulation of capital is a result or a means to achieve further results. For the purpose of the present model it is assumed that any accumulation of capital, even on the short – run, is reflected by investment cash – flow and financial cash – flow. As any cash – flow creates opportunities for appropriation of economic rent from the corresponding transactions it is further assumed that short – term accumulation of capital belongs to the set of results. Maximisation of those unicriterial strategies may be achieved through two basic modalities of action. The first one is investment in specific assets in the form of technologies, which, in turn is the embodied scientific input. The second is investment in non – specific financial assets, ex. in sovereign bonds. Therefore the set of results *R(i;t)* is a real combination of pure results as shown in Equation 2 and the set of modalities of action *MA(i;t)* is real combination of pure modalities as shown in Equation 3.

*Equation 2*

$$R(i;t)=AS(i;t);PR(i;t);SCA(i;t);LCA(i;t)$$

- where *AS(i;t)* is the scale of activity of the player *i* at the moment *t*, *PR(i;t)* is their profitability, *SCA(i;t)* is their short – term accumulation of capital and *LCA(i;t)* is their long – term ability to accumulate capital;

*Equation 3*

$$MA(i;t)=tech1(i;t),tech2(i;t),\ldots,techN(i;t);fa1(i;t),fa2(i;t),\ldots,faN(i;t)$$

- where $tech_j(i;t)$ is the investment *j* of the player *i* at the time *t* in specific technologies and $fa_j(i;t)$ is the investment *j* of the player *i* at the time *t* in non – specific financial assets; Modalities of action are twofold in kind but multiple in practical application: a firm can lead many investment projects in the same time in each of the two categories. In fact, most big firms do just so, never relying on one project;

Every individual strategy S(*i*;t) is in interaction with the space of the game in the sense that individual strategies of different players mutually shape one another. This, in turn, leads to a certain degree of isomorphism among individual strategies. Modalities of action *MA(i;t)* are heterogeneous among players, however the mechanism of mutual observation and imitation makes some typical modalities *M*(x;t)* of action arise, where *x* is a variable describing the type of modality. The $tech_j(i;t)$ modalities of action are undertaken on the grounds of both exogenous and endogenous events. The former are all kinds of internal information of a firm, linked to the development of human capital (Scherer 1967), the latter are all kinds of response to the requirements of agents external to the firm, that response greatly shaped by imitation of other market players (Davies 1979; McCardle 1985).

More $tech_j(i;t)$ projects are conducted in a sector, bigger is the probability for the product markets to reach a state of nearly optimal Dixit – Stiglitz product diversity ( Spence 1976; Dixit – Stiglitz 1977), and, consequently, for the set of results *R(i;t)* to bring poorer scores on two kinds of results: the scale of activity *AS(i;t)* and the profitability *PR(i;t)*. The optimal Dixit – Stiglitz product diversity is likely to appear mainly in consumer markets for final goods and once there, its effects will transmit upstream of the value chain to markets of intermediate and then primary goods. Therefore, on the aggregate scale, more intense is innovative activity in the business sector, more likely is this economy to yield negative marginal value added on innovation. This may but not necessarily has to lead further to poorer capital accumulation, both short – term and long term; if investments of $fa_j(i;t)$ kind bring satisfactory return on capital, they can compensate unsatisfactory return on $tech_j(i;t)$ projects and the business sector can continue on accumulating capital. Moreover, both in developed economies and in the quickly developing ones the growth of financial markets can yield such a high rate of return on investments of $fa_j(i;t)$ kind, that accumulation of capital and the resulting economic growth are not affected by the negative marginal value added on innovation.

A common reference level $R^*(t)$ may be defined at the moment $t$ for the aggregate results $R(i;t)$ of every given player $i$. $R^*(t)$ may be an external benchmark as well as an internal average or quantile. All strategies $S(i;t)$ that bear results $R(i;t)$ lower than the reference level $R^*(t)$ are inefficient and unsatisfactory for players. On the other hand strategies $S(i;t)$ with results $R(i;t) > R^*(t)$ are efficient and satisfactory. The state of the market at any given moment $t$ may be represented as the state of the set *MP* of market participants. This set is fundamentally divided into two subsets: i) the subset $\{R(i;t) > R^*(t)\}$ of those market participants, whose strategies are efficient and bring satisfactory results ii) the subset $\{R(i;t) < R^*(t)\}$ of those market participants, whose strategies are inefficient and bring unsatisfactory results. Market participants that belong to $\{R(i;t) > R^*(t)\}$ are motivated to carry on the current game in the sense of Harsanyi's theory and they do so, whilst those belonging to $\{R(i;t) < R^*(t)\}$ have interest to change the rules of the game and to pass to another game, and they correspondingly modify their modalities of action. Consequently, market participants that belong to the subset $\{R(i;t) > R^*(t)\}$ tend to keep their modalities of actions unchanged and those modalities tend to shape a relatively stable n – tuple space of the game in the sense of Nash's theory as well as tend to a Nash's dynamic equilibrium. On the other hand, market participants from $\{R(i;t) < R^*(t)\}$ do not participate in forming a dynamic Nash's equilibrium. The dynamics of the market depend on mutual proportions between the two subsets $\{R(i;t) < R^*(t)\}$ and $\{R(i;t) > R^*(t)\}$. If the subset $\{R(i;t) < R^*(t)\}$ prevails on $\{R(i;t) > R^*(t)\}$ in terms of number of participants or their relative impact on the market, the market as a whole tends towards structural change, meaning a Harsanyi's change of the rules and, consequently, a passage to another Selten's subgame. Contrarily, should the subset $\{R(i;t) > R^*(t)\}$ in prevail on $\{R(i;t) < R^*(t)\}$, the market tends to temporary homeostasis, with temporary Nash's equilibrium, without significant structural change.

Should a significant number of players be adversely affected, in the payback on their $tech_j(i;t)$ projects, by the nearly optimal Dixit – Stiglitz product diversity, the response of the whole market in terms of structural change can be twofold. If the growth of financial markets and high yields from investments of $fa_j(i;t)$ kind successfully compensate the poor returns on technological change, the market stays structurally stable. If satisfactory returns on investments of $fa_j(i;t)$ kind are not reached, then the players achieving poor results on their $tech_j(i;t)$ projects will try to change the rules of the game by trying to weaken external pressure on innovation, for example by countering legislative changes implementing “green” technologies.

Now the question arises: what is the keystone of financial payoffs from the $tech_j(i;t)$ projects ? In other words, what makes innovation and investment in specific assets really profitable and financially attractive on the long run ? Is it just the pattern of “we do innovation to be good looking enough to make profitable financial transactions” or is there something else. Case studies presented in the next subchapter attempt to answer these questions.

## 4.3 The case studies

The case studies introduced in this paper aim at demonstrating how the model is explanative to the link between innovative effort undertaken by business firms, the economic outcome of this effort and possible macroeconomic consequences. The core question of the study is the same that the one which appears in the light of macroeconomic data: why do most of the worlds innovative effort and scientific input takes place in markets which are apparently hostile to innovation, as judged by marginal GDP per patent application ?

Six corporations are in focus: Ford Motor, General Motors, Honda, Chevron, Akzo Nobel and IBM. The first three belong to the automotive sector, being under an important pressure on innovative effort, both from the part of product markets as well as increasingly exigent regulations for natural environment protection ( Of course, comparing General Motors and Ford on one hand with Honda and others can raise the remark that this is observing the obvious. The two American automotive giants are well known for their long lasting financial problems. However, they are big firms and there are representative, in a way, for a whole category of industrial businesses, having been operating for a long time at the verge of economic soundness, the maintaining of jobs and the corresponding social and political pressure being more important than purely financial considerations. The case studies are supposed to introduce complexity and not to strive for universal representativeness. Therefore studying GM and Ford in this context is, in author’s opinion, rational and informative). Ford Motor, for example, declares in its 10-K annual report for the year 2008 that one of the major challenges for the R&D activity of the firm is to comply with the regulatory framework implemented by European Commission, referring to a single system for register, evaluate and authorize the use of chemicals with a production volume above one ton per year. This framework, called “REACH” is likely to redirect, according to Ford’s managers, the development resources from the market – driven activities to those connected with REACH compliance. In a general manner, the innovative strategy of Ford Motor focuses on two points: a) product development b) basic research. Activities like manufacturing engineering are excluded from the firm's innovative strategy. As for product development, the declared priority of Ford is to offer consumers more fuel – efficient vehicle choices, including to develop plug-in hybrid vehicles and infrastructure. As for General Motors, their top priority declared to the public is the development of alternative propulsion strategy with an objective to be the recognized industry leader in fuel efficiency through the development of five specific areas: i) increased fuel efficiency in GM cars and trucks ii) development of alternative fuel vehicles, biofuels included iii) expansion of the hybrid vehicle offerings iv) plug – in electric vehicle technology v) hydrogen fuel cell technology. The GM strategy assumes that all innovative effort is divided into two different functional departments: global and local. The global R&D effort involves the non – visible parts of the vehicle, the so – called "architecture", like steering, suspension, brake system, heating, ventilation, air – condition and electrical system. The local innovative activity, at the regional level, focuses on components which are specific to the given GM brand, as exterior and interior design, tuning according to the brand character and final validation to meet local legal requirements. Honda Motor has a slightly different approach to innovative processes. First of all, the very foundations of Honda lay in the Honda Technical Research Institute established in 1946 by Soichiro Honda. Whilst for its Americal competitors the key concept of innovative effort seems to be the compliance with various kinds of external factors, Honda's main driver of innovation is endogenous creativity, with subsequent studies on practical applications. Research and development activities are conducted principally at the independent subsidiaries of the Company. Honda R&D Co., Ltd., is responsible for research and development on products, with regional subsidiaries: Honda R&D Americas, Inc. in the United States; and Honda R&D Europe (Deutschland) GmbH in Germany. Honda Engineering Co., Ltd., handles research and development in the area of production technology, supervising the activities of production technologies centres around itself as well as around Honda Engineering North America, Inc. Each of this units leads local projects of product development in three areas: motorcycle, automotive, power products, frequently in joint venture with external partners. Besides research oriented on product, Honda conducts fundamental research, the two main strands of which are: a) the development of a technological base for ethanol production from soft biomass, including plant stalks and leaf matters, such as rice straw b) robotics and ASIMO technology.

Chevron Corporation is engaged, through a number of subsidiaries, into fully integrated petroleum operations, chemicals operations, mining operations, power generation and energy services. One of the group's subsidiaries, Chevron Technology Ventures, focuses on innovation, commercialization and integration of emerging technologies within Chevron (CTV). CTV identifies, acquires, tests, validates, and – if appropriate – helps integrate those technologies into the company's core businesses. Alternatively, technologies may be studied then "shelved" for future consideration. Chevron Technology Ventures works through four business units:

i) Venture Capital, Chevron Technology Ventures Investments (CTVI), which finds and makes investments in early-stage companies offering technology valuable to Chevron. CTVI then helps Chevron business units implement that technology;

ii) Biofuels - CTV's Biofuels business unit is developing technologies related to large-scale commercial production and distribution of non-food biofuels in the United States;

iii) Hydrogen business unit operates five hydrogen demonstration fueling facilities in the United States and manages Chevron's participation in federal and state government hydrogen programs. It also monitors developments in hydrogen technology in order to maintain and improve the company's capabilities.

iv) Emerging Energy - CTV's Emerging Energy business unit is exploring innovative ways that Chevron can use renewable energy to run its operations more cost-effectively while reducing our carbon footprint.

Another unit of the group, Technology Marketing (TEMA), provides its technologies and services to refiners through its two joint venture partnerships - Chevron Lummus Global LLC and Advanced Refining Technologies LP. TEMA also commercializes emerging technologies and provides international technical service to help refiners.

Chevron is operating in a vertical market – the oil & gas one - where being in control both of the upstream mining activities and of the downstream petrochemical product markets is the core business pattern. Innovation in the oil & gas sector is strongly site – oriented, with relatively few generic, patentable product and technologies and a lot of innovative effort going on as adaptation of such generic technologies to particular drilling sites. On the other hand, the downstream Chevron’s business is more prone to patenting, with a relatively greater importance of imitable and therefore patentable innovations. Akzo Nobel is a chemical company, currently focused mainly on specialty chemicals, decorative paints and industrial coatings, though a long presence in the biotechnology sector ( Organon Biosciences ) had been to notice in the firm’s activity up to 2007. From the organizational point of view AkzoNobel runs a dedicated Research, Development & Innovation (RD&I) unit – in which the vast majority of researchers are based in dedicated customer-facing business teams, oriented mainly on new products. Some 57% of R&D expenses of AkzoNobel are spent in Europe, 22% in the Asiatic market, 21% in America. Between the automotive manufacturers on one hand and the oil & gas sector on the other, Akzo Nobel's business seems to be medium – verticalized, with a significant role assigned to the transformation of fundamental chemical research into commercial solutions. The main fields of research are: a) colloid science b) extensional rheology c) materials science.

IBM is an IT company with an ongoing strategic reorientation from commodity markets to complex IT services. Due to this fact the specificity of innovative effort at IBM is that the R&D function strictly considered is hard to distinguish, in practice, from immediate business application. According to the company's own statement, its innovation is integrated with the emergence of a new computing model. This new model, replacing the PC-based, client/server approach, is networked, modular and open, no longer confined to IT systems alone, with the digital infrastructure of the world merging with the physical infrastructure of the world.

Diversity of the companies subject to the present study is partly demonstrable on the grounds of observation of their pre – patenting innovative activity, measured with the ratio of non – capitalized R&D expenses to revenues ( Table 5). Accounting for this variable, the most important observation is the difference between Chevron, spending hardly more than 0,2% of its revenues and the other five, with spending comprised usually in an interval between 3 and 7% of their revenues. Then one can notice that Akzo – Nobel and IBM seem to spend more on R&D than the three automotive companies, whilst among the latter ones Honda seems to spend more than Ford and GM.

*Table 5 – Non – capitalized R&D expenses as a percentage of revenues for Ford Motor, General Motors, Honda, Chevron, Akzo Nobel and IBM, during the period 2001 - 2008.*

| | **Ford** | **GM** | **Honda** | **Chevron** | **Akzo Nobel** | **IBM** |
|---|---|---|---|---|---|---|
| Y2001 | 4,5% | 3,6% | 5,5% | 0,2% | 6,0% | 6,0% |
| Y2002 | 4,7% | 3,4% | 5,4% | 0,2% | 6,5% | 5,9% |
| Y2003 | 4,6% | 3,3% | 5,5% | 0,2% | 6,8% | 5,7% |
| Y2004 | 4,3% | 3,3% | 5,5% | 0,2% | 6,4% | 5,9% |
| Y2005 | 4,5% | 3,4% | 5,4% | 0,2% | 6,4% | 6,4% |
| Y2006 | 4,5% | 3,2% | 5,2% | 0,2% | 6,4% | 6,7% |
| Y2007 | 4,3% | 4,5% | 5,0% | 0,3% | 2,4% | 6,2% |
| Y2008 | 5,0% | 5,4% | 4,9% | 0,3% | 2,3% | 6,1% |
| **Average** | **4,6%** | **3,8%** | **5,3%** | **0,2%** | **5,4%** | **6,1%** |

SOURCE: ANNUAL REPORTS.

The R&D effort seems to be both firm and industry specific. As for patent applications, which are supposed to be at least a part of the outcome of the R&D expenditures, the situation is slightly more complicated ( Table 6). The biggest patenting activity had been taking place at Honda, with 5470 patent applications filled during the period of 2001 – 2008. In a general manner, in the automotive sector is very active in patenting: during the period of study the three automotive firms filled 7467 patent applications in total whilst for the other three companies the same total was of 1472. Surprisingly enough, Chevron, the "meanest" of the six as for R&D expenditures, filled more patent applications ( 686) than Akzo Nobel ( 236), IBM ( 550 ) or even General Motors (487). Disparities in the size of patenting activity, remaining quite unexplained by the differences in R&D expenditures, are not the only phenomenon worth noticing. Four of the six firms subject to analysis, IBM and Ford making an exception in this respect, seem to display a relatively even R&D spending in time and a sort of cycle of patenting, lasting some seven years, with a peak in 2006 and 2007. Once again, Chevron seems to be a separate case, with an exceptionally strong cyclical variation.

*Table 6 – Number of patent applications filled at the US patent & Trademark office by Ford Motor, General Motors, Honda, Chevron, Akzo Nobel and IBM, during the period 2001 – 2008. All six companies are strongly focused on the US market and US Patent & Trademark Office is considered as one of the three "reference" patent offices, with the Japanese and the EU patent offices going along.*

| | GM | Honda | Chevron | Akzo Nobel | IBM |
|---|---|---|---|---|---|
| Y2001 | 41 | 350 | 7 | 9 | 120 |
| Y2002 | 53 | 483 | 10 | 11 | 54 |
| Y2003 | 63 | 563 | 73 | 19 | 62 |
| Y2004 | 85 | 788 | 91 | 57 | 63 |
| Y2005 | 68 | 942 | 135 | 56 | 86 |
| Y2006 | 86 | 853 | 140 | 55 | 48 |
| Y2007 | 64 | 855 | 152 | 25 | 85 |
| Y2008 | 27 | 636 | 78 | 4 | 32 |

Source: US Patent & Trademark Office

A strong firm – specificity is to notice as for the transformation of R&D outlays into patentable innovation. This transformation, possible to measure through a ratio of R&D expenditures per 1 patent application filled, is shown in the Table 7. Important cross sectional and temporal differences are to notice. Honda is the cheapest inventor with an average of 6,42 USD mln of R&D outlays per 1 patent application filled, with Chevron immediately following at an average rate of 9,73 USD mln per 1 patent application, other firms as distant followers and General Motors closing the comparison with 129,38 USD mln per 1 patent application on average. In a general manner, productivity of R&D outlays in term of patentable innovation is more differentiated among the three automotive companies – Ford, GM and Honda – than among the whole sample of six firms. This could indicate, though not in a conclusive way yet, that the productivity of R&D outlays is strongly connected to a more broadly understood comparative advantage, thus to the relative performance of business strategies.

*Table 7- R&D outlays per 1 patent application filled at the US patent & Trademark office by Ford Motor, General Motors, Honda, Chevron, Akzo Nobel and IBM, during the period 2001 – 2008.*

| | **Ford [ USD mln]** | **GM [ USD mln]** | **Honda [USD mln]** | **Chevron [USD mln]** | **Akzo Nobel [EUR mln]** | **IBM [USD mln]** |
|---|---|---|---|---|---|---|
| Y2001 | 228,13 | 148,78 | 8,22 | 29,86 | 94,11 | 41,55 |
| Y2002 | 28,84 | 113,21 | 6,55 | 22,10 | 82,91 | 87,96 |
| Y2003 | 41,90 | 98,41 | 6,87 | 3,12 | 46,68 | 81,89 |
| Y2004 | 41,57 | 76,47 | 5,43 | 2,66 | 14,32 | 90,05 |
| Y2005 | 43,48 | 98,53 | 4,50 | 2,34 | 14,89 | 67,93 |
| Y2006 | 29,39 | 76,74 | 5,05 | 3,34 | 16,09 | 127,23 |
| Y2007 | 23,89 | 126,56 | 5,59 | 3,70 | 14,36 | 72,39 |
| Y2008 | 65,77 | 296,30 | 9,13 | 10,71 | 88,25 | 198,03 |

Source: author's

Innovative effort is supposed to end up in investment in specific assets, which, in turn, should lead to: a) some kind of temporary competitive advantage giving a result at the level of sales b) a change in profitability or the keep – up of profitability at a certain level c) a certain ability to attract investors and debt holders. As for investment, net of depreciation, every firm is a specific case, without any obvious industry – specific differences ( Table 8 ). The three automotive firms – Ford, GM and Honda – displayed an average net annual investment of 359, -4 607 and 1 375 USD mln respectively. The vertical firm – Chevron – comes as the champion of net investment with an annual average of 3 104 USD mln. AkzoNobel, the closest to Chevron in terms of industry, displays an average of – 10 USD mln annually. IBM, the only IT firm among the cases studied, exceeds 400 USD mln of average annual net investment. In terms of net investment rate ( net investment divided by revenues ) Honda and Chevron are the champions of the small sample, with 1,7% and 1,4% respectively. Then come IBM ( 0,5%) and Ford ( 0,2%), General Motors and AkzoNobel displaying no net investment at all.

*Table 8 – investment in property, plant and equipment, net of depreciation, for Ford, GM, Honda, Chevron, Akzo Nobel and IBM. Time span: 2001 – 2008.*

| | **Ford [ USD mln]** | **GM [ USD mln]** | **Honda [USD mln]** | **Chevron [USD mln]** | **Akzo Nobel [EUR mln]** | **IBM [USD mln]** |
|---|---|---|---|---|---|---|
| Y2001 | 1 300,0 | - 3 932,0 | 940,1 | - 614,0 | 148,0 | 1 025,0 |
| Y2002 | 1 900,0 | - 4 994,0 | 868,6 | 1 031,0 | 8,0 | 884,0 |
| Y2003 | 1 900,0 | - 6 422,0 | 851,0 | - 373,0 | - 71,0 | - 26,0 |
| Y2004 | - 100,0 | - 6 449,0 | 708,2 | 863,0 | - 14,0 | - 214,0 |
| Y2005 | - 1 000,0 | - 7 618,0 | 1 344,7 | 2 241,0 | - 55,0 | - 620,0 |
| Y2006 | 1 553,0 | - 2 983,0 | 1 652,2 | 5 294,0 | - 23,0 | 829,0 |
| Y2007 | - 267,0 | - 1 971,0 | 2 299,8 | 7 419,0 | 4,0 | 930,0 |
| Y2008 | - 2 413,0 | - 2 484,0 | 2 337,2 | 8 967,0 | - 78,0 | 397,0 |

Source: Annual reports

The proportions between the R&D effort, the outcome of this effort in terms of the number of patent application and net investment seem to be very firm specific. This specificity is further to notice as it comes to analyze the growth of revenues since 2001 till 2008. The assumption behind this study is that patentable innovation coming in significant quantity is likely, under the condition of a sound strategy, to bring a growth of revenues. Table 9 shows net annual revenues of the six firms in focus, since 2001 till 2008. In terms of size, Chevron is the biggest of the six, with GM, Ford, Honda, IBM and Akzo Nobel following respectively. During the period of analysis the champion of growth was Chevron, with 153,8% higher revenue in 2008 than in 2001( As far as Chevron is concerned one has to be aware of the merger with Texaco in 2004, which had obviously boosted its overall scale of activity, not only in terms of sales but also in terms of assets. However, being consistent with the theoretical background, especially with Schumpeter's, Tobin's and Phelps's theories, it is assumed that growth through mergers and acquisitions is the same kind of supposed – to – be outcome of innovation as organic growth could have been.), followed closely by Honda ( + 125%), IBM and AkzoNobel lagging significantly behind with + 24,8% and +9,2% respectively. For General Motors and Ford the period of study brought a downshifting of scale of activity, by – 11,9% and -8,9% respectively.

*Table 9 – net revenues of Ford, GM, Honda, Chevron, Akzo Nobel and IBM. Time span: 2001 – 2008.*

| | **Ford [ USD mln]** | **GM [ USD mln]** | **Honda [USD mln]** | **Chevron [USD mln]** | **Akzo Nobel [EUR mln]** | **IBM [USD mln]** |
|---|---|---|---|---|---|---|
| Y2001 | 160 652,0 | 169 051,0 | 52 682,1 | 104 409,0 | 14 110,0 | 83 067,0 |
| Y2002 | 162 256,0 | 177 867,0 | 58 949,0 | 98 961,0 | 14 002,0 | 81 186,0 |
| Y2003 | 164 331,0 | 185 837,0 | 70 581,7 | 119 575,0 | 13 051,0 | 89 131,0 |
| Y2004 | 172 255,0 | 195 351,0 | 77 809,4 | 150 865,0 | 12 833,0 | 96 293,0 |
| Y2005 | 176 835,0 | 194 655,0 | 78 473,2 | 193 641,0 | 13 000,0 | 91 134,0 |
| Y2006 | 160 065,0 | 204 467,0 | 83 682,4 | 204 892,0 | 13 737,0 | 91 424,0 |
| Y2007 | 172 455,0 | 179 984,0 | 96 104,9 | 214 091,0 | 15 255,0 | 98 786,0 |
| Y2008 | 146 277,0 | 148 979,0 | 118 546,5 | 264 958,0 | 15 415,0 | 103 630,0 |

Source: Annual reports

Profitability, short – term and long - term capital accumulation come as the next possible results of innovation, according to the Equation 2 of the model. As for profitability, its net ratio is shown in Table 10, which introduces IBM as the most profitable, with an average net profit ratio of 9,1% over the years 2001 – 2008. Then come Chevron, Akzo Nobel, Honda, Ford and GM, with respective averages of 6,6%, 6,1%, 5,2%, - 2,6% and – 5,8%.

*Table 10 – net profit ratio of Ford, GM, Honda, Chevron, Akzo Nobel and IBM. Time span: 2001 – 2008.*

| | Ford | GM | Honda | Chevron | Akzo Nobel | IBM |
|---|---|---|---|---|---|---|
| Y2001 | -3,4% | 0,2% | 3,6% | 3,1% | 4,8% | 9,3% |
| Y2002 | -0,6% | 1,0% | 4,9% | 1,1% | 5,8% | 4,4% |
| Y2003 | 0,3% | 2,1% | 5,4% | 6,0% | 4,6% | 8,5% |
| Y2004 | 1,8% | 1,4% | 5,7% | 8,8% | 7,4% | 8,8% |
| Y2005 | 0,8% | -5,4% | 5,6% | 7,3% | 7,4% | 8,7% |
| Y2006 | -7,9% | -1,2% | 6,0% | 8,4% | 8,4% | 10,4% |
| Y2007 | -1,6% | -24,1% | 5,4% | 8,7% | 5,6% | 10,5% |
| Y2008 | -10,0% | -20,7% | 5,0% | 9,0% | 4,8% | 11,9% |

Source: Annual reports

The Table 11 shows annual absolute change of the book value of assets, which means the arithmetical difference between the book value of assets at the end of the year n1 minus the book value of assets at the end of the year n0, for the six companies studied, It is an approximation of short – term capital accumulation processes. Chevron and Honda accumulate, on the short – run, much more than the other four. Ford, GM and IBM display negative average annual accumulation. If the theoretical, Schumpeterian assumption that scientific input generates accumulation of capital, it is worth to study the average change of the book value of assets per patent application, for each firm. From this point of view Chevron is the absolute leader with a long – term average of 163,88 million of USD per patent application. Then a long gap is to notice, after which Ford, Honda and IBM follow, with 14,67 million, 12,47 million and 12,46 million respectively, General Motors displaying a negative ratio of – 2,44. As for long – term ability to accumulate capital, Tobin's q ratio had been computed, at the year's end, for each firm and each of the years studied ( Table 12 ). On average IBM ( average q = 2,2 ) and Honda ( average q = 2,06) are the leaders,  with the other four keeping an average above q = 1,00.

*Table 11 – Annual absolute change of the book value of assets of Ford, GM, Honda, Chevron, Akzo Nobel and IBM. Time span: 2001 – 2008.*

| | Ford [ USD mln] | GM [ USD mln] | Honda [USD mln] | Chevron [USD mln] | Akzo Nobel [EUR mln] | IBM [USD mln] |
|---|---|---|---|---|---|---|
| Y2002 | 10 119,00 | 101,00 | 942,06 | - 213,00 | - 136,00 | 13 735,56 |
| Y2003 | 21 392,00 | 1 648,00 | 9 382,01 | 4 111,00 | - 835,00 | 6 944,23 |
| Y2004 | - 3 670,00 | 689,00 | 12 439,10 | 11 738,00 | - 3,00 | 4 650,98 |
| Y2005 | -23 750,00 | 1 595,00 | 11 381,29 | 32 625,00 | 474,00 | - 2 516,34 |
| Y2006 | 14 922,00 | -4 912,00 | 5 129,57 | 6 795,00 | 360,00 | - 4 504,25 |
| Y2007 | - 5 131,00 | -1 372,00 | 5 269,23 | 16 158,00 | 6 458,00 | 9 711,25 |
| Y2008 | -62 750,00 | 501,00 | 14 541,84 | 12 379,00 | - 509,00 | -28 971,72 |

Source: Annual reports

*Table 12 –tobin's q at the year's end for Ford, GM, Honda, Chevron, Akzo Nobel and IBM. Time span: 2001 – 2008.*

| | Ford | GM | Honda | Chevron | Akzo Nobel | IBM |
|---|---|---|---|---|---|---|
| Y2001 | 1,13 | 0,97 | 2,19 | 1,80 | 1,91 | 3,05 |
| Y2002 | 1,06 | 1,04 | 1,80 | 1,50 | 1,51 | 2,15 |
| Y2003 | 1,03 | 1,00 | 1,85 | 1,69 | 1,52 | 2,24 |
| Y2004 | 1,03 | 0,99 | 1,84 | 1,69 | 1,53 | 2,21 |
| Y2005 | 1,03 | 1,00 | 1,87 | 1,50 | 1,65 | 1,91 |
| Y2006 | 1,04 | 1,13 | 2,17 | 1,67 | 1,72 | 2,14 |
| Y2007 | 1,04 | 1,38 | 2,88 | 1,78 | 1,17 | 2,01 |
| Y2008 | 1,13 | 1,98 | 1,85 | 1,38 | 0,94 | 1,91 |

Source: Annual reports

There are different paths of translation from scientific input to real technological change. One of the two champions of investment – Honda – represents the pattern of high R&D effort combined with a high number of patentable inventions and important embodiment of this scientific input in new technologies. The second of the two – Chevron – translates a relatively small R&D effort into a moderate scientific result in terms of patent applications and all that is transformed into big net investment in specific assets as well as into important accumulation of capital. Honda and Chevron present four common traits. Firstly, they both tend to come at the stage of patentable invention at a fairly low cost in terms of non – capitalized R&D outlays. Secondly, they both seem to be able to boost their scale of activity on the grounds of their innovative effort. Thirdly, they both operate at a satisfactory, though not astounding, level of net profitability, around 5 – 6%. Finally, both display a relatively high value of average Tobin's q, thus a good ability to accumulate capital on the long run. The difference between them is the size, both absolute and relative to revenues, of their R&D effort, as well as the absolute size of their scientific input to production, in terms of patent applications.

General Motors and IBM are to find the other extremity of the scale as far as the average cost of one patent application, in terms of non – capitalized R&D outlays, is considered. That average cost for both of them is around 100 millions of USD, 129,38 for GM and 95,88 for IBM. Also, maybe incidentally, they both present a similar level of average scientific input in terms of patent applications: 60,875 annually on average for General Motors and 68,75 for IBM. From the point of view of market environment, both firms seem to conduct their innovative effort under a strong external pressure upon technological race. On the other hand, they tend to diverge under every other aspect considered. Outstanding net profitability of IBM as well as its quite good dynamics of revenues clearly contrast with the net losses and decreasing scale of activity of General Motors. Both short and long term accumulation of capital seems to be an advantage of IBM and a real problem for GM.

The average cost of one patent application, in terms of non – capitalized R&D outlays, still considered, the two cases in the middle of the scale, Ford and Akzo Nobel, are to analyze, with that cost approaching 63 millions of USD and 46 millions of USD, respectively. They both present considerable uncertainty as for accumulation of assets and for net investment, with Ford managing this uncertainty with noticeably better results. Also, they both spend a similar percentage of their revenues, about 5%, on R&D. Besides, they are rather divergent in other respects. Akzo Nobel seems to be sustainably profitable, Ford does not. On the other hand, the scientific input in terms of patent applications per year is almost ten times higher at Ford than at Akzo Nobel. The long term ability to accumulate capital seems to be significantly better for Akzo Nobel.

The productivity of R&D activity, in terms of the average amount of R&D expenses needed to bring up one patentable invention, seems to be the key variable shaping the rationale of firms' strategies. Honda and Chevron are efficient transformers of innovative effort operating in different business environments. Honda is under a strong external pressure to innovate, whilst Chevron can afford more endogenously driven innovation. On the other hand, both firms tend to consider the early stages of innovative activity as highly autonomous from the production business and they both manage innovation so as to conduct those early stages of innovation in separate organizations, with eventual arrangement of practical applications. Conclusion: regardless the magnitude and the main driving force of innovative effort in a firm, there seems to be a strong and positive interdependence between the efficiency of R&D effort in conducting innovative projects up the stage of practical patenting, and, on the other hand, the efficiency of the firm in accumulating capital, investing in specific assets and boosting sales. Firms that display that kind of business pattern, are sustainable both in their current operational activity and in their long – run interactions with capital markets. The other four cases indicate that if the R&D activity of a firm seems inefficient in terms of R&D outlays per one patent application, it could mean two things. Firstly, the apparent inefficiency of innovative activity may mean real efficiency problems of the whole business, as in the case of General Motors. Secondly, the inefficiency of R&D could be just a mistaking appearance, for example due to the fact that technological race goes on so fast that there is not enough time for patenting every valuable outcome of R&D activity.

The core question of the case studies was: why do most of the worlds innovative effort and scientific input takes place in markets which are apparently hostile to innovation, as judged by marginal GDP per patent application ? The simplest possible answer is that firms do innovation either because they have to or because this is their comparative advantage and they can do it in an exceptionally efficient way. The two are linked, by the way. A comparative advantage in the field of R&D is likely to appear when an external pressure is felt. Exogenous pressure on innovation is strongly rooted in local product markets and their institutions, and thus long – lasting, just as the comparative advantage in R&D. Economies develop as firms develop. Economic growth is grounded in efficient business patterns. In some countries those business patterns shape themselves in an environment which hems them in with a lot of stimuli to develop innovative activity. This leads to the development of an economy which, regardless its pace of economic growth and balance of payments, comes to a point when marginal value added on innovation is negative. At this point, however, incentives to innovate do not disappear and firms continue to apply the same business patterns and thus do create scientific input which gives back negative marginal real output.

# 5 Conclusions

In the light of what precedes the big question is: is the present pattern of technological progress, both in its macroeconomic and microeconomic plan, likely to last and how long ? What could it be replaced with ? Both the model and the case studies seem to indicate that the pattern is pretty durable. The main condition to its stability seems to be the development of financial markets, as well as their stability to recover after crises. As long as financial placements assure decent payoffs, accumulation of capital is likely to keep on going, particularly in firms with highly efficient R&D activity even if at the aggregate level marginal value added on innovation is negative. This seem to confirm the Frank Knight's opinion, that the development of corporations had created a unique kind of link between the accumulation of capital and the practical, operational conduct of the business, with all the related risks and uncertainties (Knight 1921). On the long run, since the beginnings of the corporation, financial markets demonstrate a peculiar ability to survive crises and to get reborn even after decades of relative downshifting ( Harris 2005; Chaudhuri 1965; Hansmann, Kraakman, Squire 2006; Michie 2000). Thus, the keystone of the present global pattern of technological progress seems to remain durable on the long run, which does not exclude, of course, short term disturbances. Also, it is hard to imagine what could replace the present pattern. Would innovation systematically take place in markets in which there is not external pressure on innovation or in economies in which successful financial placements cannot give an opportunity to compensate the downturns of innovative projects ?

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