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The Role of Commercialization Competence in Endogenous Economic Growth

Gerard Ballot[1], Gunnar Eliasson[2]*, Erol Taymaz[3]

[1]ERMES, Paris 2-University, Paris, France; [2]Royal Insrtitute of Technology (KTH) and the Ratio Institute, Stockholm, Sweden; [3]METU, Ankara, Türkiye

Abstract While innovation supply is creative, unpredictable, and not necessarily related to future economic usefulness, resource provision is focused on economic returns, experience based and narrower, implying a positive economic risk of not understanding innovative commercial winners. We demonstrate through simulation experiments on an economy wide firm-based model that industrial growth is explained by industrially competent identification and financial support of winners that are carried on to industrial scale production and distribution. The simulations capture the dynamic economic systems effects on the entire economy, from micro responses to macro and the feedback on micro behaviour of expectational mistakes. *Competence bloc theory* is used to model the supply of innovations and their commercialization in what we call an *Experimentally Organized Economy*. We demonstrate that lack of commercialization competence, notably industrial competence embodied in venture capitalists´ ability to identify, select and finance radically new innovations breaks the conventionally assumed linearity between innovation supply and economic growth. We also demonstrate the existence of long-term and possibly very large losses in output from the loss of winners during the commercial filtering of the competence bloc, and that the economy wide costs incurred by protecting losers may be large.

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***For correspondence:**
g.eliasson@outlook.com

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1. The theoretical problem

The standard neoclassical version of innovation theory is an innovation production function (F(R&D, ...), the main explanatory variable of which is R&D investment. A stochastic spread in innovative output is assumed, and innovative output is fed into a standard production function as a shift factor, relating innovation to output or growth in a linear fashion. This linear relation between R&D investment and growth has strong a priori policy implications. Since R&D finance can be provided by government as a controlled policy measure the model predicts a direct positive influence on growth. This story has its origin in ***Arrow (1962)*** and has been reinforced in numerous so called neo-***Schumpeter (1942)*** based innovation systems models. We think this is a policy argument more based on prior assumption than on empirical evidence and will demonstrate why. If you add price taking and profit maximizing behaviour these ***Schumpeter (1942)*** engineering models can be made identical to a standard neoclassical or "new growth" theory model. As a rule, both approaches are aggregate, or based on the Marshallian notion of representative firms.

None of these linear growth models square well with reality. *First*, growth theory should not be formulated independently of dynamic resource allocation theory. Hence, to make empirical sense, it must be based on an explicit market resource allocation model populated by heterogeneous agents with individual price setting capacity. *Second*, the relationship between the decision to spend on R&D

Table 1. (A) The two types of economic mistakes. (B) Actors in the competence bloc.

The two types of economic mistakes
Type I: Losers kept too long
Type II: Winners lost
Actors in the competence bloc
1. Competent and active *customers*
Innovation Supply
2. Innovators who integrate technologies in new ways
Markets for innovation and commercializing intermediaries
3. Entrepreneurs who identify profitable innovations
4. Competent venture capitalists who recognize and finance the entrepreneurs
5. Exit markets that facilitate ownership change
6. Industrialists who take successful innovations to industrial scale production

Source: Eliasson and Eliasson, 1996. "The Biotechnological Competence Bloc". *Revue d'Economie Industrielle*, 78-4^0, Trimestre.

account, involving countless, often conflicting market selections, and economic growth at many levels of aggregation cannot reasonably be assumed to be linear.

Our approach is to move the theoretical base of our argument back onto an early ***Schumpeter (1911)*** and/or Austrian theoretical platform. We model innovation supply and the demand for innovations, or the commercialization process separately, and create a *market for innovations* in between, in which innovations are identified, selected, and financed (see ***Table 1B***). To capture the role of this innovation and discovery process in economic growth an economy wide model is used that (1) features learning and innovation supply on the one hand, and on the other (2) a realistic modelling of both the commercialization of innovations, or innovation demand, and (3) the market selections that occur when supplies and demands are confronted in the markets for innovation. During that market process (4) business mistakes are constantly made. We regard these business mistakes as a normal *transactions cost* for economic development (***Eliasson and Eliasson, 2005***). To do that, and to be able to assess the dynamic efficiency of the consequent allocation process 1 through 4 in ***Table 1B*** we introduce *competence bloc theory* (***Eliasson and Eliasson, 1996***). The main point argued is that innovation is creative and unpredictable, while the selection of innovative output is based on experience. In the markets for innovation therefore a wide diversity of innovative supplies is confronted with a more narrow competence to discover and successfully select winning projects ("winners") for commercialization. The logical consequence of that fact will be an unavoidable flow of economic mistakes. Some losers will always be kept on the budget for too long (Mistake Type I), and some winners (Mistakes Type II) will constantly be lost (***Eliasson and Eliasson, 1996***; ***Eliasson, 2005a***). This selection is dynamically efficient when the total costs of the two types of mistakes are minimized. Since the minimization is driven by market competition the role of markets in economy wide behaviour becomes central for our story, and competence bloc theory explains how. This selection, or commercialization process breaks the linearity of the neoclassical and standard Schumpeterian models. It should also be obvious that the flow of business mistakes should not be modelled as a stochastic process, which is common practice in neoclassical growth models, all of which lacking explicit markets. Let us call our distinctively different growth model evolutionary or Austrian/ early ***Schumpeter (1911)***.

To begin with we assume conventionally that innovation supply (INS) is a stochastic function of R&D input, and unconventionally that it is purely technological in the sense of generating new combinations of new and old technologies, such as an improved automobile engine or a radically redefined automobile, for instance with an electric motor.

$$\mathrm{INS} = \mathrm{F}(\mathrm{R\&D}, \ldots)$$

Table 1 introduces *competence bloc theory*. Competence bloc theory is part of the theory of the *Experimentally Organized Economy* (EOE) and lists the pricipal actors engaged in the selection and commercialization of new technologies such that the economic incidence of the two types of business mistakes is minimized i.e., of keeping losers on the budget for too long, and of losing the winners (***Eliasson, 1996***; ***Eliasson, 2005a***) . Competence bloc theory is therefore instrumental in defining the dynamic efficiency of commercialization and scale up of innovations, or the *receiver competence* of the local market. Competence blocs take form, often spontaneously, either within hiearchies or in markets, or as hybrids. Market selection and commercialization commonly mean the comittment of economic mistakes, mostly in the form of below expected outcomes, but also as outright failure and exit from the market. At the economy wide level those economic mistakes will be interpreted (in the EOE) as a *normal transactions cost* of economc development (***Eliasson and Eliasson, 2005***; ***Eliasson, 2005a***). Since systematic economic mistakes are not recognized in neoclassical equilibrium modeling, except sometimes as random departures from static equilibrium, we here have one well defined departure from neoclassical orthodoxy. ***von Hayek (1935)*** and ***Dahmèn (1942)*** both discussed them in the form of systematic investment mistakes ("Fehlinvestitionen"). ***Schumpeter (1911)*** and ***Schumpeter (1942)***, however, did not recognize the feedback influence of economic mistakes on the behavior of market agents that we refer to as a Stockholm School example of ex ante-ex post analysis, and central to both the theory of the experimentally organized economy (EOE), and the micro firm based model approximation of the EOE, called MOSES, that we use in this study. As already mentioned, *business mistakes for us become a normal market phenomenon* that originates in *the pervasive ignorance of "boundedly rational" agents about circumstances that may now and then threaten their very existence.*[1] Such systemic economic mistakes, representing fundamental economics in the theory of the EOE, and the micro macro model MOSES, both affect agents' attitudes to uncertainty and are a source of learning from experience. The latter, we repeat, distinguishes MOSES economics from neoclassical equilibrium economics, which is only compatible with random and costless departures from equilibrium, insurable risks that contain no information to learn from. This implies that the dynamic efficiency of the selection and commercialization process cannot be defined in the neoclassical equilibrium model, since you cannot demonstrate the "market based minimization" of the economy wide costs of type I and type II economic mistakes under ***Table 1A***. The feed back from business mistakes to the formation of new business decisions and plans, and later realized behaviour are explicit in the micro-to-macro model we use both to define the *receiver competence* of the local economy (***Eliasson, 1990***) to identify,capture and take new technologies on to industrial scale production, and to quantify the role of commercialization competence in economic growth in terms of competence bloc theory in ***Table 1B***. This unique model feature represents an early Austrian influence on economic theory that was introduced by Wicksell and developed further into so called Stockholm School economics (***Eliasson, 1992***).

1.1. Commercialization competence determines dynamic selection efficiency

Table 2. The four mechanisms of Schumpeterian creative destruction and economic growth.

1.	Entrepreneurial entry enforces (through competition)
2.	Reorganization and/or
3.	Rationalization or
4.	Exit (shut down) of incumbent firms

Source: Eliasson (1995), "The Economics of Technical Change: The macroeconomic Consequences of Business Competence in an Experimentally Organized Economy", *Revue D'economie Industrielle: Developpements Recent,* Numero Exceptionell, 1995:53-82.

The role of commercializing agents in the competence bloc (***Table 1B***) is to match market (customer) demands for innovative new products with the technological properties of innovation supplies, to select winners and to take them on to industrial scale production and distribution. Growth then occurs through the dynamics of Schumpeterian creative destruction of ***Table 2*** in which winners enter and grow and exert competitive pressure on incumbents that must reorganize innovatively for new markets, and/or rationalize or die, exit.[2] Obviously, the efficiency of that market selection is critical for the economy wide growth outcome. If the requisite competence is lacking at the commercialization stage, winners will be "increasingly lost", however rich and competent

1. This is something fundamentally different from the "asymmetric information" proposition of neoclassical economics introduced to deal with "imperfect markets". See further ***Eliasson (1990)*** and ***Eliasson and Eliasson (2005)***.

2. A practitioner would argue that the distinction between reorganization and rationalization is not relevant. The two always occur together. True. But since neoclassical theory only recognizes rationalization, we keep the term as a limiting case.

innovation supplies.[3] And vice versa, competent commercializing agents may identify winners in a meagre innovation supply. Indeed, it was concluded as a paradox that Sweden, despite its rich supply of innovative technologies, did not show a consequent record in new industry formation. A deficient commercialization competence however explained that (***ISA, 2003***; ***Eliasson, 2005a***). We can also learn from the technological spillover literature that Japanese firms had been better than their "closer" American competitors to capture spillovers from R&D intensive US firms (***Bernstein and Mohnen, 1994***).

Terminology in this field however is not entirely clear. With our technological definition of innovations in competence bloc theory (see ***Table 1B***), we cannot call the identification and selection of economic winners in the supply flow of new technological combinations an act of innovation. It is an act of commercialization, for instance entrepreneurship (under Item 3 in ***Table 1B***). Commercialization competence depends on how this selection is organized. Competence bloc theory covers, as one extreme case, the complete internalization of an entire commercialization sequence within one firm hierarchy. The other extreme is an entirely decentralized market selection with all agents in ***Table 1B*** operating independently in markets. Apparently the competence bloc therefore embodies a Coasian type theory of the firm, the limits of which are determined where administrative coordination beats the market in coming up with new products and technologies (***Coase, 1937***). A fully decentralized competence bloc coordinates the tacit competences of individual agents through asset markets. *The efficient transfer of innovation assets across the competence bloc, therefore, requires the existence of well-defined property rights, and in the case of a completely decentralized market based competence bloc, very sophisticated asset markets are required* (**Eliasson and Wihlborg, 2003**).

The centralized (internalized) competence bloc may be cost efficient in terms of *measured direct transactions costs but* suffers from a higher rate of loss of winners (business mistakes Type II) than the decentralized approach because of a narrower commercialization base. A fair efficiency comparison of the two approaches, hence, requires that the economic costs of loss of winners (in terms of foregone profits) be included in the definition of transactions costs (***Eliasson and Eliasson, 2005***). And the empirical argument is that under those different criteria the decentralized selection process over the actors of the competence bloc will be more dynamically efficient since it requires less in the form of total information and communications (transactions) costs to generate the same "amount of growth". Hence, the economic consequences of the two business mistakes should both count as a transactions cost (***Eliasson and Eliasson, 2005***).

The competence of the agents of commercialization is assumed to be based on past learning and experience accumulation. The "assumption" is that better choices are made, and a more efficient selection achieved if venture capital providers understand the economic and industrial significance of the innovative technologies proposed by the entrepreneurs (***Eliasson and Eliasson, 1996***). Indirect evidence to that effect is provided by ***Gentry and Hubbard (2000)*** who show that entrepreneurial households do hold undiversified asset portfolios concentrated to investments in which they are actively involved.[4] Being industrially competent they believe in their choices and feel no need to diversify their risks (***Eliasson, 1977***; ***Eliasson, 2003b***; ***Eliasson, 2005b***).

Venture capitalists have learned successfully through experience and become privately rich, and then accumulated further wealth and experience from continued investing. *Since experience-based commercialization competence is narrower than innovation supply a loss of winners will always occur*. Key to dynamic market efficiency is the ability to minimize that loss. The nature of venture capitalist's industrial competence then becomes determined by the type of industrial technologies they have acquired their experience from (computing and communications, biotech, engineering etc), and the performance of the firm (profitability, productivity etc). On this ***Mas and Vignes (2006)*** demonstrate econometrically that the latter type of experience from venture capitalists´ investment practice improves their performance, and notably the existence of a superiority of US venture capitalists over European venture capitalists in terms of a higher ex post success rate.

3. ***Acemoglu (2001)*** even argues that the inability of European financial markets (compared to US financial markets) to channel funds to the right entrepreneurs who carry growth and new employment, adds to the already negative effects on employment of rigid European labour markets.
4. ***Gentry and Hubbard (2000)*** define their entrepreneurial households as a hybrid between an entrepreneur and a venture capitalist.

With this we have defined a market selection game the efficiency of which will be influenced by (1) how commercialization competence has been accumulated, and on how (2) the commercial market selection has been organized. If commercialization competence is lacking in a particular area or economy, it may be raised by imports of the same competence, say venture capital competence.[5]

2. The micro-to-macro model and economic systems dynamics

To capture the role of markets in commercializing innovations and the implications for allocation of new technologies and economic growth within one and the same theoretical structure, a new and more general representation of the economy than the mainstream general equilibrium or new growth models is called for. For this we use the micro (firm) based market self-coordinated macro model MOSES in which market self-coordination is achieved under an upper technology constraint by competing heterogeneous agents with price setting autonomy. Competition is driven endogenous entrepreneurial entry that pushes economic growth, forces exits of low performers and leaves in its wake an endogenous population of firms. This model is capable of explicitly explaining the long term economy wide outcomes of different market intermediated resource allocations associated with more or less well organized financing by industrially competent venture capital provision.

First, our theory must be based on an *explicit market process*, featuring endogenous resource allocation across the firm population and over time. *Diversity of firm structures (heterogeneity*) can then be demonstrated to matter for macroeconomic growth (***Eliasson, 1984***). *Second*, only an economy wide systems representation of the economy, including *complete demand and expectational outcome feedback*, and error correction, that endogenizes price and quantity decisions of firms will define a satisfactory platform for such dynamic analysis. *Third*, for macroeconomic growth to be endogenized innovative behaviour also must be endogenized.

The Swedish micro-to-macro (M-M) model MOSES has these needed properties. It approximates what we call an *Experimentally Organized Economy* (EOE) in which growth is endogenized through the stylized Schumpeterian creative destruction process of ***Table 2***. The M-M model has been documented in detail in several publications.[6] The most salient features of the model to be emphasized in the context of the simulations in this paper are:

- A Schumpeterian creative destruction model of growth or of the *Experimentally Organized Economy* (EOE). See ***Table 2***, and ***Eliasson, (1996)***.
- The creation and selection of new technology (*Competence bloc* theory; ***Eliasson and Eliasson, 1996***; ***Eliasson and Eliasson, 2005***; ***Eliasson, 2005a*** and ***Table 1***).
- The selection and commercialization of new technology through leaern from successful introductions (*genetic algorithms*, ***Ballot and Taymaz, 1996***; ***Ballot and Taymaz, 1998***).

2.1. The dynamic core of the M-M model

The micro-to-macro model has a modular design with well defined interfaces within the firm/division and between the firm/division and all other firms, or the markets.[7] This modular design has made it easy to improve upon and update the behavioural specification of the model.[8]

5. Since technology supply in Sweden appears to be abundant, while commercialization competence is deficient, it was suggested in ***ISA (2003)*** that Sweden should actively pursue a policy to encourage competent venture capitalists to localize their activities to Sweden.
6. For a fast introduction we refer to ***Albrecht et al (1992)***; ***Ballot and Taymaz (1998)***; ***Ballot and Taymaz (1999)***; ***Bergholm (1989)***; ***Eliasson, (1976b)***; ***Eliasson, (1991a)***. The most recent update of the model can be found in ***Eliasson et al. (2004)*** and ***Eliasson et al. (2005)***.
7. The original core modular system of behavioural relationships within the firm and between firms is diagrammatically illustrated in ***Eliasson (1977)***.
8. There is only one area where the original modular systems design has created a problem and that is the interface between firms and individuals/ workers. Firms/divisions are being kept track of over their entire life cycles. Individuals are employed out of, and laid off into an anonymous pool of people, the labour force. To study the effects of education and competence development individuals must be modelled separately and then linked to the individual firm through a simple aggregation device. See for instance ***Ballot and Taymaz (1996)*** and ***Ballot and Taymaz (1998)***. We are planning to attend to that problem by explicitly following the life and learning histories of a select group of highly productive individual employees.

The model runs by quarter, which was earlier considered a typical production planning period in large firms (***Eliasson, 1976a***). Products are homogeneous within each market (see below). Hence, currently we only model process innovations. This means that product quality diversification is assumed to be perfectly arbitraged in the markets each period, and that product quality change has been fully converted into output volume (***Eliasson, 1976b***; ***Eliasson, 1978***; ***Eliasson, 1980***).[9] The dynamic core and source of endogenous growth is represented by the creative destruction process of ***Table 2***. Market driven growth is kept active by endogenous competitive entry, and preventive innovation among incumbent actors fearing being overtaken by competition (***Eliasson, 1991b***; ***Eliasson, 1992***; ***Eliasson, 1995***; ***Eliasson, 1996***).

The firm or the division is defined as a *profit-oriented production organization with financially defined outer limits*. This financially "controlled" hierarchy is represented in the model by its internal statistical accounts. Firms upgrade their performance through investments that bring with them new technology. Investments are determined by expected returns, but may be limited by availability of finance, or be forced by competition. Firm behaviour - given its production capacity- is governed by an internal short- and long-term budgeting and production planning process governed in turn by the *Maintain or Improve Profits* (MIP) criterion (***Eliasson, 1976a***; ***Eliasson, 1977 Eliasson, 1985***; ***Eliasson, 1991a***).[10] Each incumbent firm, each period makes up an investment, production, and employment plan designed to be compatible with a satisfactory ex ante rate of return (the MIP criterion) and attempts to realize that plan in competition with other firms, based on its own expectations of market prices.

The MIP criterion approximates an ex ante long term wealth maximizing target by firms that is never realized. *Firms climb ex ante profit hills that are constantly changed by the ongoing "climbing traffic"*. Structures are remodelled and market prices change from period to period, forcing firms to constantly revise their ex ante perceptions of the profit hills. They halt search temporarily (for that quarter) when a satisfactory profit level has been reached. Firms interact through competition in product, labour, and financial markets and integrate their market considerations within their quarterly business plans. Product quantities of individual firms and market prices are endogenously determined through a sequence of demand and supply interactions within each quarter. Expectational mistakes are sequentially fed back and incorporated in next period plans (for more detail on this Stockholm School feature (see ***Eliasson, 1976b***; ***Eliasson, 1977***).

Firms constantly make business mistakes that affect their decisions, but from which they also learn. Hence, business mistakes in the form of deviations from expected outcomes should be regarded as a transaction or learning cost.[11] The nature of this "business expectations error correction" process is an important part of the dynamics of economic growth in the MOSES model. It is a unique Austrian – Wicksellian – Stockholm School feature of the MOSES model (***Eliasson, 1991a***; ***Eliasson, 1992***). The ex ante, ex post correction behaviour updates the position of incumbent firms on Salter economic performance rankings. If a firm fails to meet its profit target for many periods and/or depletes its equity it is forced to exit (see item 4 in ***Table 2***).

Mathematically, total model dynamics can be seen as the first iteration in a gigantic market intermediated numerical ex ante optimization process in which all actors are striving towards their individually perceived long term ex ante profit or wealth maxima. Competition (the strategic game, see below) is pushing them. But since the perceived optimum depends both on exogenous and endogenous (to the model) circumstances, including resources used up in the search itself, all perceived optima must be recomputed for the next step in the iteration, and the nature of the market dynamics is that this recompilation may involve drastic revision and/or dramatic business failure on the part of individual

9. ***Aghion and Howitt (1998)*** make the same assumption for all product markets, except the market for intermediate goods, their market for "innovations". Since this market is imperfect, they assume instead that wages in that sector equal the monopoly profits for innovations. Total output is then fully exhausted by factor costs. Under the assumption of zero transactions costs they can then demonstrate the existence of an exogenous equilibrium. We do not need such awkward assumptions. Wages in MOSES are endogenous everywhere and total output does not have to be exhausted ex post by factor prices.

10. For a detailed presentation, see ***Eliasson (1976b)*** and ***Eliasson (1985)***.

11. Firms correct their price and sales expectations as they learn from ex post realizations. They also revise their profit targets according to a similar algorithm to conform to their MIP criteria (***Eliasson, 1977; Eliasson, 1978***). The latter is a common, but not altogether rational mode of behaviour based on firms´ actual internal budgeting practices and accounting systems (see ***Eliasson (1976a)*** and discussion of implications in ***Eliasson (1985)***.

actors. Progress is *sequential* in the sense that next period (quarter) change starts from the allocation platform reached the previous quarter. Since the salient feature of market intermediation is selection, and individual firms have to constantly reposition themselves to new endogenous circumstances, the entire model is highly nonlinear and progress characterized by *cumulative tendencies* now and then interrupted by unpredictable market disorder (for more on "deterministic chaos", see ***Eliasson, 1983***; ***Eliasson, 1984***; ***Eliasson, 1991a***). The complexity and multidimensionality of this market game, as staged within the model, therefore is such that there is no way to scan all possible outcomes over the long term (say 50 to 100 years) horizon to make ex post optimization even a theoretical alternative within the M-M modelling framework.[12] During the process product and factor prices and the interest rate are endogenously determined.

2.2. Strategic competitive positioning of firms exerts a constant pressure on all to improve performance

Macroeconomic growth is moved by the constantly ongoing "strategic" competitive game between new and incumbent firms.[13] Each firm faces superior firms that can outbid it in the factor markets and outcompete it in the product market. But there are also inferior firms subjected to the same competitive pressure that strive to improve their positions, often by attempting to leapfrog their superior competitors through innovation. In the wings of this market theatre new potential entrants hide, ready to enter. On average, as they are specified in MOSES, they are inferior to the average incumbent, but the spread is much larger. Now and then, and in fact quite often, very superior entrepreneurial entrants therefore enter the market. Hence, there is no rest (read "equilibrium") for any firm if entry is free. This ongoing game *forces* each firm to constantly strive to improve its performance through innovation, or risk failure and exit. This constant challenge is sufficient to keep the endogenous macroeconomic growth process alive through Schumpeterian creative destruction (see further ***Table 2*** and ***Eliasson, 1992***; ***Eliasson, 1995***; ***Eliasson, 1996***). Hence, in the end *the macroeconomic growth achieved over the longer term will depend on the capacity of markets to have selected winners ex post, and phased out losers*. The important factor maintaining this competitive dynamic of the model is free endogenous entrepreneurial entry that forces incumbents to innovate preventively to stay in business.[14]

2.3. Endogenous growth in the MOSES economy

Endogenous growth in the MOSES economy thus occurs through five complementary and mutually reinforcing mechanisms. *First*, individual firms upgrade their productivity through endogenously determined new investments that bring in new technology. *Second*, capital and workers are being endogenously reallocated over dynamic markets guided by firms´ ambition to improve profits. This establishes an explicit link between the market allocation of resources at the micro level, on the one hand, and measured macroeconomic growth on the other. We originally thought of this as an endogenization of a Schumpeterian growth cycle (***Eliasson, 1985***). *Third*, firms upgrade their productivities through learning and endogenous competence accumulation by accessing an exogenous international pool of technology brought into the firm through their investments. Since ***Ballot and Taymaz (1998)*** and ***Ballot and Taymaz (1999)*** individual firms can break through that upper constraint on growth in the MOSES model economy through innovation by combining their own knowledge and experience with what they learn from exploring the global pool of technology.

Fourth (a novelty, introduced in this paper and a consequence of competition), acquired industrial competence through learning from experience among commercializing and financial intermediaries (the *competence bloc) improves the allocation of physical resources through endogenized*

12. Since each firm's price expectations depend on all other firms' price expectations and quantity reactions to those expectations, to push the economy closer to such an ex ante optimum (as in Eliasson 19991a), an infinite regress will eventually be encountered.This is another way of formulating the assumption of the Experimentally Organized Economy of an immense and for all practical purposes infinite state space.See ***Eliasson (1992)***; ***Eliasson (1996); Eliasson, (2001)*** .

13. This presentation is carried out as if the MOSES model economy is a closed system. It is of course not. The MOSES model economy features individual firm exports and imports determined at the market level and the economy is placed amid a global economy in assumed static equilibrium and exogenous (to MOSES) product prices and interest rates. In world markets MOSES firms are thus price takers ***Eliasson (1985)***.

14. See further ***Eliasson et al. (2005)***.

learning, thereby also improving the allocation of the competence capital itself. Since this means that the competence capital in pursuit of profit is allocating itself the M-M model will (normally) be unable to converge to a unique exogenous equilibrium.[15] The reason is again that endogenous market governed resource allocations change production structures, that prices are not independent of one another and that, hence, the nonlinear structure of the MOSES model does not have an exogenous mathematically determinable and unique "fix point" equilibrium.

Finally, and *fifth*, even in the long term endogenous demand feed back will influence the extent to which the economy is utilizing its resources each quarter, and never "fully" utilizes its resources. Keynesian "deficiency of demand" may hold back feasible short run growth. Less value than technically feasible *may* be generated to be invested or consumed.[16] But there is a limit to how far slack reduction can be taken, for instance by countercyclical policy, in that resource redundancies are needed for macroeconomic stability.

2.4. Scope of opportunities space

At each point (quarter) in time production and utility sets are characterized by the standard convexities of neoclassical theory. The four first "growth mechanisms" mentioned above constantly push those production sets outward.[17]

The model economy and all its actors are, however, operating far below the outer limits of the opportunities space, and micro decisions involve a constant exploration of, learning about and discovery within this opportunities space, which therefore keeps expanding and staying well ahead of the learning process. (We have called this the Särimner Effect, from the pig in the Viking sagas ***Eliasson, 1987***).[18] As a consequence all actors stay fundamentally ignorant for ever about circumstances that may determine their long run survival, and constantly commit more or less serious expectational mistakes.[19] Attempts to speed up exploration, learning and discovery fast encounter steeply increasing (transactions) costs in the form of unreliable market price signals and escalating business mistakes (***Eliasson et al., 2005***). Hence, ***Marshall (1890)*** concern about making static equilibrium compatible with increasing returns is "naturally" resolved within the MOSES micro to macro

15. This may be achieved by the prior introduction of a hierarchy in the competence capital structure. But why would we want such unnecessary prior assumptions.

16. This is not entirely correct. The M-M model will never be capable of fully utilizing its resources over the longer term. A certain amount of slack or X-inefficiency is necessary to keep the economic system stable. This is another way of saying that pushing the economy too close to an approximate exogenous equilibrium will destabilize the price signalling system of the economy and reduce the information content of prices, thus lowering the capacitiy of markets to self-coordinate the economy and its resource allocation efficiency,, and occasionally even force economic systems collapse (***Eliasson, 1983***; ***Eliasson, 1984; Eliasson, 1991a; Eliasson et al., 2005***).

17. This is not exactly correct for the consumption demand side, which is specified in the form of a macro non linear Stone type expenditure system (***Eliasson, 1976b***; ***Eliasson, 1978***). For the sake of the argument, however, we can correctly assume that this expenditure system can be derived under neoclassical micro assumptions.

18. Särimner was a pig, that the Vikings in Valhalla ate for supper. In the morning the pig came back again, alive, to be ready for supper, and so on. The difference between Särimner and the theory of the EOE is that the economy grows from being explored. It is a positive sum game. This assumption is principally important. We do not want the state space of neither the theory nor the economy to be infinite, because it is not, and because such assumptions are mathematically awkward. We want the opportunities space to be limited in size, but very large and non transparent, and we want it to stay that way for ever. See further the discussion in ***Eliasson (2005a)***.

19. The assumption of a large, complex, and intractable opportunities space, fundamental ignorance among actors and economic potentials far ahead of current operating performance are typical Austrian/ ***Schumpeter (1911)*** in spirit, and fundamental for both the theory of the EOE and its model approximation, the MOSES model. This assumption and the consequent absence of a unique equilibrium, set the theory of the EOE and the MOSES model apart from the mainstream neoclassical model. In a recent presentation of the paper at a seminar at MERIT in Maastricht (May 2006) it was argued that you do not have to assume a large opportunities space the size and complexity of which is constantly maintained through simultaneous exploration, learning and discovery (innovation). Forgetting is sufficient to prevent the economy from converging onto a unique equilibrium point. True. Depending upon what you forget convergence can go anywhere. But this only does away with exogenous equilibrium. To have a positive sum game and endogenous growth you need explorative learning and the Särimner effect, i.e., a *constantly maintained*, very large, complex, and non-transparent opportunities space that grows from being explored.

model. Marshall made a point of organization being a factor of production and came up with the idea of an "industrial district" that generated long term systemic economies of scale within a cluster of producers, while limiting, at each moment in time, attempts to capture that potential in the short run. Each actor would then encounter strictly decreasing returns to its search. Over the longer term however firms would learn from their interaction and come up with new solutions that would raise the collective body of technology. Based on such assumptions **Marshall (1890)** and **Marshall (1919)** could argue that an interior solution existed at each point in time.[20] For the same reason the MOSES economy is always operating along an interior trajectory within the opportunities space and the model itself spontaneously forms Marshallian industrial districts (see **Carlsson et al., 1997**).[21]

2.5. The statistical base of the model

The MOSES project had the opportunity in 1975 to specify the questions of the so called *Planning Survey* of the Swedish Federation of Industries such that they fitted the needs of the M-M model, notably the need (1) of a high quality initial state description (capacity utilization, profit rates, wages, etc) of firms, and (2) to integrate financial targets with the physical production system of the firm according to observed internal budgeting practices (**Albrecht, 1992**; **Eliasson, 1976a**; **Taymaz, 1992a**; **Taymaz, 1992b**; **Virin, 1976**). The Planning Survey has been repeated annually and has served as a unique annual data input in the development of the M-M model.

When seen "from above" the dynamic micro core of the MOSES model is concealed, and the Swedish micro-to-macro model appears as a Leontief – Keynesian 11 sector model. All incomes generated in firms are filtered through the tax and income transfer system and fed back through a non-linear Stone type consumption expenditure system as demand in domestic markets (**Eliasson, 1976b**; **Eliasson, 1980**). A combination of profit dependent and financially constrained investment planning algorithms determines individual firms' upgrading of their capacity to produce.

The M-M model is embedded in a complete and consistent micro-to-macro statistical system defined at the Swedish national accounts level (**Albrecht, 1992**). Five manufacturing sectors have been carved out of the national accounts and the input/output matrix and been redefined to correspond to the OECD end use of products classification: raw materials, intermediate goods, non-durable consumption goods, investment goods (consumer and producer) and Computing and Communications (C&C) goods and services.[22] Individual firms purchase in the 11 markets in proportion to their individual input output coefficients.[23] For each initial year a stock flow consistent micro (firm) to macro (National Accounts) data base has been constructed in the financial, production (output) and input (labour, purchasing etc.) dimensions. In that context the entire micro-to-macro initial data base of firms was updated to the year 1997 using the Planning Survey of the Federation of Swedish Industries (**Albrecht, 1992**; **Virin, 1976**) and a special survey on the same format of the largest 100 firms in the C&C industry (see **Eliasson et al., 2004**; **Johansson, 2001**). The C&C industry to a great extent covers the private services industry and significant redefinitions of national accounts data were needed to obtain a consistent micro-to-macro data set of both stocks and flows. Consistency of the initial state accounts in those respects is automatically maintained over time in MOSES simulations, and is critically important, since small circumstances, whether real or statistical errors may cumulate over time because of the market selection processes and pronounced non linearities of the MOSES model.

The macro data of the five market defined segments in the national accounts and the input output table have been replaced by five sets of firm/division data from the above Planning Survey and the special survey of the C&C industry. The difference between the national accounts macro data and the

20. This is what **Romer (1986)** repeats mathematically 96 years later, but in a macro model.
21. Except when forced too close to an approximate capital market clearing equilibrium by artificially intensified competition, the model economy will become collapse prone (**Eliasson, 1991a**).
22. See **Ahlström (1978)** and **Johansson (2001)**. Johansson conducted a survey to C&C firms modelled on the Planning Survey of the Federation of Swedish Industries, and separated out a C & C industry from the private service sector in the national accounts and the durable goods industry, (already represented in micro in MOSES) to simulate the role of C&C technologies in the macro economy.
23. Except in the investment goods markets. Purchases there are determined by the investment function of the individual firm. Total purchases in percent of value added of each firm are obtained from the Planning Survey. For each firm they are then distributed over the markets of the model in proportion to the input output coefficients of their respective industries. Since firms grow endogenously at different rates and exhibit different investment behaviour the input output tables of Sweden are thereby endogenously updated from period to period.

five aggregates (in all dimensions; financial, profits, value added etc.) of individual firms have been computed and regarded as "synthetic" firms.[24]

The initial state of the model consists of a complete and consistent set of Salter rankings (of all performance variables of firms) for each micro defined industry (see ***Albrecht et al, 1992***; ***Salter, 1960***). *Aggregation is dynamic* over markets featuring endogenous prices. This means that each macro trajectory is based on different relative prices. The endogenous micro behaviour of firms during a simulation updates the firms and the Salter curves *each quarter* and growth occurs through the Schumpeterian creative destruction process of ***Table 2***.

The entire model has been calibrated on industry, price and firm distribution data over a historic period using a specially developed calibration model (***Taymaz, 1991b***; ***Taymaz, 1993***). In that sense MOSES simulations are empirical and based on (1) a complex set of initial state data from the Planning Survey of the Federation of Swedish Industries, (2) econometrically established behavioural relations, (3) a consistent micro to macro real and financial accounting systems scaled up to NA level, and (4) the final calibration.

2.6. The venture capitalist

The venture capitalists are new agents introduced into the MOSES model economy in this paper. They appear as individuals or households who have detached themselves from the macro household sector and appear in the financial market as sophisticated savers, investors, and borrowers, who clear their accounts with the savings and wealth accounts of the macro household sector (***Eliasson, 1982***; ***Eliasson, 1985***). These are stylized actors on which we have little systematic econometric evidence except the series of interviews carried out in ***Eliasson, 1997***; ***Eliasson, 2003b***; ***Eliasson, 2005b*** and preliminary data from the HUS project (***Eliasson and Klevmarken, 1981***; ***Eliasson, 1982***). The main thing learned from the interview studies, however, is that *venture capitalists are financial actors/individuals with industrial experience and competence and should be modelled accordingly,* as we will demonstrate in section 4 below. In the model they represent a hybrid between a household and a business firm, and a standard wage earner turned entrepreneur (***Eliasson, 2006***), and a first step in detaching micro agents from the household aggregate of the model.

3. Technology choice and innovation supply

The logical sequence of innovation supply, entrepreneurial choice and the commercialization of innovations can be read from the competence bloc in ***Table 1B***. At the top we have the customer demand connection (actors 1). At the bottom we have the commercialization actors (actors 3, 4, 5 and 6) which perceive customer preferences ex ante to make the appropriate choices from the innovation supply flows (actors 2).

Innovations are defined as new technological combinations from existing and new technologies. The choice of profitable innovations is the task of entrepreneurs (actors 3).

Innovative new technologies are introduced into the economy through investments in the incumbent firms and through the entry of new firms. Entrants are assumed to come with best practice technology. *Technology choice, therefore, is part of the investment decision.* New technology upgrades firm productivities, as does disembodied learning-by-doing.

3.1. Technology choice

To understand the simulation experiments in this paper some modules of the model need further clarification. First, the rate of entry of new firms in each year is modelled as a random function of industry profitability. Key characteristics of new entering firms (entry size, technological level, etc.) are determined as drawings from empirical distributions in such a way that the size of new entering firms

24. Each “residual aggregate” has been “chopped up” into several synthetic firms. We have tried, when constructing the “synthetic firms”, to preserve known distributional patterns of the industry/market. ***Taymaz (1992a)***.

on average is 15% of the average of incumbent firms in terms of (initial) employment. On average, furthermore, the technological level of a new firm is lower than that of incumbents, but the spread is much wider (***Granstrand, 1986***). Most of the time some new entrants (the "winners") are therefore significantly more productive than the best incumbent firms, and low productivity entrants as a rule are soon forced by competition to exit (see ***Eliasson, 1991b***). Hence, a higher rate of innovative entry is normally associated with a higher rate of exits.

In earlier versions of the model all entrants, so determined, were fully financed and the final selection was determined by competition in the markets of the model, some emerging as winners, but many of them failing and exiting. In this version of the model some entrepreneurial entrants (Item 3 in ***Table 1B***) are discovered by venture capitalists as potential winners (Item 4) and granted exceptional finance by them. See further next section 4.

There are two types of innovation. An *incremental* innovation yields an improvement in the capital and labour productivity (INVEFF and MTEC) variables of the model, within the limits of an optimal technology, which we label the "global best practice technology".[25] The point, and a characteristic of the theory of the EOE are that firms do not know the global technology and therefore cannot jump to it. Incremental innovation is obtained by discoveries within the firm or by imitation and improvement of another firm's technology. *Radical* innovation reflects a change in global technology. Global technologies are also ranked by their productivity, and all technologies that have the same limiting global technology belong to the same technological paradigm. Such a paradigm, also called techno-economic paradigm by ***Freeman and Perez (1988)***, corresponds to a cluster of inter-related innovations that affect most of the industries. We have also introduced user-producer learning that stimulates the diffusion of innovations between industries.

3.2. The technological level index

A "technological level" index TECH is introduced to represent the average of technology codes in a market or in the economy. TECH is a statistical proxy for the average technology level of the same kind as the number of patents issued used in many empirical studies. In the MOSES model we use the TECH index to represent qualitative differences in technologies. An increase in the TECH index for a set of chosen technologies reflects an improved technology potential. A "high technology" level, however, is not necessarily synonymous to an economically superior technology, and rarely the economically best technology. To determine the economic potential of a particular TECH index it must first be filtered through the entire competence bloc, and experience from many previous simulation studies on MOSES, for instance ***Eliasson (1980)*** and ***Eliasson (1987)***, suggest that the market allocation regime matters more than technology for economic growth. This paper adds a downstream commercialization filter to the selection. An increase in the TECH index recorded in the simulations therefore means (and especially in the context of this paper) that innovations have passed the early market selection test, or the new competence bloc test to access venture finance. An increase, therefore, reflects an improved commercial choice of technologies.

3.3. Diminishing returns to R&D investment

Technologies are ranked from 1 to 100 and the rank of the technology defines its potential limit. For example, technology 10's potential limit is higher than technology 4's, etc. A firm gets closer to that technological limit by incremental innovation and the closer it gets the more difficult it becomes to improve productivity. Then the firm will try to switch to another technology that is more likely to have a higher potential limit. Therefore, *it must discover/identify a better technology*, which takes it outside its own experience range and therefore involves greater risk. *The firm has a choice to allocate part of its R&D budget on incremental innovations, and the rest on radical R&D to discover new superior technologies*. The more threatened by superior competitors (to the left in the Salter ranking) and by inferior competitors to the right, trying to leapfrog their positions, the more inclined the firm will be to

25. All early experiments on the model where based on a case study on the expected development of "best practice" INVEF and MTEC technology from different industries (***Carlsson, 1981***; ***Carlsson, 1991***). New investment simply brought in new vintages of capital with those performance characteristics that were integrated with existing capital stocks. The new specification introduced with ***Ballot and Taymaz (1998)*** and used here is based partly on such, but much more sophisticated, exogenous technology assumptions.

opt for high-risk low- probability radical outcomes. As is clear from what has just been said, attempts to jump onto the radically new technology potential encounter strongly *diminishing returns to R&D investments* (***Eliasson, 1995***; ***Eliasson, 1996***).

When the firm gets closer to the potential of existing technology, it will be more difficult to increase productivity through incremental innovation, and *the firm will allocate increasingly larger parts of its R&D budget to radical R&D*. This strategy involves larger risks. The innovation outcome of radical R&D investments has a random element in that there is a low probability of drawing a winner. The firm can thus choose between opting for a low probability random radical innovation outcome among one of the potential technologies, and the safer high probability bet on imitating a technology already adopted by other firms. To the extent that firms succeed in upgrading the technological paradigm through successful introductions of radically new technologies they are making them available "for learning" by other firms ("spillovers"). This can therefore be said to be a rendering of a Marshall/Romer new growth theory learning effect.[26]

3.4. Learning to discover

The probability that the firm discovers a winner is raised by learning. In ***Carlsson et al. (1997)*** (also see ***Ballot and Taymaz, 1998***) *the outcome depends on the firm´s accumulated memory for recombination* (***Carlsson et al., 1997***; ***Ballot and Taymaz, 1998***). The firm may have learned the right things by chance, but *firms with broad based experience also have a larger capacity ("receiver competence", Eliasson, 1990) to make the right technological choices*. Hence, radical, innovative choices are based on learning and experimentation in combination, involving by definition a high risk, but also the potential for great rewards. The better firms are at discovering winners the stronger the bias towards macroeconomic growth in the model economy.

Learning and innovation occur in both incumbent and new firms and contribute to improving their technological performance. Key to success is *the ability of the firm to choose superior projects* and this capacity *depends on the experience of firms embodied in their memory* (***Ballot and Taymaz, 1998***). Firms currently update their memory. In the current version of the model their memory is sufficient to remember three technologies at a time. In their technology choices they use the best among those three. They furthermore try to improve the memorized technologies by innovation/imitation (experimentation). If they improve anyone of them, they update their memory with the better one, and forget about the inferior one. Through innovation and imitation, they may generate the old, inferior technology again, but they do not adopt it because it is inferior. Even though firms have learned through experimentation and updated their memories, in MOSES this represents ex post knowledge and is no guarantee that it helps in choosing a superior future technology.

3.5. Non-linear endogenous growth through selection

A shift of the economy onto a new paradigm can be incentivised by decreasing returns to incremental innovations. Success at the macro level, however, depends on the ability and the willingness of many firms to follow the first firms that have successfully ventured into the new paradigm. There are increasing returns to adoption (***Arthur, 1988***). Radically new paradigms still might not develop if the returns to the current paradigm are satisfactory. Simulations on the MOSES model demonstrate that for a long time several paradigms may be represented simultaneously in manufacturing markets. Such lock-ins into inferior paradigms may also block the development of a better paradigm (***Ballot and Taymaz, 1998***).

New technology is introduced through new entering firms and through new investment in incumbent firms. Radically new technology tends to be introduced more frequently into production through new firm entry than in incumbent firms. When it occurs through new investment in incumbent firms the impact is reduced because it must be integrated in old vintages of capital. On the other hand, the new technology, if successfully introduced in an incumbent large firm applies to a much larger capital base, with a larger (than with the small firm) leverage on total firm productivity growth. One could look at the introduction of new technology in a MOSES firm (and scale up through investment) as a strategic

26. For Marshall on new growth theory, also see ***Eliasson (2003a)***.

acquisition of a new technology firm the capital structure of which is then integrated with the existing capital structure (see ***Eliasson, 1985***; ***Eliasson and Eliasson, 2005***).

The identification**,** discovery and technological choice process described above defines the *receiver competence* (***Eliasson, 1990***) of the economy at different levels, beginning with the firm. The fact that firms make business mistakes and that winners may be lost for ever**,** tilting the economy o to a slower growth path "for ever" makes it necessary to model this choice process explicitly. Since the long-term growth outcome depends on the economic efficiency of this choice process the definition of the *dynamic efficiency of the economy* becomes tricky. We define it as the capacity of the economy to minimize the economic incidence of two types of business mistakes: keeping the losers on the books[27] for too long (Type I mistakes), and of losing the winners (Type II mistakes) in ***Table 1A***. This means that growth depends critically on the capacity of the economy to select, and not lose winners and to efficiently introduce the winners in production, i.e., on the commercialization competence of the economy as embodied in competence blocs (***Eliasson, 2001***; ***Eliasson, 2003a***; ***Eliasson and Eliasson, 1996***) .

Deficient receiver competence at different levels means that firms are unable to access the pool of globally available technology and/or that good but radical technology choices by firms/entrants do not survive because industrially incompetent financial providers are unable to understand the economic potential of radically new technology (***Eliasson and Eliasson, 1996***; ***Eliasson, 2003b***; ***Eliasson, 2005b***). Hence technology, *however advanced, residing in firms is not sufficient for growth. If downstream commercialization technology is lacking the economy at large may miss the boat to prosperity that the new technology is promising.* This commercialization competence is embodied in the *competence bloc* in which the (technical) innovator is only one of several players (see further next section).

Eliasson et al. (2005) demonstrated that growth in the MOSES economy depended on a balanced firm turnover and labour market process. Increased innovative entry (1) gave no, or small growth effects if the requisite reallocation of resources, notably of workers did not occur. On the other hand (2), if reallocation of resources and structural change was too fast, such that market price setting became disorderly, the rate of mistaken business decisions escalated, and eventually the expected growth effect failed to occur, but this time for an entirely different reason. Even without any technical change or innovative entry, an early result from MOSES analysis (3) has been that if a positive market induced allocation of resources, again notably workers, can be engineered short term productivity growth improvements would follow, but again only up to the limit where the governance of market pricing is disturbed (***Eliasson, 1979***; ***Eliasson, 1987***). In short, up to a limit innovative entry raises the rate of growth but this positive outcome is tempered by the capacity of factor markets to reallocate resources flexibly, the labour market being of particular importance. An optimum growth promoting firm turnover rate exists that depends on the capacity of factor markets to reallocate resources flexibly. (An increase in innovative entry gives only a small growth response at the economy wide level if resources are not freed from their current allocations through the exit of inferior firms and workers flexibly transferred to expanding producers). Common to all experiments is that the *effects of small parameter changes are slow in showing up at the macro level, but with time sometimes tend to cumulate*. This is also a typical property of selection based, initial state dependent non linear models. In agent based models with these properties we find in addition that the balancing of all these factors depends on a complex of cirumstances, some of which being policy parameters, that must be right for "optimal" receiver competence and macro performance. Not only is that very difficult and competence demanding of policy makers. Policies can also, and easily turn destructive when they interfere left-handedly with the internal selection dynamics of economies. Since the gestation period of the macroeconomic effects is so long, when discovered, it may be too late to correct policy mistakes. And for obvious reasons, the policy maker who caused the mistakes should not be expected to know how to correct the consequences of his mistakes. The damage to the economy may even be permanent. Thus, evidence is not in favour of policy fine tuning. Rational policy makers should rather opt for

27. This problem has been with us for a long time. Thus, for instance (see ***Eliasson and Lindberg, 1981***) one conclusion from early simulation experiments on the M-M model was that even a big investment mistake need not be a great disaster, if production at the investment is terminated quickly. Early close down of production activity on grossly mistaken investments, therefore, is part of competent management.

making factor market more flexible and support a broadening of the experience base of the competence blocs of their economies.

If the policy maker wants to change the composition of growth there are economically less harmful methods than messing up the markets' allocation and supply machinery, for instance working through demand. This way it will also be possible to determine the costs to society of running the economy politically against the preferences of its market agents (**Eliasson and Taymaz, 1992**).

One important feature of the competence bloc and manifest in the MOSES model, is that it breaks the direct technology – growth drive typical of Post-War II growth models in the neoclassical or "linear" **Schumpeter (1942)** traditions. In contrast, the competence bloc is defined from the demand (customer) side and screens innovative technological "suggestions" for profitability (the *entrepreneurial* and *venture* capital functions). If the economic circumstances, including institutions and the industrial competence of financial intermediaries, are not the right ones, however advanced, the technology residing in the economy does not lead to growth. If so, we have the case of lacking commercialization or receiver competence at the economy wide level that has been explicitly represented in the MOSES model of this study.

3.6. The positive role of business mistakes and dynamic efficiency

The choice of new technology, notably radically new technology involves business risks. Therefore, *business mistakes* occur frequently in the EOE and in the MOSES model. They *should in fact be looked at as a normal cost for economic development and learning*. Because no investment venture can be perfectly planned and enacted, as assumed in the general equilibrium setting of mainstream modelling, *the dominant transactions cost in the EOE and in the MOSES model is made up of business mistakes* (**Eliasson and Eliasson, 2005**), and they are composed of the consequences of the two types of expectations mistakes in **Table 1A**. All other measured costs are regarded as production costs geared to measured output. Hence, *to experience any successes at all – and growth – the economy must absorb many mistaken business experiments along the way*. (We have also demonstrated elsewhere on the model (**Eliasson, 1984**; **Eliasson et al., 2005**) that a balancing of firm turnover between entry and exit is necessary for stable macroeconomic growth). Under such "dynamic" circumstances it becomes important that both project creation, selection and learning be efficient in the sense that the economic consequences of the two types of errors are minimized, i.e. of not keeping losers on the books for too long, and of not losing winners (**Table 1A**). Competence bloc theory (**Eliasson and Eliasson, 1996**; **Eliasson and Eliasson, 2005**; **Eliasson, 2001**) attends to that within the theoretical environment of the EOE.

3.7. The Self-coordinating Equilibrating Properties of the Micro-to-Macro model economy

Under normal "institutional" circumstances market agents self-coordinate the micro-to-macro model economy MOSES within a "growth corridor", but never places it on an exogenous and analytically determinate growth trajectory. Market self-coordination occurs under an upper technology constraint. The outer limits of the "growth corridor" can be influenced by policy, but it is extremely demanding of the policy maker to keep that corridor narrow in the long run, because the more narrow the more disturbed and unpredictable the micro market envronment where people and firms live and have to cope (**Eliasson, 1983**; **Eliasson and Taymaz, 1992**; **Eliasson and Taymaz, 2000**). Under exceptional circumstances the model economy may even collapse if pushed to close to such a steady state, but in general the model economy is quite robust (**Eliasson, 1984**; **Eliasson, 1991a**). The rational "welfare objective" of the policy maker is thus to achieve fast growth (within some such welfare defining corridor), not maximum possible and stable growth. In fact, from a welfare perspective stability becomes the interesting policy target, but then it should not be understood as countercyclical demand policy policy. This can only be achieved in the MOSES model by raising the instability of the micro market environment where people live and work, a policy dilemma that should be kept in mind when running ambitious macro policies. To succeed the demands on private social capital (**Eliasson, 1983**; **Eliasson, 2001**). We can report from experience with the model that long term sustainable growth at the macro level requires constant, significant, unpredictable, and flexible adjustments of structures at the micro level, that markets, notably the labour market, are the main intermediators of that flexibility, and that fast long-term sustainable growth requires a fairly wide "growth corridor".

4. Modelling innovative technology creation and commercialization – competence bloc theory

Commercializing agents operate as intermediaries in the markets for innovation between innovation supply (Item 2 in **Table 1B**) and resource providers (Items 3 through 6). Those market intermediaries also draw resources (a transactions cost) and therefore invalidate the Fisherian separability theorem upon which standard financial economic theorizing is based, or that the real and the financial parts of an economy can be studied separately. Hence a different theoretical approach is needed to understand the role of financial markets in growth. Financial markets not only provide finance. The complementary and resource using task of guiding the resources to the right allocations must also be explained. Competence bloc theory does that, and the charges for that guidance service come in the form of capital gains and losses of the intermediaries (**Eliasson and Eliasson, 1996**; **Eliasson, 1998a**; **Eliasson, 2005a**).

Competence bloc theory is an organizational design of the commercialization process, featuring the minimum number of actors with categorized functional competences that are needed to create and select projects and to carry winners on to industrial scale production and distribution. Schumpeterian efficiency by our definition therefore also concerns the efficiency of selection, as distinct from the efficiency concepts of the neoclassical model (**Eliasson, 1985**; **Eliasson, 1991a**). Since MOSES growth is generated through competitive market selection, a maximum, exogenously determined, and sustainable (or "equilibrium") growth rate cannot be determined as a reference or a benchmark because it requires that the economic value of lost winners be identified. For our purposes we only need to conclude that Schumpeterian efficiency requires significant exit, but that only a minimum of potential winners should belong to the exit flow (**Eliasson et al., 2005**, republished in this Anthology).

Receiver competence, hence, has two dimensions in the real world; (1) The ability of the firm (new or incumbent) to identify, and take winning innovations on to industrial scale production, and (2) the capacity of the markets to identify and force losers to exit. *The receiver competence of the economic system is defined by competence bloc theory*, and here the industrial competence of venture capitalists figures importantly (**Eliasson and Eliasson, 1996**; **Eliasson, 2003b**).

With **Ballot and Taymaz (1998)** the earlier dependence on historical experience to guide search, and on luck to be innovative has been upgraded by a realistic learning and discovery process modelled through genetic learning algorithms that improve the selective ability of firms. Firms, using classifier systems, could now learn about rules of resource allocation for imitative activities, and even imitate other more successful firms´ rules.**Ballot and Taymaz (1998)**

In earlier versions of the MOSES model innovation supply (item 2 in **Table 1B**) occurred through a stochastic innovation function, and the selection of winners and losers took place in final product markets as described above. We now introduce *pre-sorting of a selection of projects (in the markets of the competence bloc) through industrially competent venture capitalists* (item 4 in **Table 1B**).

4.1. Technology creation – the innovation supply module (item 2 in Table 1B)[28]

A firm's knowledge of technology is represented by a set of "techniques":

$$F^{P} = \{f_1^p, f_2^p, \ldots f_{nt}^p\} \tag{1}$$

where F^P is the technology known to the firm, and f_i^P is the i[th] element, i=1,…, *nt* of that set. Superscript P denotes the relevant technological paradigm. We assume that a firm uses only one type of production technology. For simplicity (and without lack of generality), an element can be assumed to have only two alternatives encoded in a binary alphabet as either 0 or 1.

28. This and the following sections draw directly on **Ballot and Taymaz (1998)** and **Ballot and Taymaz (1999)**.

The *best practice technology* in a technological paradigm P (the "global technology") describes a specific combination of elements:

$$G^P = \{g_1^P, g_2^P, ...g_{nt}^P\} \tag{2}$$

The firm that uses all elements in the set of global technologies G^P reaches the highest technological level defined by that paradigm. *A firm is however generally ignorant about the large part of global technology* (or the opportunities space, see **Eliasson, 1990**). The production function of a firm is represented by its labor productivity (T) and its output capital ratio ("capital productivity", k). For new investment vintages brought into the firms through their investments, or into the economy with new market entrants, the corresponding productivity parameters are (T^{new}, k^{new}). The firm's technological level (T^{new}, k^{new}) is therefore determined by the distance D^{PF} between the global technology (the vector of techniques that defines the global technology) and the technology applied by the firm, and similarly for capital productivity:

$$\begin{aligned} &T^{new} = T(P, D^{PF}), k^{new} = k(P, D^{PF}) \\ &\partial T^{new}/\partial D^{PT} < 0, \partial k^{new}/\partial D^{PT} < 0, T(P, 0) = T^P_{max}, k(P, 0) = k^P_{max} \end{aligned} \tag{3}$$

$$D^{pf} = 1 - \sum wici \tag{4}$$

$$c_i = 1 \text{ if } f_i^p = g_i^p, 0 \text{ otherwise} \tag{5}$$

where P is the index for the technological paradigm, D^{PF} the distance between the global technology P and the knowledge of the firm F, *c* the indicator function, and w_i the weight assigned to the i^{th} element. The firm will achieve the highest technological level defined by the paradigm when $D^{PF} = 0$. In this case, $T^{new} = T^P_{max}$. Technological paradigms are indexed such that the higher the P value, the higher the paradigm's maximum technological level, i.e., $T^1_{max} < T^2_{max} < \dots < T^m_{max}$.

4.2. Learning and incremental innovations

Firms use "genetic algorithms" to explore the global technology space of a certain technological paradigm (**Goldberg, 1989**; **Ballot and Taymaz, 1998**). A firm has a memory to retain a certain number of alternative technologies at a time (in our experiments 3 sets) and uses the set that yields the highest productivity. Since they do not know the global technology space in full, firms "learn" about the global technology either by recombining their own technologies (*experimentation*), or by recombining their sets with other firms' sets (*imitation*). There is also a third form of learning strategy that we call *mutation*.

The most important market processes of economics are *selection,* and selection is also the trademark of evolutionary economics. Market selection in the MOSES model economy occurs primarily through entrepreneurial entry, and competitive exit of firms. Firms` decision to enter a market depends on market incentives, notably excess returns to capital over the interest rate earned by incumbent firms in the market. Badly managed firms (and technologies used by them) may go bankrupt and exit. This goes for both incumbents and entering firms that have been overoptimistic and overconfident. This is the way learning takes place at the national economic system's level (see **Eliasson, 1996**).

At the beginning of each year the firm opts for one of the three learning strategies. Which one is determined by the firm`s competence level. It is executed in four steps for all technologies in each firm's memory.

First, the firm decides whether it will go for imitation or experimentation. The firm will decide to go for an imitation strategy when

$$\begin{aligned} &p_i^{imit} = p(H_i^{gen}, n) \\ &\partial p_i^{imit}/\partial H_i^{gen} > 0, \partial p_i^{imit}/\partial n > 0 \end{aligned} \tag{6}$$

where p_i^{imit} is the probability of imitation for firm *i*, H_i^{gen} the i^{th} firm's general human capital stock per employee, and n the number of firms in the same sector using the same type of technology. The *probability of successful imitation increases with the general human capital stock of the firm.* The more educated and knowledgeable its workers the more easily the firm will understand and assimilate new technologies developed by other firms.

If the firm has decided to go for imitation, then it will select a technology for recombination *from another firm* in the same market using the same type of technology. The probability of a particular selection then depends on the firm's technological levels:

$$p_j^{\mathrm{imed}} = \mathrm{p}(\mathrm{T}_\mathrm{j}^{\mathrm{new}}, \mathrm{k}_\mathrm{j}^{\mathrm{new}}) \\ \partial p_j^{\mathrm{imed}} / \partial \mathrm{T}_j^{\mathrm{new}} > 0, \partial p_j^{\mathrm{imed}} / \partial k_j^{new} > 0 \tag{7}$$

where p_j^{imed} is the probability that the firm *j* will be imitated by firm *i*, if firm *i* tries imitation. Thus, *a firm with a large general human capital stock tends to imitate technologically advanced firms operating in the same market and to experience a higher probability of success*.

If the firm (*second*) decides on an *experimentation* strategy (with the probability (1- p_i^{imit}), it will select a technology *from its memory* for recombination to attempt to achieve a radical upgrading to a new technological paradigm. This means a strategy of higher risk with a higher probability of failure. The probability of a successful selection again depends on the T^{new} and k^{new} values.

The firm randomly selects *ns* elements of the technology to be used for recombination. Then, the values of those elements (i.e., techniques) are replaced with the corresponding elements from the vector of the imitated firm/technology. *If the degree of correspondence improves, the firm keeps the modified technology in its memory*. Otherwise, the existing technology remains in the memory. *The main difference between experimentation and imitation is the source of technology to be used in recombination*. In the case of experimentation, the firm experiments by replacing *ns* techniques of one of its technologies with the corresponding techniques of another technology in its memory. Remember that a firm can keep three different technologies in its memory. In the case of imitation, the firm experiments by recombining the techniques of a certain technology in its memory with the corresponding techniques from another firm's technology. The number of elements to be imitated is determined by the amount of R&D expenditure aimed for incremental innovation.

$$ns = \mathrm{ns}(\mathrm{RD}^{\mathrm{inc}}) \\ dns/\mathrm{dRD}^{\mathrm{inc}} > 0 \tag{8}$$

Third, and finally, the firm may also go for the *mutation* strategy with p^{mutat} probability. In the case of mutation, a randomly selected *nm* number of elements of the technology vector are replaced with their opposites (0 by 1, and 1 by 0). The probability of successful mutation depends on the *general human capital stock*.

$$p^{\mathrm{mutat}} = \mathrm{p}(\mathrm{H}^{\mathrm{gen}}) \\ dp^{\mathrm{mutat}}/\mathrm{dH}^{\mathrm{gen}} > 0 \tag{9}$$

$$nm = \mathrm{nm}(\mathrm{RD}^{\mathrm{inc}}) \\ \mathrm{d}nm/\mathrm{dRD}^{\mathrm{inc}} > 0 \tag{10}$$

Learning is based on four critical variables: p^{imit}, *ns*, p^{mutat} and *nm*. An increase in p^{imit} means the firm will increase its out-search to learn more from other firms (imitation). Out-search should stand a better chance than in-search to generate economically successful technology choices, since the set of available technologies is broader, because the number of firms in the sector is larger than the number of technologies that resides in the firm's own memory. Above all, with out-search the firm runs a lower risk of losing winners than restricting search to its own experience (***Eliasson, 2001***; ***Eliasson, 2003a***). Moreover, excepting the most advanced firm, at least one firm's technological level is higher than that of the imitating firm. Our simulation experiments with the learning module support this intuition. When the p^{imit} variable is exogenously increased, the learning process goes faster, i.e., firms discover the elements of global technology more quickly.

The second variable, *ns*, is critical for learning performance. A low value for *ns* means the firm can change only a few elements (techniques) at a time. This implies a slow learning process. Experiments with the learning module show that increasing the *ns* variable improves learning performance. The

p^{mutat} and *nm* variables, which determine the probability of successful mutation and the number of elements to be changed in mutation, have a positive impact on learning.

We have assumed that imitation (out-search) and mutation probabilities, p^{imit} and p^{mutat}, depend on firms' stock of general knowledge (H^{gen}). The firm with a large stock of general knowledge will be able to experiment successfully with other firms' techniques and achieve a higher rate of learning. *The number of elements to be changed in experimentation, imitation (ns) and mutation (nm) are determined by real R&D expenditures*. In a sense, *the firm "buys" experiments in the market by investing in R&D, and the quality (the probability of success) of those activities depends on its stock of general knowledge*. This is similar to the increasing practice of highly competent (very R&D intensive) large pharmaceutical firms to search the markets for strategic acquisitions of new technology firms that are close to a commercial break through that R&D intensive firms understand much earlier than the market in general (***Eliasson and Eliasson, 2005***). Hence R&D investments combined with the stock of general knowledge are important elements of the *receiver competence* of the firm.

A firm can improve its technological level by learning and incremental innovations, but only within the limits of its global technology (the technological paradigm). The closer to the limit the firm gets, the more difficulties it encounters in improving its technological level within the existing paradigm, and the more inclined the firm becomes to allocate more funds for radical innovation. By doing so, the firm opts for the high risk opportunity of jumping onto a higher technological trajectory. *This behavior* does not depend on any prior knowledge about the limits of global technology but *is triggered by the low level of learning observed for a certain period*, or by being excposed to life threatening competition (***Eliasson, 1995***).

4.3. Radical innovations and changes in techno-economic paradigms

Firms, and especially firms close to the technological frontier, may try to achieve a radical innovation leap into a new type of technology, a new paradigm, or to imitate a radical innovation in other firms. Radical innovations and imitations of different paradigms are determined in three steps. In the first step, we have a probabilistic draw for innovation/imitation. If the firm turns out to be an *innovator/imitator*, we determine the paradigm P to be innovated/imitated. If the new technology looks better according to the computations below, the firm adopts it.

The probability of a radical innovation (p^{radin}) depends on real *R&D expenditures aimed for radical innovation* (RD^{rad}), the stock of general knowledge (H^{gen}), and knowledge spillovers from other firms in the same sector (H^{spil}).

$$\begin{aligned} &p^{\mathrm{radin}} = \mathrm{p}^{\mathrm{radin}}(\mathrm{RD}^{\mathrm{rad}}, \mathrm{H}^{\mathrm{gen}}, \mathrm{H}^{\mathrm{spil}}) \\ &\partial p^{\mathrm{radin}}/\partial \mathrm{RD}^{\mathrm{rad}} > 0, \partial p^{\mathrm{radin}}/\partial \mathrm{H}^{\mathrm{gen}} > 0, \partial p^{\mathrm{radin}}/\partial \mathrm{H}^{\mathrm{spil}} > 0 \end{aligned} \tag{11}$$

Knowledge spillovers, in turn, depend on the firm's *receiver competence* or absorptive capacity (determined inter alia by H^{gen}), and the aggregate stock of general human capital.

$$\mathrm{H}^{\mathrm{spil}} = \mathrm{H}^{\mathrm{spil}}(\mathrm{H}^{\mathrm{gen}}, \sum \mathrm{H}^{\mathrm{gen}}) \tag{12}$$

If the firm adopts a radical innovation strategy and succeeds in obtaining a successful innovation draw, the new technology is randomly determined:

$$\begin{aligned} &p^{\mathrm{selin}} = p^{\mathrm{selin}}(P) \\ &\mathrm{d}p^{\mathrm{selin}}/\mathrm{dP} < 0 \end{aligned} \tag{13}$$

where the probability that the technological paradigm P will be innovated (p^{selin}) depends only on its index value, P. The negative sign for the derivative of p^{selin} with respect to P means that it is more difficult (less likely) to innovate a technology with a high than a low productivity potential. When a new technology is innovated, its techniques are initialized with a randomly selected set.

Radical imitations are modeled in a similar way.[29] The probability of imitating a new technology from another firm (p^{radim}) depends on *R&D expenditures aimed for radical innovation* (RD^{rad}), the stock of general knowledge (H^{gen}), and knowledge spillovers from other firms in the same sector (H^{spil}).[30]

$$p^{radim} = p^{radim}(RD^{rad}, H^{gen}, H^{spil})$$
$$\partial p^{radim}/\partial RD^{rad} > 0, \partial p^{radim}/\partial H^{gen} > 0, \partial p^{radim}/\partial H^{spil} > 0 \quad (14)$$

If the firm draws a radical imitation, the new technology is randomly determined:

$$p^{selim} = p^{selim}(P, P^{F}, |P - P^{F}|, np)$$
$$\partial p^{selim}/\partial P < 0, \partial p^{selim}/\partial P^{F} > 0, \partial p^{selim}/\partial(|P - P^{F}|) < 0, \partial p^{selim}/\partial np > 0 \quad (15)$$

where p^{selim} is the probability that technology paradigm P will be imitated. P is the index value of that technology to be imitated, P^F the index value of the technology currently used by the firm, $|P-P^F|$ the "distance" between P and P^F, and *np* the number of firms in the same industry using technology P.

4.4. Commercialization - entrepreneurial entry (Item 3 in Table 1B)

The number of new firms entering a market is a random function of the profitability of firms in that market and an exogenous entry parameter. In other words, *even if an industry is not profitable, some new firms will, nevertheless, enter that industry because of high-profit expectations*. The probability that the technology P is used by a new firm is determined as follows:

$$p^{entry} = p^{entry}(|P - P^{A}|, np)$$
$$\partial p^{entry}/\partial(|P - P^{A}|) < 0, \partial p^{selim}/\partial np > 0 \quad (16)$$

where p^{entry} is the probability that the global technology P will be used by a new entrant, P^A the average technological level in the market, and *np* the number of firms in the same industry using technology P.

New entrants start with a technology widely used in the market but are exposed to the probability that some new firms may enter with much better technology. Therefore, even if the average of new entrants is below that of incumbents, if there are many new entrants, the probability that some of them are superior to even the best incumbent firms will increase. In the Experimentally Organized Economy even the best firms, that also believe themselves to have the best technologies, will thus never be safe from being overrun by even better competitors (***Eliasson, 1992***; ***Eliasson, 1995***; ***Eliasson, 1996***; ***Eliasson, 2005a***). Also, a new firm that starts with superior potential technology may not survive for long in the market if its actual initial productivity level is low (even though its potential level may be very high), if it does not get sufficient and sustainable funding to commercialize and scale up its new technology. And for that funding to come forward at a reasonable expected risk and cost the resource providers will have to be sufficiently industrially competent to understand the potential productivity level and future earnings capacity of the entering firm. *Hence, even though the entrepreneur or the firm has come up with a winner, the resource providers may not understand that*. The venture capitalists represent this understanding in financial markets (***Eliasson, 2003b***).

4.5. More or less industrially competent venture capitalists

Venture capitalists play a critical role in the commercialization sequence of the competence bloc. Their ability to understand and identify winners and their willingness to provide funding for them at reasonable costs depend on their industrial competence. This industrial competence on the part of venture capitalists is therefore a key allocator of resources in the economy, and a critical growth determinant. *Each venture capitalist is defined by a certain level of competence in identifying "winners"*.

29. In the case of (incremental) imitation, a firm imitates the elements from another firm's technology if both are using the same technology, i.e., certain elements in the set of technologies are replaced. In the case of radical imitation, the firm imitates the technology itself, i.e., it adopts a new set with randomly determined elements.
30. Note that RDrad is the same in Equation 11 and Equation 14. We can make it different but then we would need a new decision rule. Since there are already many, this would not increase the principal understanding of how firms learn.

New financially constrained firms search markets randomly for venture capitalists. The problem is that knowledge is asymmetrically distributed. *The entrepreneur knows his (expected) productivity potential, while the venture capitalist knows as much, or less depending upon his/her industrial competence*. The more of them, and the more diversified their industrial knowledge, the more likely that the understanding of at least one of them comes close to what the entrepreneur knows. It is therefore important that the market can help the right venture capitalist meet the right entrepreneur. The broader the range of knowledge in the venture capital market, and the more of them ("horizontal diversity") the lower the risk that winners will be lost at this stage. A venture capitalist will invest in a new firm if the ratio of its "expected" potential productivity to average productivity in the market exceeds a certain threshold, i.e., if

$$PL^{EP}/PL^{A} > vi, \text{where } vi > 1 \tag{17}$$

PL^{EP} is the *potential productivity of the firm that the venture capitalist expects*, PL^{A} the known average productivity of the market and *vi* the investment financing threshold. In this study the number of venture capitalist firms is fixed (there are 20), and no new entry of venture capitalists occurs. A venture capitalist invests in only one firm each year. Therefore, if two firms exceed the investment threshold, the one that has the highest PL^{EP} level is acquired by the venture capitalist.

The expected potential productivity of the firm, therefore, can be defined as a function of the competence of the venture capitalist:

$$PL^{EP} = W_{v}PL^{P} + (1 - W_{v})PL^{R} \tag{18}$$

where PL^{R} is a random draw from the distribution of new firms´ entry level of technology and PL^{P} the *real* (and not observed) *potential productivity* of the entering firm. The PL^{R} distribution is the same as the one defined by Equation (16). The weight parameter w_v represents *the competence of the venture capitalist to identify the potential technology* PL^{P}. The venture capitalist tries to find out the true value of PL^{P}, and w_v defines its competence to do that. If $w_v = 1$, then the venture capitalist correctly assesses the potential productivity of the new firm. On the other hand, if $w_v = 0$, the venture capitalist has no idea about the new firm's potential productivity. It accepts a random draw from Equation (16), but won't invest if not significantly larger than the known average for producers in the market (or PL^{A} in Equation (16). The venture capitalist may now make two types of mistakes. It may support a low productivity firm, believing it to be a high productivity firm (Error Type I), or not support a high productivity firm, believing it to be a low productivity firm (Error Type II. ***Eliasson and Eliasson, 1996***). The closer to 1 w_v the more unlikely both mistakes

4.6. Learning of venture capitalists

The competence w_v to identify a particular technology P is partly determined by learning. If the venture capitalist has invested in firms using technology P, s/he will accumulate knowledge about that technology so that s/he will become increasingly more competent in assessing the potential of that technology (See Equation (7) above and accompanying text). More specifically, w_v is venture capitalist and technology specific, and each venture capitalist has a memory where it stores what it has learned from successful investments in several technologies (in the experiments of this essay three), each element being upgraded linearly by successful choices.[31] With time this will lead to an *endogenous specialization of venture capitalists* in certain technological fields because each venture capitalist will tend to concentrate in those technologies where s/he feels most competent. *This means more knowledgeable venture capitalists in their specialist fields, and a tendency to cluster in certain fields, but with time also a narrowing of the industrial competence base of the venture capitalist market*.

If a firm with a high PL^{P} from Equation (18) does not find support from a competent venture capitalist it won't be able to finance the commercialization of its promising new technology, and won't be able to learn through further experimentation or imitation, and may eventually be forced to exit.

31. We would have preferred a more complex learning algorithm, for instance making the information stored dependent on the magnitude of the commercial success, and adding more dimensions to the memory, etc but available computer capacity did not allow that.

4.7. Venture investment

There is a predetermined number of venture capitalists in the model (in our experiments, 20). Technically the experiment thus means that for a certain number of new entrants those venture capitalists have influenced their selection and commercialization by providing industrial knowledge as an intermediary service to new entrants. Formally the venture capitalist is a sophisticated specialist household who takes over the financing of a new entrant expecting to make a return on the investment. Because of its superior competence the venture financed entrants stand a higher chance of succeeding long term than if being on their own with only bank finance, for instance in overcoming temporary spells of losses, or avoiding Type II mistakes. This also means that entrants with low initial PL^R, but high PL^P (being therefore candidates for Type II mistakes) are likely to be deprived of financing earlier than in the alternative case with no venture capitalists. Technically the venture capitalist/sophisticated household clears gains and losses with household aggregate savings.

For the time being there is no entry and exit of venture capitalists. Since the acquisition of industrial knowledge and experience ("learning") of venture capital is a very long run process the fifty-year period covered by the simulation experiments will not be sufficient to demonstrate more than *the existence of the hypothesized economy wide effects of industrial knowledge contributions from venture capitalists over and above the funding of new ventures by the regular financial system without that knowledge contribution*. But that is good enough to begin with, because venture capital literature has not, so far, recognized such economy wide effects, and notably not through the minimization of Type II economic mistakes. The effects however must have the right sign at the macro level, and if that can be shown (in the next section) it will be a reason to continue to model a full-scale emergence of an industrially competent venture capital industry over the very long term on the format of the new stock and derivatives market module (***Eliasson and Taymaz, 2001***; ***Taymaz, 1999***). We know, however, already that this will involve a major computing effort.[32]

A venture capitalist invests in a firm for at most ten years. At the end of the tenth year, the venture capitalist sells its shares in the stock market and may pocket a capital gain. However, in many cases, the firm goes bankrupt before it reaches the age of 10. The venture capitalist may thus lose its investment. Already for this relatively simple experimental set up we therefore hypothesize that the market shares of venture capitalists will diverge because of differences in competence levels.

5. Simulation results

We have run five sets of simulations. In the **BASE** simulation, there is no venture capital market, and all firms pay the same (endogenously determined) interest rate. The MOSES model economy has a stock market as described in ***Eliasson and Taymaz (2001)***, and firm equity has a market value. In the second case (**Firm-specific Interest**), there is no venture capital market, but firms pay a firm-specific interest rate that depends on their individual debt/equity ratios.[33] This case makes debt financing more costly for small firms that try to grow rapidly with external finance, and especially firms with long gestation periods between investment and cash flows, that are particularly at risk to suffer from Type II errors. In the third case (**Venture** Capital), we introduce a venture capital market, where all venture capitalists have the same initial competence level (w*). Fourth, (in **Heto Venture**), venture capitalists have different initial levels of exogenously determined competence. Technically this simulation starts with initial competence levels randomly distributed around the w* in the Venture experiment.

The venture capitalists are new agents that have detached themselves from the household aggregate. They are governed by a profit or wealth objective, or more precisely by taking a financial position in new entrants expecting, because of their industrial competence w, to be capable of identifying winners in the market (See Equations 17 and 18). They invest in new firms and will exit the project with a capital gain or a loss, depending upon how the new firm fares in the market. The financial gain or loss is cleared against wealth in the household sector.[34]

32. Already the relatively minor experimental set up for this study, using the new ***Taymaz (1999)*** stock market module required that three top of the line PCs were integrated for the computations.

33. But no market for financial derivatives.

34. The household sector in MOSES is a macro-Stone type expenditure system with certain non linear features. Estimated parameters from the ***Klevmarken and Dahlman (1971)*** linear expenditure system have been directly introduced into the MOSES model. The expenditure system receives all incomes generated in the production firms, net of the Swedish taxes, as detailed in ***Eliasson (1980)***, and are then fed back from quarter to quarter to

As production firms also venture capitalists have a memory (but with limited capacity) in that successful investments upgrade their industrial competence w in the market/technology they have successfully invested, earned a capital gain and learned. The fifth experiment (**Spec-venture**) is therefore more sophisticated and aims at *capturing the evolution of an industrially competent venture capital industry*. Venture capitalists´ industrial competence is based on experience, or on – the - job learning in successful industrial ventures in new industries. This time the simulation experiments start with the same initial competence levels w as in the Heto experiment. Venture capitalists then upgrade their competence levels w from their own venture experience. Their w s increase gradually, but never reach 1. The rate of upgrading w depends on what technology they have invested in, and on how much they have gained or lost on their investments. A loss therefore means a lowering of the w next quarter. Over the 50 years of quarterly experiments the VC firms thus become increasingly specialized into technology areas they have successfully invested in.

We run each case 50 times to control for the effects of random factors. The main performance variable is manufacturing output at the end of the simulation. Since a venture investment is a long-term investment, we run our simulations for 50 years, or rather 4x50 = 200 quarters.

Simulation results (average values for each set of experiments) are summarized in ***Figure 1***. They came out as expected with a steady increase in end of period output and technology levels because of an improved allocation of investments. The tougher financing requirements going from **Base** to **Firm Specific Interest** however lower the average increase in productivity for the entire simulation period somewhat, suggesting that interest sensitive firms select more profitable investments, but not necessarily more productive investments.

When industrially competent venture capitalists enter the market and improve upon the selection macro performance increases with the industrial competence of venture capitalists as we go from an homogenous venture capital industry (**Venture** case with no individual venture capitalist being more competent than any other), via heterogeneous venture capitalists (**Heto- Venture**, with venture capitalists being endowed exogenously with different industrial competence capabilities), to the final (**Spec- venture**) learning experiments, where venture capitalists learn individually from own investment experience to increase their industrial competence. Macro performance steadily increases as winners are being identified at a higher rate and carried on to industrial scale production. This is reflected in the significantly higher technology level in the Spec-venture experiments than in the other experiments.

Since each venture capital experiment starts from the previous as a base, interestingly, the results show decreasing returns to increased sophistication in the selection and commercialization of winners by venture capitalists in that percentage growth in macro-output decreases. Increases in technology levels and productivity are not the reason for the (slower) growth in macro manufacturing output recorded, but apparently the market allocation of resources among firms.

6. Conclusions

The basic hypothesis of this paper has been that the industrial competence of (financial) agents to make informed selections of profitable technologies/projects matters for long term macroeconomic growth. This competence, furthermore, is experience based and takes a long time to acquire (“learn”). The local presence of industrially competent venture capitalists thus becomes a critical element of the long run economy wide outcome of the allocation of resources on commercial winners, and scale up.

final goods markets as demand. Onto this expenditure system of MOSES two novel nonlinear features have been affixed; (1) a separate savings category called *future consumption*, and (2) a temporary investment category making it possible for households to save extra or accelerate purchases of investment goods depending upon expected inflation and the real interest rate. As has become custom in neoclassical macro analysis this expenditure system can be assumed to be based on an aggregate of representative atomic households that at at each point in time, are assumed, as in the ***Modigliani and Brumberg (1955)*** model, to maximize their lifetime consumption (***Eliasson, 1976b***) . The household sector has been prepared for a micro household module. Hence, the household was to be modelled as a rational commercial actor and a sophisticated wealth manager of an extended family aimed at leaving positive monetary wealth at the expected death of current family members, partly for the rational reason that current family members might live longer than expected, and therefore should not starve during their final years, but also because of extended family preferences (***Eliasson, 1982***; ***Eliasson, 1985***). Even though the micro household model has yet to be readied, a compatible data base for several years of the 1980s has been collected (***Eliasson and Klevmarken, 1981***).

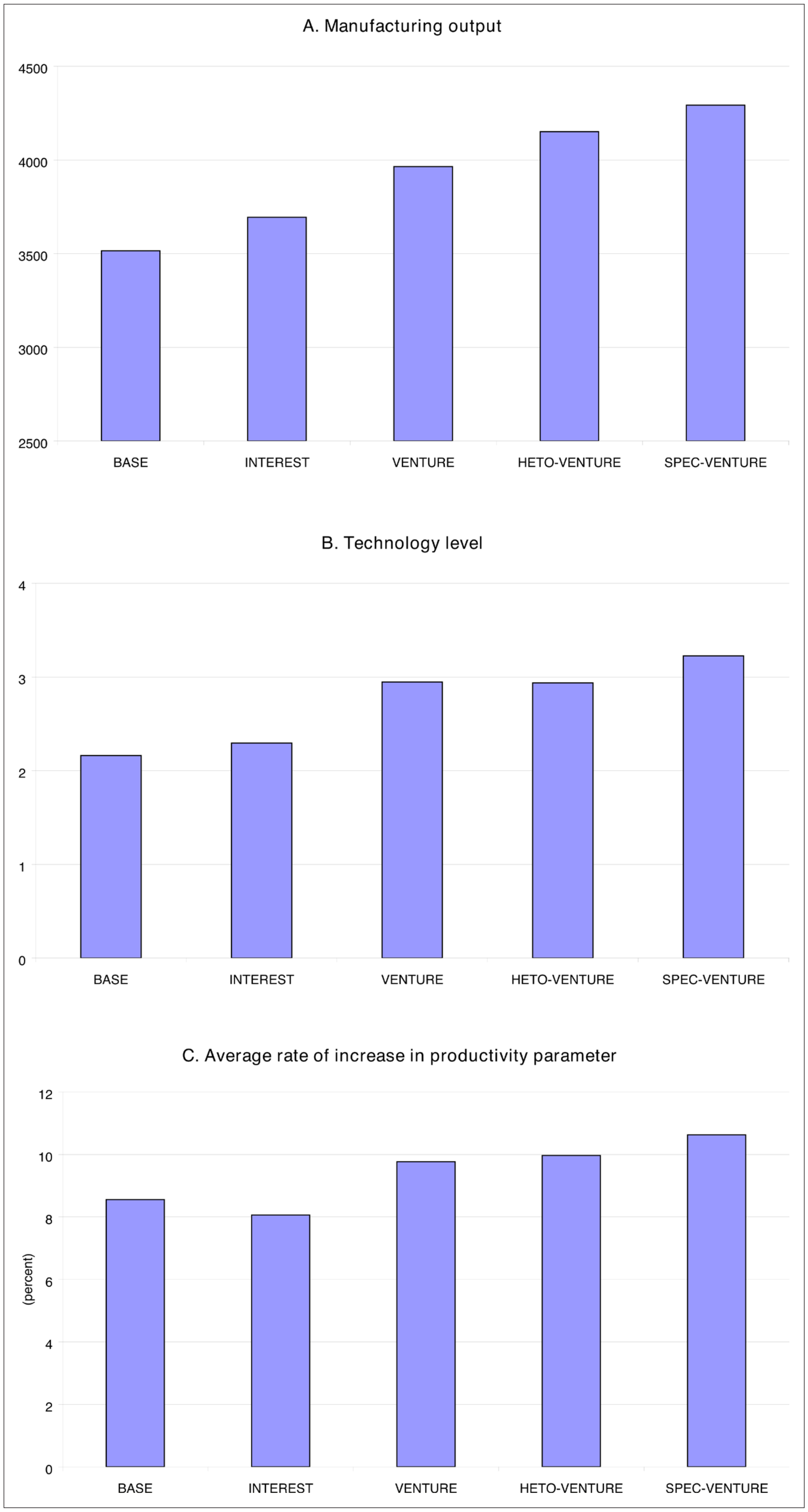

Figure 1. Simulation Results (end of period average values for 50 runs).

We have demonstrated the "theoretical" existence of positive long term economy wide effects of industrially competent venture capital provisions and observe that it should come as no surprise that industrially experienced financial agents allocate financial resources more efficiently than inexperienced financial agents without this competence attribute. An interesting observation is *how long it takes for a viable venture capital industry of sufficient size to make a difference at the macro level to spontaneously emerge in the market*. Understanding how it works in this simple rendering in the MOSES model economy we conjecture that there probably is no alternative way to build such an industrially competent venture capital industry than through individual accumulation of market commercialization experience

We have been able to capture those economy wide effects by realistically modelling both (1) the commercialization process and (2) the dynamic interaction of innovators and commercializing agents. The selective capacity of the economy improves with the entry of more competent commercializing agents. Because of the small number of venture capitalists in our simulations, the absence of entry into the venture capital industry, and the short period allowed for change (50 years), we hypothesize that by implication the marginal effects documented in this study might cumulate into major positive change if given more time. By raising the capacity of economic agents to filter winners out of the flow of innovations and to carry them on to industrial scale production, reducing the incidence of Type II economic mistakes the economy becomes dynamically more efficient and sustainable long term macro-economic growth increases.

The simulation experiments also suggest that the emergence of an industrially competent venture capital industry of some size is a very long-term story, and that it is unlikely to occur spontaneously in regulated financial markets of the European type dominated by public sources of finance. By implication this means that for Europe to catch up to *the competitive advantage the US has had (over Europe) at least so far* (***Eliasson, 1997***; ***Eliasson, 2003b***; ***Eliasson, 2005b***) will require many more years. A next step would therefore be to study the time dimension of this market based emergence process in more realistic MOSES simulations, and perhaps also derive some estimable parameters of this process from the model for empirical testing.

ORCID iDs
Gerard Ballot https://orcid.org/0000-0001-7455-0599
Gunnar Eliasson https://orcid.org/0000-0002-7967-6120
Erol Taymaz https://orcid.org/0000-0001-7525-6674

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As it is in the early versions of the micro to macro model we will use (see Hanson, 1986; Hanson, 1989 and Taymaz, 1991a). This is of course an oversimplification as soon as you reach below the aggregate level. At that level "laboratories" are specialized to produce technical combinations related to the type of commercial activity of the firm. Furthermore, and contrary to the implicit assumption of Arrow (1962), there are efficiency characteristics of the innovation function related to the ways research is organized and the scale of the activity. There is evidence suggesting that small scale is more congenial to turning out winners per dollar invested than is research organized in the laboratories of large firms or universities. Large firms may, however, be better at commercializing new innovations once they have understood them. They also have the resources to rapidly carry winners, once they have been understood to be winners, on to industrial scale production and distribution (Eliasson and Eliasson, 2005). While competence bloc theory defines actors by function, in reality both innovation, entrepreneurship and venture financing may be conducted within the same firm entity. Commercial considerations may therefore enter already at the innovation stage, and bias innovation supplies in a more profitable direction.

Conflict of Interest

No competing interests reported.

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