An evolutionary model of a small start-up firm

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Abstract : Start-up firms face a number of critical periods during their evolution. The aim of this paper is the construction of a model that captures the interrelationships of all the main assets small start-up firm needs for its development. The main motivation for building this model was to bring an understanding of small firm evolution into university education.
The results of the simulation runs with the model show the same growth patterns as have been observed in reality during the first three years of the firm's existence, for example, the important effects of pricing, flexible bank credit, the private consumption of the entrepreneur. The model can help the entrepreneur understand growth paths in the next years. The model can be used as an additional learning tool for entrepreneurs of start-up firms.

Keywords : System dynamics; theory of the firm; evolution of firms; modelling; small and medium-sized enterprises (SME),

1. Introduction

Traditionally the evolution of firms is captured as a succession of states that are described in balance sheets and income statements. Stock charts also present a kinematical view of evolution. These data can be used for scientific analyses as it was done in econometric analyses with the Bonner Datenbank for German enterprises. It contains balance sheet data since 1960[1]. In our research we try to get an understanding in which way a firm transforms from one state into the other. In our opinion for this deeper understanding of firm evolution the interrelationships of all the main assets should be captured.

In the literature we find three dominant streams that investigate interrelationships within firms: Econometrics, Evolutionary Economics and System Dynamics. The traditional concept by which business economics regards interrelationships within a firm is the production function. It is founded on the microeconomic theory of the firm. However, this function reduces a real enterprise to 3 - 4 variables. The theory mainly uses static models, most of them built in the econometric tradition - if time is incorporated at all. Few models claim to show empirical relevance – using empirical time series - but the results of this research are rarely challenged by independent research and validation efforts. For example, Albach (1986) uses a production function with 3 variables in a model with approximately 15 variables.

The models of Evolutionary Economics[2] are not being built around the main stock and flow variables that determine the evolution of a firm. At least they don't generate future

[1] See Albach et al. (1999)
[2] See for example Nelson and Winter (1996).

balance sheets for the evolution of the assets of a firm. There seem to be some promises from a field which started under the name "Industrial Dynamics" and is now known as System Dynamics. This literature is mainly concerned with partial models which describe the dynamics of a problem or a part within a firm (see e.g. Sterman, 2000, Schöneborn, 2001). In SD literature only three attempts concerning the business dynamics of a whole firm give the researcher the opportunity for a replication: the relatively complex models of Zahn (1971), Lyneis (1980) and Schöneborn (2003). These authors modelled larger firms and did not attempt to understand the evolution of small firms and the problems small firms face. In Zahn's model important capacity expansion and cost features are missing: depreciation and scrapping.[3] The model proposed by Lyneis cannot be replicated and therefore it is of little value for university education.[4] To our knowledge there have been no other authors replicated these models.

We attempt a top-down approach to create a dynamic model of a whole firm. On the one hand, we base the model on a simplified theory of the firm. We regard the key production factors (or assets) and their causal relations as described in microeconomics. Staff (or labour) and capital assets are the main production factors and their combination creates –as in the production function- an output of a single type of product. This concept describes a one-product firm. In our model the customer base (or the customer stock) is added as an important intangible asset of the firm.

On the other hand, we were looking for the smallest viable firm in reality. This restricts the model to the smallest possible scale and at the same time allows empirical falsification. Accordingly, as an example we investigated a small Internet firm founded by one private person with restricted financial and personnel resources.

With this model we wish to understand the critical influences of variables that determine the evolution of a firm, especially of small and medium-size enterprises. This means that a model of firm evolution should explain both growth and decline up to bankruptcy. Start-up firms face a number of critical periods during their evolution. Literature investigated a number of reasons but usually they are not combined into a whole model. For example, the Institute for the Study of SME's presented a comprehensive survey of causes for insolvency in German firms[5]. Their list contains 81 causes for insolvency that were grouped into the following categories: leadership, procurement, sales, administration/personnel matters, structure, performance, financing, accounting, credit institutes (banks), customers, suppliers, competitors and the social-economic framework. This investigation found a ranking of these groups. The most important causes for insolvency came from weak leadership, followed by problems with financing and sales. Despite methodological weaknesses of such investigations and the time dependency of their results they give a general impression or even a checklist of possible causes, which determine the evolution and the fate of SME's. However, such investigations cannot explain why any of the named factors causes insolvency of one firm whereas it does not harm another firm's evolution. We argue that this depends on the interdependency of all of those factors and on the quantitative value of each variable

[3] See Schwarz and Maybaum (2004, 18-25).
[4] See an attempt by Schwarz and Maybaum (2001, 6)
[5] Insolvenzursachen mittelständischer Betriebe (1976, 57-58).

as well. A single variable can be regarded critical (loss and insolvency generating) or profit generating only if its value is evaluated in the context of the values of all other variables and the time paths of all of them.

In a former paper we developed a dynamic model that can help to investigate the evolution of small firms. In the simulations with this model the path to bankruptcy could be found only under some hard assumptions.[6] In the present paper we present a new version of that model that we name Cottbus 1. We drop the former assumption that the market can not be contested (which was the case with the real Internet firm). The price for the product of the firm will be compared with the reference price in the market. The demand for the product is influenced besides marketing and reputation by the price and by weak service too. The marketing budget is now restricted to a plausible percentage of the available liquidity. We have added a vintage perspective (or an aging chain) for the equipment to the model. The results of the simulations over time are shown in the form of balance sheets and income statements.

The structure of this paper is as follows. The basic characteristics of the firm are described in the next section. First the relations between the variables of the firm are shown within a causal loop diagram. Then the structure of the system dynamics model will be outlined in terms of the stock and flow variables. In section three we present the results of simulation runs with the model. After the base case of normal growth we investigate the effect of some of the causes for insolvency: extensive private consumption of the entrepreneur, the case of credit restrictions and a declining demand. In the final section we discuss the results and some directions of further work.

2. Outline of the basic model structure

The firm policy focuses on profitable growth avoiding any risk of going into private bankruptcy. It is a one-product firm. The supply of this product meets a demand. The flow of the production factors and the sales of the products are expressed in money terms as revenues and costs. Their difference is the profit, which has to be maximised in the long term. A part of the profit gained is being reinvested to support firm growth.
The growth of the firm is assured by hiring staff and investments in physical assets.

The characteristics of this start-up firm constitute the main **assumptions for the model Cottbus 1**: The firm adds features and service to a special innovative product and uses the Internet for advertising. It ships the product in a traditional way. Profit making is the dominant short and long-term objective for the entrepreneur. Market demand is growing. Orders placed by customers can be completed when products are in stock and when both the needed staff and capacity are available. The components of the product are purchased when orders arrive. That policy minimises storage and capital costs. There are no delays in payments by customers.

[6] Schwarz and Schöneborn (2004).

The entrepreneur decides to expand the firm's activities only when hiring and investing is based on his own capital. Liquidity is his main decision criteria in the start-up phase. The firm has no long term credits.

The causal-loop diagram (Fig. 1) illustrates the dynamic relations between product and market characteristics, customers, and financial elements.

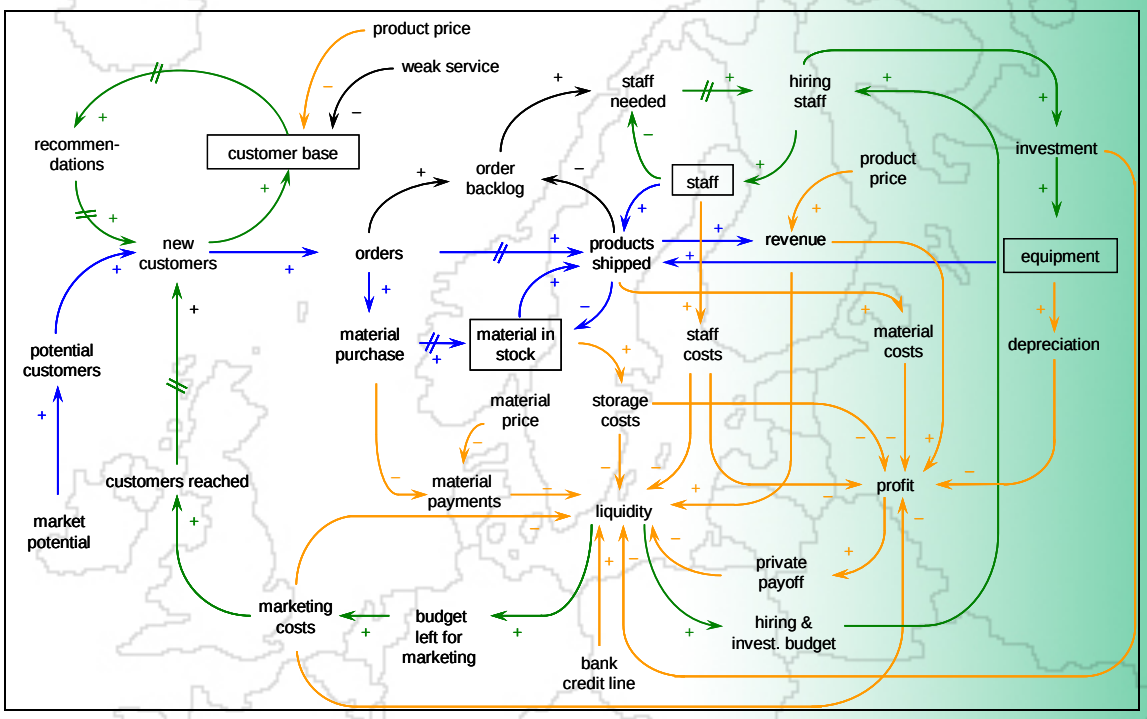


Fig. 1: Causal loop diagram of the firm

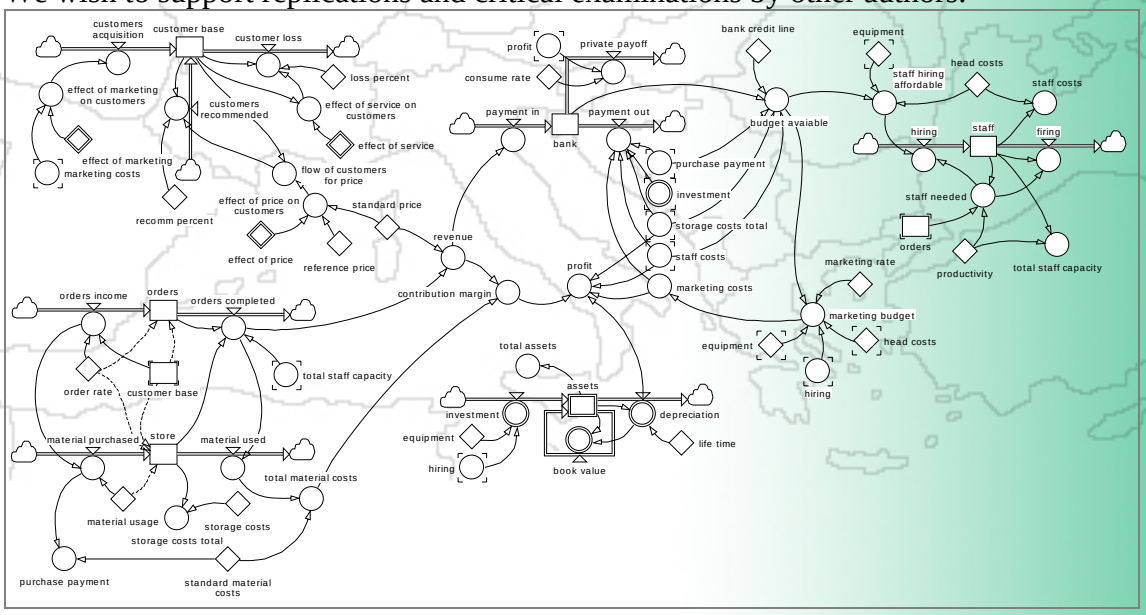
Starting from the market potential for the firm's product the central line in the diagram shows the core business chain from market potential to sale of the product. Depending on customer orders components are purchased which increase stock and storage costs. The products can be shipped if components are in stock and enough staff capacity is available. The number of orders processed and the number of products shipped influence the order backlog. If the order backlog increases hiring of added staff is necessary to adapt capacity in order to provide customers with the product within an acceptable delivery time. The number of products shipped and the product price determine the revenue. An increase in revenue leads to an increase in liquidity and profit as well. Profit is calculated as the difference between revenue and costs (material costs, staff costs, depreciation, storage costs and marketing costs). In addition to the bank credit line and the revenue the liquidity depends on some more variables. All unavoidable payments by the firm decrease liquidity: the amount of money for purchasing components, storage costs, staff costs, marketing costs, investments as well as a certain private pay-off to the entrepreneur. This payoff is only possible if the profit of the past period was positive.

There are two basic feedback loops for the expansion of the firm which are both determined by the liquidity as the main control variable of the firm. If the firm has accumulated enough liquidity it is spent for a hiring of new experts (right hand loop) and for marketing (left hand loop). Hiring of new staff (when needed because of an order backlog) is prior to additional marketing expenses. When new experts are hired an investment in equipment is necessary. The growth in staff and equipment allows more products to be shipped. A third feedback loop is reinforcing and shows the relation between new customers and the customer stock. Former customers generate new customers through recommendations.

Based on those causal relations between variables determining the growth of this firm a system dynamics model was developed. The corresponding stock and flow structure of the system dynamics model is shown in Fig. 2.

It consists of a customer sector with variables influencing the dynamics of new customers. The second part of the model represents the value chain of the firm: order processing, component purchase and product shipment. The third and most interesting sector of the model captures the dynamics of the liquidity (represented by the bank account) which controls the growth of the firm. Revenue and all payments are modelled as flows. Further sectors include variables influencing the growth of the staff and the equipment as the main restrictions on capacity. Capacity expansion by hiring or investing is important for the internal growth of the firm. The feedback loop starts with budgeting where the financial opportunities as well as staff and investment demand and additional marketing activities are modelled. After staff and investment demand is covered a marketing budget may be left which is used to model the acquisition of new customers.

The appendix all equations of the model can be requested by email from the authors. We wish to support replications and critical examinations by other authors.[7]



[7] The limited space of this paper is the only reason we could not do it here.

Fig. 2: System dynamics model of the firm

3. Results of the simulation runs with Cottbus 1

3.1 Base case

The starting point of the model was the observation of a real start-up firm. The objective of this model was to get a simulation result which is close to the real financial performance of the observed firm. Therefore in the structure of the model as shown in Fig. 2 some specific assumptions about parameters and initial values describe special features of the real firm (see the parameters in appendix A). These can be changed according to different strategic options of the entrepreneur. This will be the subject of the next scenarios and of further research. After running the simulation the results are displayed through spreadsheets and graphs. They are also shown in the form of balance sheets and income statements (see Fig 3.) The following results focus on some important variables which feature the dynamics of customers, orders, products, staff and capital assets as indicators of the firm's growth as well as key financial figures.

For the base case we can show here because of the restricted place only the development of staff (Fig. 4) as an important indicator of the growth of a firm. As assumed, the hiring of a new expert leads to an additional investment in equipment which the firm needs to process the products. Therefore the staff and the capital assets show the same time behaviour. The key financial figures will be shown in comparison with the results for the scenarios in the next section.

After the base case of normal growth we investigate the effect of some of the causes for insolvency from the survey of Institute for the Study of SME's in Germany.[8] As we already mentioned in the introduction, the most important causes for insolvency came from weak leadership, followed by problems with financing and sales. We select the following variables from the more detailed causes in each of the three groups as an indicator: excessive private consumption of the entrepreneur, credit restrictions and declining demand.

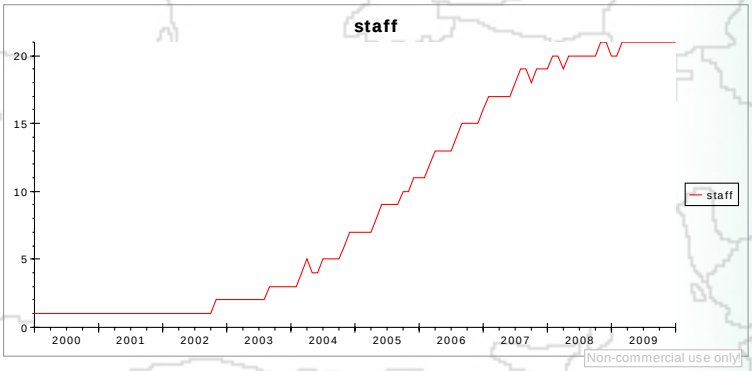
[8] Insolvenzursachen mittelständischer Betriebe (1976, 57-58).

Income Statement

from 1/1/ until 12/30/2009

Turnover	+18,543,750.00 €
+ Stock changes of goods	+0.00 €
- Raw and working materials	+11,140,650.00 €
= Gross profit margin	**+7,403,100.00 €**
- Personnel costs	+552,872.00 €
- Depreciation	+10,839.00 €
- Accruals	+0.00 €
- Other expenses	+6,395,934.80 €
= Operating result	**+443,454.20 €**
+ Interest receivable	+0.00 €
- Interest expense	+0.00 €
= Net income for the year	**+443,454.20 €**
- Income taxes	+0.00 €
= Net profit	**+443,454.20 €**

Fig. 3: Example of an Income Statement

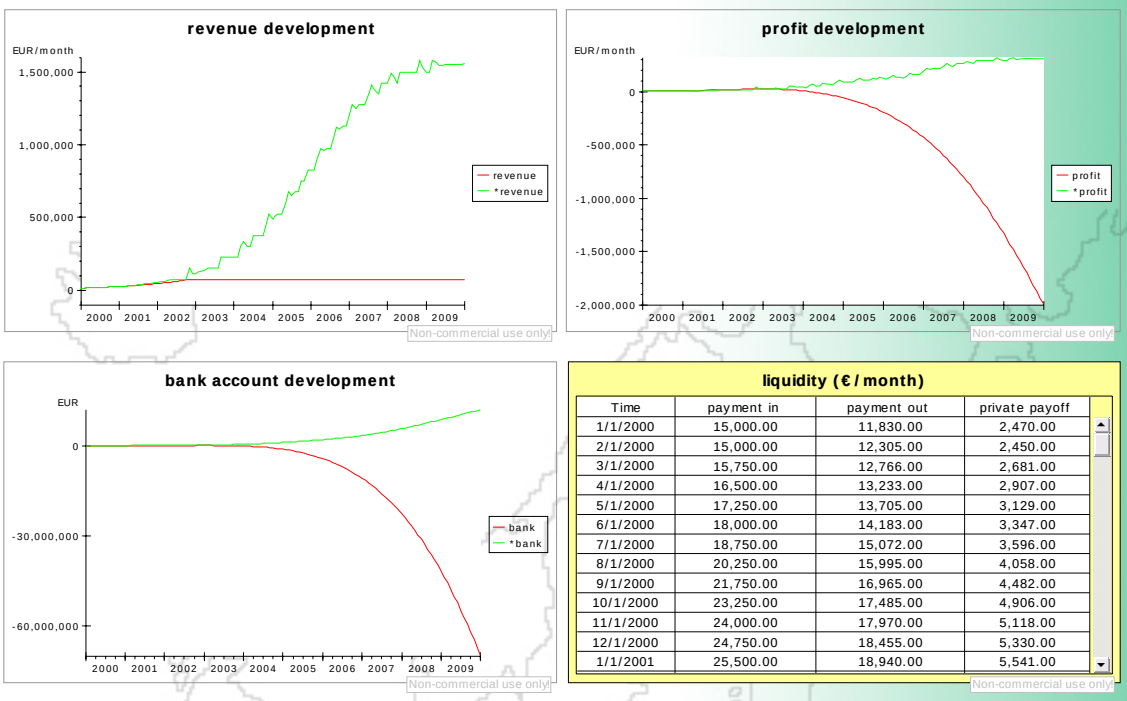


staff (head / month)

Time	hiring	firing
1/1/2000	0.00	0.00
2/1/2000	0.00	0.00
3/1/2000	0.00	0.00
4/1/2000	0.00	0.00
5/1/2000	0.00	0.00
6/1/2000	0.00	0.00
7/1/2000	0.00	0.00
8/1/2000	0.00	0.00
9/1/2000	0.00	0.00
10/1/2000	0.00	0.00
11/1/2000	0.00	0.00
12/1/2000	0.00	0.00
1/1/2001	0.00	0.00

Fig. 4: Simulation results for staff

3.2 Results in the case of excessive private consumption of the entrepreneur



liquidity (€ / month)

Time	payment in	payment out	private payoff
1/1/2000	15,000.00	11,830.00	2,470.00
2/1/2000	15,000.00	12,305.00	2,450.00
3/1/2000	15,750.00	12,766.00	2,681.00
4/1/2000	16,500.00	13,233.00	2,907.00
5/1/2000	17,250.00	13,705.00	3,129.00
6/1/2000	18,000.00	14,183.00	3,347.00
7/1/2000	18,750.00	15,072.00	3,596.00
8/1/2000	20,250.00	15,995.00	4,058.00
9/1/2000	21,750.00	16,965.00	4,482.00
10/1/2000	23,250.00	17,485.00	4,906.00
11/1/2000	24,000.00	17,970.00	5,118.00
12/1/2000	24,750.00	18,455.00	5,330.00
1/1/2001	25,500.00	18,940.00	5,541.00

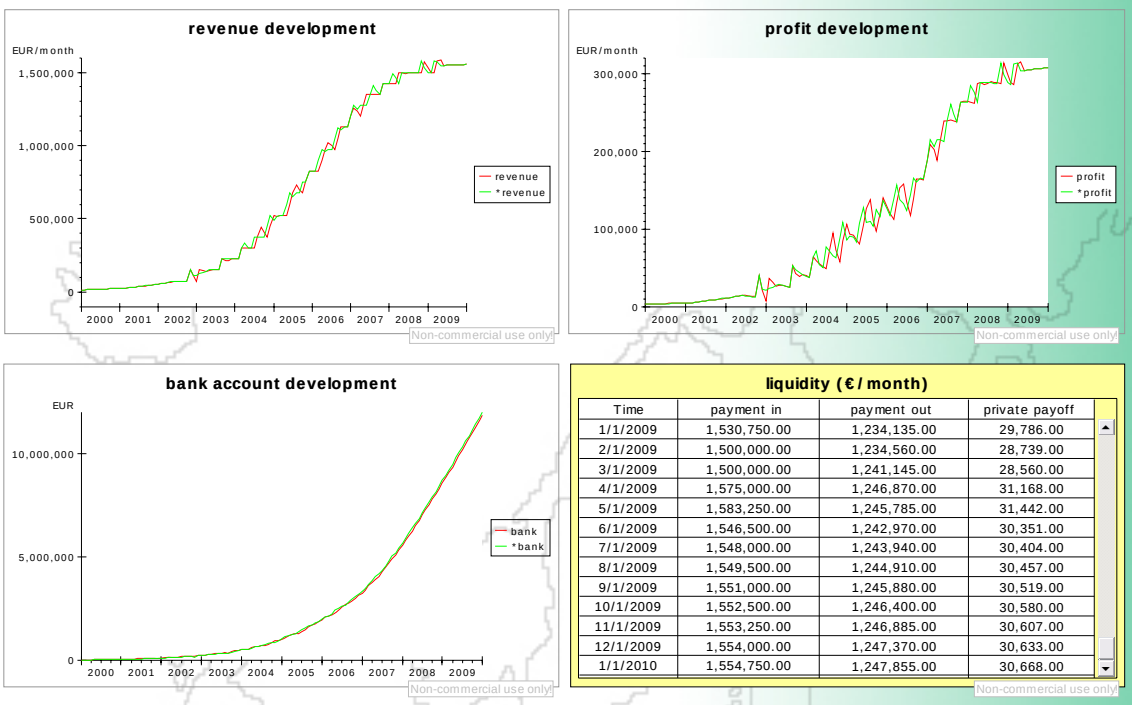
Fig. 5: Simulation results for key financial figures in scenario 1

In the base case a special assumption was taken: the entrepreneur takes 10 % of the profit made in the month before for private purposes. Now we change that value to 80 %. That value represents a strategy of the entrepreneur that short-term-oriented high private consumption is superior to a perspective of long-term growth. The figures show both scenarios. The base case results are illustrated with "*" in the pictures. The new scenario results are shown without any added sign. The following figure shows the key financial figures. As one can expect this strategy leads to bankruptcy.

3.3 Results in the case of credit restrictions

In the following scenario we want to examine the impact of a strong credit restriction policy of the bank. In the base case a special assumption was made: the bank account credit line is 10,000 euro and allows increasing the expansion budget for staff hiring, investment and additional marketing. Now we change that value to 0 euro. The following figure shows key financial figures.

When looking at the graphs there is no significant difference in the results of the financial figures. The revenue per month grows in the same path like in the base case. There is only one difference: a certain delay of some months. That means that revenue and profit will not develop as fast as in the base case. But at the beginning of the simulation the bank account is sometimes below 0 euro. It could bring the firm into bankruptcy if a bank with restricted credit policy does not accept few losses in the start-up of a firm.



liquidity (€ / month)

Time	payment in	payment out	private payoff
1/1/2009	1,530,750.00	1,234,135.00	29,786.00
2/1/2009	1,500,000.00	1,234,560.00	28,739.00
3/1/2009	1,500,000.00	1,241,145.00	28,560.00
4/1/2009	1,575,000.00	1,246,870.00	31,168.00
5/1/2009	1,583,250.00	1,245,785.00	31,442.00
6/1/2009	1,546,500.00	1,242,970.00	30,351.00
7/1/2009	1,548,000.00	1,243,940.00	30,404.00
8/1/2009	1,549,500.00	1,244,910.00	30,457.00
9/1/2009	1,551,000.00	1,245,880.00	30,519.00
10/1/2009	1,552,500.00	1,246,400.00	30,580.00
11/1/2009	1,553,250.00	1,246,885.00	30,607.00
12/1/2009	1,554,000.00	1,247,370.00	30,633.00
1/1/2010	1,554,750.00	1,247,855.00	30,668.00

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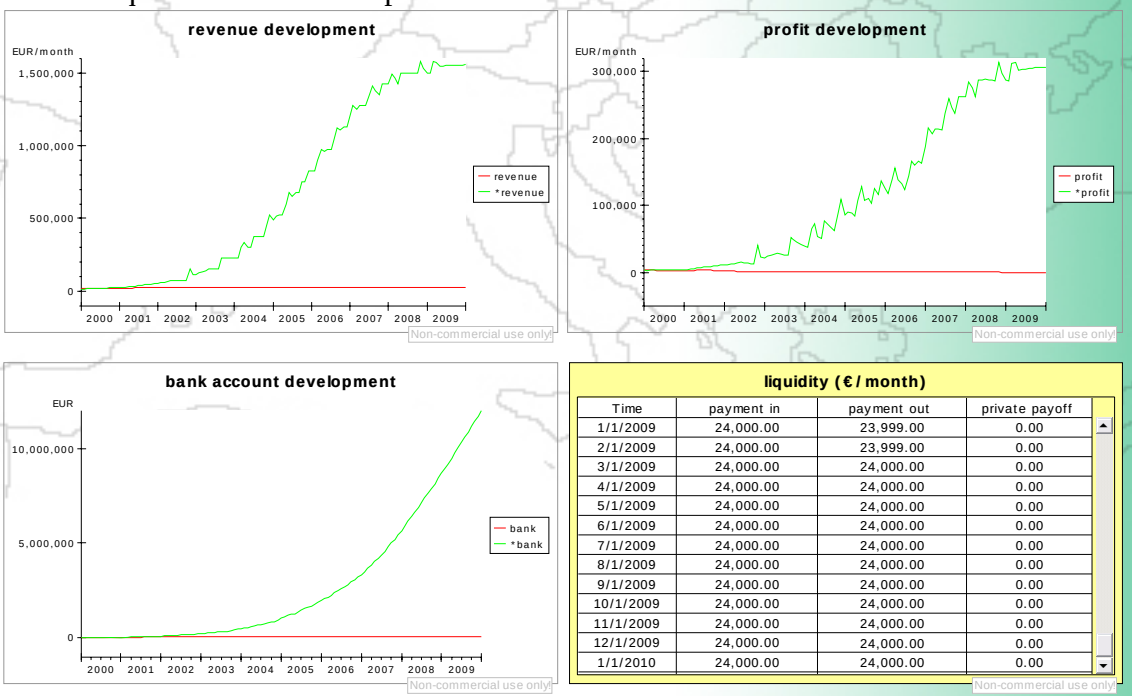
Fig. 6: Simulation results for key financial figures in scenario 2

3.4 Results in the case of declining demand

In the model demand is influenced by pricing and by weak service. In this scenario we examine only the impact of a price rise by 50€ for the product (from 750€ to 800€). The firm again goes bankrupt. With the control panel in the model the user can investigate the consequences of different price rises.



liquidity (€ / month)

Time	payment in	payment out	private payoff
1/1/2009	24,000.00	23,999.00	0.00
2/1/2009	24,000.00	23,999.00	0.00
3/1/2009	24,000.00	24,000.00	0.00
4/1/2009	24,000.00	24,000.00	0.00
5/1/2009	24,000.00	24,000.00	0.00
6/1/2009	24,000.00	24,000.00	0.00
7/1/2009	24,000.00	24,000.00	0.00
8/1/2009	24,000.00	24,000.00	0.00
9/1/2009	24,000.00	24,000.00	0.00
10/1/2009	24,000.00	24,000.00	0.00
11/1/2009	24,000.00	24,000.00	0.00
12/1/2009	24,000.00	24,000.00	0.00
1/1/2010	24,000.00	24,000.00	0.00

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Fig. 10: Simulation results for key financial figures in scenario 3

Finally, that scenario gives the strong idea that, in addition to pure financial figures, a good estimation of the possible impacts of price policy and service quality on demand are as important as liquidity orientation for the start-up firm's survival and growth.

4. Conclusions

The model Cottbus 1 presented in this paper reflects basic concepts of the theory of the firm and at the same time the attitudes and work experience of an entrepreneur who founded a small start-up firm. For the base case the results of the simulation show that the basic business dynamics is replicated. The entrepreneur's policy of not taking long-term credits from banks leads to a discontinuous growth. Only after enough capital is accumulated in the bank it will first be used for new staff and equipment. The second priority is the marketing budget. This growth path no longer holds if the start-up firm has a weak leadership or if it faces a restricted credit limit or a declining demand. However, these causes have the effect of insolvency only if the variables exceed some boundary value. The model can be used as an additional learning tool for entrepreneurs of start-up firms. It shows that liquidity is a more important control variable to avoid bankruptcy. Moreover, it emphasizes the role of a flexible bank credit. Therefore bankers should recognize that dynamic behaviour of a small firm during its initial period of operations.

The model has been restricted to a minimal set of elements of a viable firm and to some strict assumptions which can be relaxed. Other scenarios for the growth of a small firm will be the object of our further research. A more principal direction of further research can expand the elements, sectors and problems incorporated. Firstly, it would be interesting to explore the effect of some more intangible assets. Secondly, factors influencing the productivity are of interest, above all effects of the innovation of the product and the development of the human capital.

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