DISCUSSION PAPER

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INVESTMENT, CREDIT CONSTRAINTS AND PUBLIC POLICY IN A NEOCLASSICAL ADJUSTMENT COST FRAMEWORK

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ABSTRACT

This paper deals with the analysis of the impact of credit rationing on the farmer's economic equilibrium and the analysis of different policy scenarios in a derived neoclassical adjustment cost framework. The theoretical model is an optimal dynamic investment model, in which the upper bound on investment is introduced. The limit of the investment enables to analyse the consequence of the occurrence of credit rationing on farmer's capital accumulation, investment and supply. The method of optimal control is used to solve the optimization problem. The results show that the occurrence of credit rationing may significantly determine a farmer's economic equilibrium. Then the analysis of defined policy scenarios suggests that a loan guarantee efficiently solves the problem of the occurrence of external credit rationing. Interest rate subsidy may produce overinvestment and, thus, increases the probability of occurrence of the crowding-out effect, especially in the group of non-credit constraint farmers. Moreover, as far as the cost of agricultural policy is concerned, other agricultural support tools are less effective. The numerical application shows that the farmer's economic equilibrium is mostly sensitive to the initial bound on investment, the parameter of the cost function, the price, the level of technology and the discount rate. Finally, if the uncertainty is introduced, then the level of investment spending and capital accumulation is lower.

JEL: C61, Q12, Q14, Q18

Keywords: Credit constraint, investment, capital, SGAFF (Supporting and Guarantee Agricultural and Forestry Fund), Adjustment cost and farmer's economic equilibrium.

ZUSAMMENFASSUNG

INVESTITIONEN, KREDITRATIONIERUNG UND AGRARPOLITIK IN EINEM DYNAMISCHEN NEOKLASSISCHEN MODELL MIT ANPASSUNGSKOSTEN

Das Diskussionspapier beschäftigt sich den Einflüssen der Kreditrationierung auf das unternehmerische Verhalten von landwirtschaftlichen Betriebsleitern und wie dieses durch agrarpolitische Eingriffe beeinflusst wird. Die Effekte werden mit Hilfe eines dynamischen neoklassischen Investitionsmodels mit unteren und oberen Schranken analysiert. Neben der Investitionstätigkeit werden in diesem Kontext die Konsequenzen der Kreditrationierung auf die betriebliche Kapitalakkumulation und das landwirtschaftliche Angebot untersucht. Die Modelle werden mit Hilfe der Kontrolltheorie gelöst. Die Ergebnisse zeigen, dass die Kreditrationierung die Entwicklungsmöglichkeiten der landwirtschaftlichen Betriebe erheblich einschränken. Darüber hinaus ergab sich bei der Analyse von Politikszenarien, dass sich die negativen Effekte der Rationierung durch die Einführung von Bürgschaften effizient reduzieren lassen. Zinssubventionen können dagegen zu einer Überinvestition und Mitnahmeeffekten in der Gruppe der Landwirte führen, die nicht kreditrationiert sind, wodurch auch eine Verdrängung privater zugunsten öffentlich geförderter Investitionen erfolgt. Andere agrarpolitische Eingriffe sind weniger effektiv, insbesondere wenn die Kosten der Durchführung dieser Maßnahmen berücksichtigt werden. Simulationsberechnungen zeigten, dass das langfristige Gleichgewicht der Betriebe durch den anfänglichen Zugang zu Krediten, der Parametern der Kostenfunktion, den Produktpreis, dem Stand der Technologie und dem Zinssatz beeinflusst wird. Wird Unsicherheit in dem Model berücksichtigt, so führt dies generell zu einer geringeren Investitionstätigkeit und zu einer geringeren Kapitalakkumulation.

JEL: C61, Q12, Q14, Q18

Schlüsselwörter: Kreditrationierung, Investitionen, Kapital, EAGFL (Europäische Ausrichtungs- und Garantiefond für die Landwirtschaft), Dynamische Anpassungskosten und langfristiges Gleichgewicht.

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1 INTRODUCTION

Traditional macroeconomic analysis assumes that the credit market works efficiently and is cleared by the interest rate. The analysis is, however, based on the strong assumption that economic agents have full-information. If the assumption of full-information is relaxed, market efficiency deteriorates. In other words, the information asymmetry among debtors and creditors has a negative effect on the market mechanism, i.e. the market is not cleared by the interest rate. Creditors are not able to observe sufficiently bad debtors due to the presence of imperfect information. As a result a certain part of potential debtors might be rationed.

Generally speaking, credit rationing occurs in cases when the economic agent, i.e. in our case the farmer, has limited access to credit even if she/he is able to pay a higher interest rate than the market interest rate. The occurrence of this phenomenon can be explained in terms of information economics. Farmers willing to pay a higher interest rate belong to the group of high risk clients. Their investments have a high rate of return but at the same time are very risky. That is why higher interest rates increase the problems of adverse selection and moral hazards, and vice versa. It is empirically proved that banks set limits on the loan amount. Then, there is a surplus of loan demand over loan supply in reality. Banks (and other financial institutions) do not clear the credit market by the interest rate and in this sence the element of frustrated demand is always present.

Plenty of definitions of credit rationing can be found that are more or less specific. Also more reasons for the occurrence of credit rationing can be identified which depend on the specific factors of a given economy and/or a sector of interest. No matter what the credit rationing definition is, it is always the case that the farmer does not access the loan or has limited access. The restriction can be either external or internal. External credit rationing is the case when the farmer's application is refused by the bank. LLEWELLYN et al. (1991) identified three forms of external credit rationing. First, the situation in which banks set the risk limits that they are willing to accept, is called risk-treshold rationing. Second, disequilibrium rationing is the support of a visible and measurable surplus of loan demand over loan supply. Third, the equilibrium or market-clearing rationing is the situation in which the other forms of financing are set up in a way that causes the shift of the loan demand. Llewellyn identified two basic reasons for the occurrence of external credit rationing that are not mutually exclusive. That is, either the banks are risk averse or they have imperfect information. BESLEY (1994), in the analysis of market failures in rural credit markets of developing countries, concludes that the source of external credit rationing might be high transactional costs and/or the insufficient supply of funds. The next source of external credit rationing might be, according to PETRICK (2004), government intervention that has the form of imposed regulations or interest ceilings. Internal credit rationing is the case when the farmer does not apply for the loan even if she/he would like to. The reasons for internal credit rationing might be (see LATRUFFE et al., 2002) that the farmer is not able to meet the conditions of the loan contract or she/he is discouraged by the high cost during the application process and after that.

In general, credit financing becomes important when it is significant and scarcely substitutable part of firm's cash flow. In this situation, credit rationing may determine the firm's economic activity. The more difficult is the substitution in the form of shareholder's capital and/or business credit, the more significant may be the impact of credit rationing on the firm. Taking into account the extreme form, i.e. the impossibility of credit (loan) financing substitution, then the credit rationing occurrence causes the decay of firm's production because the firm has not enough money for purchase and rent of inputs into the production. The rate of substitution is determined by the firm's size and activities. In the case of direct loan substitution, BLINDER and STIGLITZ (1983) conclude that "although the credit market is "competitive" in the usual sense (free entry, many buyers and sellers), lenders will view different borrowers as highly imperfect substitutes, and borrowers will have the same attitudes about different lenders – at least in the short run. There may, in particular, be classes of borrowers (like small businesses) for whom denial of credit by "their" bank has the effect of making credit inaccessible."

Moreover, it is empirically proved that the small and middle firms are first affected by the restrictions of the credit market. The agricultural sector is characterized by a high number of small enterprises or farmers, respectively, the low profitability and low collaterals point that credit rationing may be an important determinant of their development. The analysis which is carried out in this paper, aims at the examination of credit rationing impact on economic equilibrium of farmers in different public policy settings.

2 AIMS AND METHODOLOGY

The aim of this paper is to analyze the impact of credit rationing on the economic equilibrium of farmers and to analyze different policy scenarios in a derived neoclassical adjustment cost framework.

The theoretical analysis should answer the following questions: What is the potential effect of the credit rationing on farmer's economic equilibrium or, more specifically, on farmer's capital accumulation and supply function, respectively? What is the role of SGAFF (Supporting and Guarantee Agricultural and Forestry Fund) and other agricultural support mechanisms?

The strategy of the analysis is as follows. The role of agricultural loans in Czech agriculture is analyzed to evaluate the importance of credit financing. As a result, the impact of credit rationing occurrence might be deduced. Analysis of the SGAFF may show the role of the fund in the support of agricultural loans. The derived theoretical model in the form of a dynamic investment model enables the analysis of the impact of credit rationing on the farmer's investment, the capital accumulation and the supply function in a dynamic framework, i.e. the analysis shows the paths of farmer's investment, capital and supply. Comparative dynamic analysis provides us with the comparison of different scenarios and results in the analysis of their consequences. Finally, the synthesis of the results from the empirical part, theoretical analysis and numerical application is carried out and discussed.

The hypotheses of the paper are as follows:

(i) The occurrence of credit rationing in the agricultural loan market significantly determines the capital accumulation and investment decisions of farmers and as a result their supply functions.

(ii) The SGAFF's activities efficiently solve the problem of the occurrence of credit rationing.

(iii) Other agricultural support (defined in the paper) is less effective.

The hypotheses are verified, based on the analysis of a derived theoretical model in different scenarios. The following scenarios are analyzed and simulated:

(i) Scenario 0 – The situation without any support serves as a baseline.

(ii) Scenario 1 – Represents the support of the SGAFF. As the SGAFF offers different programs with different support (see section 4.1 of this paper), the following situations are analyzed:

   a. Loan guarantees;

b. Interest rate subsidies;
c. Loan guarantees and interest rate subsidies.

Scenario 2 – Represents the support in the form of direct payments

To sum up, the content of the paper is the following. Firstly, literature overview is carried out. Secondly, the analysis of agricultural loans and their institutional support is introduced. Thirdly, the theoretical model in the form of a dynamic model is derived. The dynamic analysis is carried out and the above-mentioned scenarios are analyzed. Fourthly, the numerical application or sensitivity analysis is processed, respectively. Fifthly, the model with uncertainty is introduced. Finally, the theoretical-empirical consequences are drawn.

The data set in part 4.1 is available in the annual reports of the SGAFF 2000-2005 and in the "Green Report" (The annual report of the Czech agriculture) 1994-2005.

As we deal with credit rationing and economic equilibrium, we must define how these two terms are employed for our purposes. External credit rationing is a situation where a farmer or a group of farmers apply for a loan but do not receive it or do not receive the demanded amount. Internal credit rationing means that a farmer or a group do not apply for a loan although they would like to. The farmer's economic equilibrium in this paper is the state when the farmer follows the optimal path of capital, investment and supply without financial constraint during the time period.

The theoretical model is defined in the form of a dynamic optimization model. The derived model stems from the simple investment model. The paper is novel because of the introduction of upper constraints on the control variable, which represents the occurrence of credit rationing, and solution and analysis of the paths of capital, investment and supply in the situation of financial constraints under defined scenarios. The method of optimal control is used to solve the optimization problem.

The numerical application examines the sensitivity of paths to different parameters change. The parameters' values represent the characteristics of agricultural enterprises with 100 and more employees during the period 1998-2002.

3 LITERATURE OVERVIEW

Two important model approaches that deal with credit rationing can be brought in. First of all, the reasons for the occurrence of credit rationing are analyzed in the framework of information economics or more specifically in the framework of asymmetric information models. Then, the implications of credit rationing or generally financial constraints are theoretically studied by the dynamic investment or farm-household models. Moreover, the broad family of investment models has been empirically applied for the analysis of credit market imperfections.

The asymmetric information models are especially represented by models that belong to the large family of Stiglitz's and Weiss's model. The paper by STIGLITZ and WEISS (1981) introduces the adverse selection theory of credit markets and many papers dealing with the credit rationing stem from their theory. The theory is based on two main assumptions: Banks cannot distinguish the risk types of borrowers and the second assumption is the limited liability of loan contracts. Then, the imperfect information leads to adverse selection and moral hazard problems which mean (under given assumptions) that lenders cannot increase the interest rates when there is excess demand in the credit market. Thus, imperfect information results in credit rationing. The theory has been further developed by e.g. BESTER (1985), BESANKO and THAKOR (1987a, 1987b). WILLIAMSON (1986, 1987) shows that in addition to the adverse selection and moral hazard problem, credit rationing may also exist due to the fact that asymmetric information produces costly state verification.

The dynamic investment models or farm-household models have been used to study the consequences of credit rationing or financial constraint, respectively. Among others, SCHWORM (1980) introduced the framework for the analysis of a capital accumulation path under financial constraint. He showed that investment behaviour is sensitive to imperfections in the capital market and the resulting financial constraints. STEIGUM (1983) analyzed the firm's optimal capital policy where the cost of borrowing depends on its debt-equity ratio. He showed that the rate of investment is related to the rate of profit retention and that the optimal plan can be approximated by a flexible accelerator model of investment. CHAMBERS et al. (1987) studied the implications of income, profit and consumption taxes on financially constrained farm households based on a dynamic inter-temporal framework. Then, the investment models were widely empirically applied in the study of credit market imperfection or firm's credit constraints, respectively, e.g. by TYBOUT (1983), KLACKREUTH (2004), BOND et al. (1994, 2003). In the Czech Republic the analyses of the credit rationing problem by using investment models were processed by e.g. LÍZAL (1996), LENSINK et al. (1998) and the broad analysis of investment, credit rationing and the soft budget constraint was carried out by LÍZAL et al. (2001) using panel data on 4000 industrial firms during 1992-1998. The authors found among other things that firms, especially small firms, face credit market imperfections and in LÍZAL (2001) cooperatives are credit rationed. In the agricultural sector the investment models are applied in the study of credit market imperfections by e.g. HUBBARD et al. (1992), BENJAMIN et al. (2002) and in the Czech Republic – by MEDONOS (2007). MEDONOS (2007) used the accelerator model to analyze the investment behaviour of agricultural corporations. He found that the highest investment sensitivity was in the group of less technical efficient enterprises and mid-sized enterprises in 2002 and 2003 that may have been caused by the occurrence of credit rationing in these groups. On the other hand, in the period 1998-2003 high sensitivity was found in the group, which is not likely to be a credit constraint. Then, this group may rely more on retained earnings rather than on credit raised by financing investments.

Furthermore, the credit problematic has been studied at both microeconomic and macroeconomic levels in the Czech Republic by several authors. IZÁK (1998), HAMPL and MATOUŠEK (2000) and others analyzed the macroeconomic consequences of credit. BUCHTÍKOVÁ (1997 and 1999) studied the role of credit in different sectors. The authors conform that credit played an important role in the Czech economy at both microeconomic and macroeconomic levels in the nineties. Credit rationing in Czech agriculture has been theoretically analyzed by JANDA (1994, 2002) and both theoretically and empirically – by ČECHURA (2005). JANDA (1994) employs an asymmetric information model to study the credit rationing problem and the role of SGAFF. He found that programs were more socially and economically efficient if they were open to all farmers instead of only low risk farmers who are refused by the bank. Based on an empirically applied theoretical framework, ČECHURA (2005) concluded that large agricultural enterprises were not sensitive to the possible occurrence of credit rationing but that may not be the case for small agricultural enterprises. The activities of SGAFF, which were founded to make agricultural loans more accessible to farmers, were further analyzed by e.g. BEČVÁŘOVÁ (2006), ČECHURA (2006), JANDA and ČAJKA (2006), JANDA (2006), ŠILAR (1995). The authors agree that SGAFF makes agricultural credit accessible, although several aspects of their activities were criticized.

4 RESULTS

4.1 Agricultural loans and their institutional support in the Czech Republic

The system of agricultural subsidies during the period 1991-1993 that was especially regarded by the Ministry of Finance to be inefficient, arose a discussion about the change in the system of the support of Czech agriculture and forestry. The change should have led to a more effective factors employment.

The partial subsidised and guaranteed loan seemed to be a more effective way of agricultural support compared to other alternatives. The most important reasons are (see ŠILAR, 1995): a) the bank loan ensures the market allocation of capital into agriculture, b) the bank loan supports market allocation of capital inside the agricultural sector and c) the risk is distributed among the bank, the state and the farmer.

The SGAFF (Supporting and Guarantee Agricultural and Forestry Fund) was founded on 23rd June 1993 to support the loan creation in Czech agriculture in the form of a partially subsidised interest rate and/or a partially guaranteed loan. The loan guarantee and interest rate subsidy have been granted to agriculture from 1994 according to the defined rules and in the frame of the defined programs, i.e. for a specified purpose. Three basic programs were set out in 1994: OPERATION, FARMER and SERVICES. These programs were subsequently supplemented by specific programs, which have also had a one-shot object. The program EXPORT was approved in 1997. It was the first program in which the non-agricultural entrepreneurs could get support. The program INVESTMENTS with subprograms FARMER, MARKETING BOARD, PROCESSER was approved in 1999 and the program HYGIENE – on 1st July 2000. The supplementary program YOUTH was set out to support young farmers. The important change occurred due to the entrance of the Czech Republic into the EU. The program OPERATION, which provided farmers with loans for operating activities, was abolished by the entrance into the EU. The supports were granted in frame of programs INVESTMENTS, YOUTH and OFFSET OF INTEREST RATE CHARGE in 2005. As far as the further details about the programs are concerned, they are not introduced due to the object of the analysis.

Support in form of partially subsidised interest rate and/or partially guaranteed loan was chosen to maintain the criterial function of a bank loan and an interest rate. In other words, the SGAFF's supports may decrease the effect of asymmetric information on the agricultural loan market but they do not fully eliminate the result of the presence of asymmetric information. Thereby farmers have an access to bank loans, i.e. the occurrence of credit rationing is reduced. But herewith the market allocation of loans into agriculture works because the bank shares the business risk. Then, the efficiency of this allocation is significantly determined by the setting of the size of loan guarantee and interest rate subsidy. Credit rationing is here defined in two forms: External credit rationing and internal credit rationing (see the definition in part 2). The SGAFF's activities may reduce both forms of the credit rationing. However, the effects on each of the forms differ due to their unlike nature. What were the conditions of the agricultural credit market and what was the role of the SGAFF in financing agricultural activities in the period of 1994-2006? To find the answers it is the object of this part of the paper.

The development of agricultural loans in the period of 1993-2006 can be divided into three phases. The division into three parts was based on the calculation of the roots of the fitted polynomial trend function of total loans in economy (in mil. CZK). The polynomial trend function of the third order explains the variation in total loans from 94% and has the following form: $y = 0{,}94t^3 - 236{,}68t^2 + 17276t + 497713$. The first phase is from January 1993 till May 1997, the second phase from June 1997 till June 2002 and the third phase is from July 2002 till June 2006.

The analysis of the farmers' position on the loan market is thus made for these phases which are characterised by different conditions on the loan market. The product cycle and the corresponding setting of fiscal and monetary policy and the form of ownership of large banks were the most important determinants of different conditions on the loan market in the analysed period. The monetary policy performed its basic target, i.e. the maintenance of the stable price level. Among others, through the credit channel of monetary transmission the central bank determined the loan creation on the loan market.

The conditions on the loan market are important for the precise analysis of the agricultural loan and the evaluation of the role of the SGAFF in the analyzed period. Thus, we briefly describe the economic characteristics of the defined phases.

The first phase is characterised by the positive development of macroeconomic variables and optimistic expectations of economic agents. The amount of bank loans increased nearly in all sectors (except the household sector). This development was a result of several factors. The economy was in the growth phase and a number of investment projects were realized. Nevertheless, a lot of enterprises, which were privatized, had serious economic problems especially due to the unfinished or badly performed restructuring. These enterprises had debts from the past that they were not able to pay off. The old debts, which had the form of loans, were renewed and, thus, transferred to the future. But, due to the low efficiency, enterprises ran furthermore into higher debts. Moreover, the interest rate was too high according to the author's opinion and also the opinions of other economists (especially liberal economists). The costs of external recourses were in most cases higher than the capital profitability (even several times higher) that resulted in the additional increase of indebtedness of enterprises and then in the problem with solvency. Banks were not careful enough in this phase and provided the economy with necessary liquidity. The credit policy was also influenced by the political scene that indirectly advocated a sufficient availability of financial resources (especially till the year 1996). The loan market was then all the more important when the capital market did not provide the enterprises with the capital, generally speaking. The credit policy was also determined by the fact that the best part of the banks was not privatized yet. The central bank changed its policy in autumn 1996 due to the persisting external and internal imbalance of Czech economy. That is, the central bank began with the restrictive monetary policy to support the balancing processes. The monetary turbulences occurred in the middle of 1997 that caused the discomposure on the financial market. The credit policy was also influenced. Banks started to revaluate their credit portfolios due to several reasons. Among others, we can name the increase of the classified and irredeemable loans, maturity of many investment loans, the unsure development of enterprises and the need to improve the portfolio due to the successful privatization.

The second phase, from June 1997 till June 2002, can be divided into two parts according to the course of monetary policy. In the first part, i.e. from June 1997 till autumn 1998, the central bank exercised the restrictive monetary policy. The banks continued the improvement of their credit portfolios. The revaluation of credit portfolio and other important determinants caused the change of bank credit policy, which was characterized by risk aversion. That is, banks tried to target on less risky clients, i.e. to minimize business risk. The change can be observed from the time series of total loans of individual sectors and branches of Czech economy. The second part of this phase, i.e. from autumn 1998 till June 2002, is characterised by the expansive monetary policy. The change from the restrictive to expansive monetary policy was determined by the positive figures of inflation and the need to support economic growth. Large banks were already in the hands of private capital in this period and continued in careful credit policy aiming at the risk minimization. The empirical evidence is the drop of total loans in the sector of non-financial enterprises and the significant increase of total loans in the sector of governments and households. Moreover, according to this it can be deducted that the group of small and middle enterprises faced the credit rationing phenomenon (at least internal).

The third phase is defined from July 2002 till June 2006. The amount of total loans increased in this phase. The total loans of all branches went up as well (see the trend function in Table 1). The increase of total loans was determined by the positive economic environment, the expansive monetary policy and softer bank credit policy to the sector of non-financial enterprises (especially to the group of small- and mid-sized economic agents).

After the brief characterisation of economic environment and loan market, loan time series in individual branches of Czech economy with the particular interest in agriculture can be analysed in a greater detail. The analysis is based on the fitted trend functions for relevant phase of analyzed period. The trend functions are all linear and in most cases fit well to the analysed time series.

Table 1 contains the trend function of total loans in all branches of the economy, the trend function of total loans in agriculture and in food-processing industry. The total loans in all branches increased in the first period. The fitted trend function shows that the annual increase was 6 411.7 mil. CZK. The increase is typical for nearly all branches of the economy in this phase. Agriculture is therefore not an exception. The fitted agricultural trend function shows the growing trend with a slope of 157.29. It means that the annual increase in total agricultural loans was 157.29 mil. CZK according to the fitted trend function.

The second phase has opposite patterns. The time series of total loans in all branches has a decreasing trend with the annual decline of 2 343.6 mil. CZK. Nearly all branches exercised a decreasing trend of total loans in this phase. The agricultural trend function has the slope – 268.91, i.e. the annual decline of 268.91 mil. CZK.

The third phase is characterized by a further change in the loan market. That also results from the above-described economic conditions of the analyzed period and from the way of the determination of analyzed phases. The time series of total loans in all branches have an annual increase of 7 364.9 mil. CZK. Total agricultural loans increase as well, annually by 124.04 mil. CZK.

The trend analysis shows that agriculture copied the established tendencies in economy. However, it does not tell us anything about the position of farmers in the loan market. To answer the question at least partly, we may analyze the development of the ratio of total agricultural loans to total loans.

Table 1: Trend functions of total (state) loans (in mil. CZK)

Trend functions of total (state) loans (in mil. CZK)			
Phase	**Total loans (all branches)**	**Agriculture, hunting and fishery**	**Food-processing industry**
01/1993 - 05/1997	y = 592 869 + 6 411.7t; R^2=0.98	y = 24 108 + 157.29t; R^2=0.61	y = 25 411 + 478.86t; R^2=0.98
06/1997 - 06/2002	y = 920 368 – 2 343.6t; R^2=0.82	y = 33 020 – 268.91t; R^2=0.9	y = 55 457 – 396.75t; R^2 = 0.8
07/2002 - 06/2006	y = 690 235 + 7364.9t; R^2=0.93	y = 17 004 + 124.04t; R^2=0.88	y = 23 601 + 58.642t; R^2=0.44
Trend functions – The ratio of the branch on total loans			
01/1993 - 05/1997	x	y = 0.0407 – 0.0001t; R^2=0.27	y = 0.0439 + 0.0002t; R^2=0.81
06/1997 - 06/2002	x	y = 0.0363 – 0.0002t; R^2=0.88	y = 0.0611 – 0.0003t; R^2=0.67
07/2002 - 06/2006	x	y = 0.0242 – 5E-05t; R^2=0.29	y = 0.0332 – 0.0002t; R^2=0.77

Source: Own calculations.

Table 1 (in its second part) presents the trend function of the ratio of total agricultural loans to total loans in the sector of non-financial enterprises. The slopes of fitted trend functions in analysed phases suggest that the ratio of total agricultural loans to total loans went down in all phases. However, the decline in the third phase is slight. It suggests that farmers had the worst position on the loan market compared to economic agents from other branches. Moreover, it implies that farmers faced the credit rationing phenomenon with a higher probability. The worst position of agricultural enterprises was probably caused by a higher rate of indebtedness of agricultural enterprises, a low level of profitability of agricultural activities and, in general, of a higher riskiness of agricultural activities. However, the slight decrease of the ratio in the last phase (see the slope of the trend function) suggests that the rate of agricultural loan in the total credit portfolio of non-financial enterprises stabilized on the level of approximately 2.4 %. Thus, we may deduce that only competitive agricultural enterprises remained among the bank clients after the revaluation of the credit portfolio. Consequently, the presence of credit rationing might have been less probable. Though, this is not the case of internal credit rationing. Since the SGAFF was founded to support the creation of agricultural loans, its existence cannot be omitted in this phase of the analysis.

The specific models of credit rationing show that its occurrence is determined by limited supply, limited farmer's collaterals and transactional costs. The SGAFF partly solves these problems by interest rate subsidizing and loan guaranteeing. That is, the activities of the SGAFF should reduce the presence of credit rationing or in general – the effects of asymmetric information on the loan market. The activities of the SGAFF can be analyzed as follows.

Table 2 contains data about the supported total loans by the SGAFF, subsidised interest rate and the average interest rate in the economy. Table 3 presents the history of agricultural loans and table 4 contains indicators which can be used for a deeper examination of the role of the SGAFF in financing agricultural loans in the analyzed period.

Table 2: The supported total loans by the SGAFF, subsidised interest rate and average interest rate in economy

Supported total loans by SGAFF in period of 1994-2005 (mil. CZK, %)												
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
The number of application	2605	2945	3426	2540	1934	1746	1539	1723	1993	1802	2657	1917
Supported total loans	6235	10130	14847	14622	9299	7695	5324	6369	7361	6088	7963	5098
Supported invest-ment loans	4302	6787	9100	5088	4709	2008	2931	4012	4699	3045	4825	3371
Interest rate subsi-dies (prepaid)	1118	1008	2827	2700	2682	2208	1610	1333	1267	964	880	609
The size of loans guarantee	1544	4436	8265	4788	2307	1138	876	1129	1365	1714	2306	605
Subsidised interest rate by the SGAFF	x	x	x	x	12	9.3	9.7	9	8.1	6.9	5.8	3.49
The average interest rate paid by clients of the SGAFF	2.7	3.8	3.2	6.4	5.2	2.4	2	1.8	1.5	1.4	1.7	1.98
The average bank interest rate for clients of the SGAFF	x	x	x	x	17.2	11.6	11.6	10.7	9.6	8.3	7.5	6.72
The average bank interest rate in economy	13.1	12.8	12.5	13.2	12.9	8.7	7.2	6.8	5.2	4.5	4.7	4.2
Inflation	10	9.1	8.8	8.5	10.7	2.1	3.9	4.7	1.8	0.1	2.8	1.9

Source: Annual Reports SGAFF 2000-2004; Green Reports for years 1994-2004.

The average bank interest rate for clients of the SGAFF highly exceeded the average bank interest rate in the economy in all years. The average difference was 3.79 %. The subsidised interest rate by SGAFF had a decreasing trend from 1998. The decreasing trend is an analogy of the decreasing trend of the financial market interest rate. The decline in the financial market interest rate determined the fall of loan interest rates (see the transmission mechanism). As the decrease in the average bank interest rate for the clients of the SGAFF was larger than the decrease in the subsidised interest rate, the average interest rate paid by the clients of the SGAFF went down from 1998 as well. This decreasing trend was exercised till 2003 when the average bank interest rate for the clients of the SGAFF reached the level of 1.4 %, being 3.1 % less than the average bank interest rate in economy. That is, farmers or clients of the SGAFF faced a higher interest rate than other clients in the economy. However, if the farmer took part in the programs of the SGAFF and received a loan subsidy, the interest rate paid by him/her was significantly lower. The average interest rate paid by the clients of the SGAFF was lower than the average bank interest rate in the economy in all years and even lower than the rate of inflation in most of the years. It means that the real interest rate was negative in the greater part of the analyzed period (especially till 2002).

The size of supported total loans grew up till 1996 in which it reached 14 847 mil. CZK. After 1997 the supported total loans went down significantly. The supported total loans reached their minimum in 2000. From 2001 till 2004, the supported total loans moved inside the interval of 6 000 till 8 000 mil. CZK. The size of loans guarantee had similar patterns. The important point of the analysis is, however, the relation among the described time series and the variables on loan market and/or with the development of investments in agriculture.

Table 3: The development of total agricultural bank loans

Mil. CZK	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total loans – agriculture	26351	25749	30942	32154	31647	27999	26106	21699	17290	17893	19290	21729	22608
From that – investment loans	2497	3112	6325	7254	10049	12845	13009	11394	11138	12130	12348	13352	14706

Source: Green Reports for years 1994-2004.

Table 4: Chosen characteristics of agricultural loan market and operation of SGAFF (%)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
The ratio of agricultural investment loans on total agricultural loans	12.09	20.44	22.56	31.75	45.88	49.83	52.51	64.42	67.79	64.01	61.45	65.05
The ratio of agricultural investment loans on total value of new tangible property	32.38	50.63	56.89	71.79	117.84	127.84	115.13	94.64	103.27	117.81	x	x
The ratio of total agricultural investment loans on the creation of GFC	19.88	34.91	30.47	67.11	80.84	114.95	82.33	59.38	61.87	85.29	79.70	102.40
The ratio of supported loans on total agricultural loans	24.21	32.74	46.17	46.20	33.21	29.48	24.54	36.84	41.14	31.56	36.65	22.55
The ratio of supported agricultural investment loans on total supported agricultural loans	69.00	67.00	61.29	34.80	50.64	26.09	55.05	62.99	63.84	50.02	60.59	66.12
The ratio of supported agricultural investment loans on total agricultural investment loans	x	x	x	50.63	36.66	15.44	25.72	36.02	38.74	24.66	36.14	22.92
The ratio of supported agricultural investment loans on total value of new tangible property	44.76	54.33	71.36	36.35	43.20	19.73	29.62	34.09	40.01	29.05	x	x
The ratio of supported agricultural investment loans on the creation of GFC	27.48	37.46	38.23	33.98	29.64	17.74	21.18	21.39	23.97	21.03	28.80	23.47

Source: Own calculations.

Table 3 shows the development of total loans in agriculture and the agricultural investment loans. As was stated above, according to the trend functions that total loans in agriculture copied the tendencies in the economy as a whole. Thus, the size of agricultural loans reached its maximum in 1996 and minimum in 2001. Total loans in agriculture stagnated inside the interval of 11 000 to 12 500 mil. CZK in period 2000-2003 and then they grew up to the level of 14 706 mil. CZK in 2005. Table 4 shows the structure of agricultural loans. The ratio of agricultural investment loans to total agricultural loans increased during the analyzed period. It was around 65 % in period of 2001-2005. The ratio of agricultural investment loans in total agricultural loans reached during the nineties the level of the structure of supported total loans, i.e. the level of the ratio of supported investment loans in supported total loans. Moreover, the table 4 shows that the ratio of supported total loans in total agricultural loans was in most of the years inside the interval of 30 and 40 %. It can be regarded as a very high percentage with respect to the fact that agricultural loans are a state value. Thus, we may conclude that the majority of agricultural loans were supported and/or guaranteed by the SGAFF. The next characteristics in table 4 are related to investment loans and also to the agricultural investments. According to the calculated ratios, we may conclude that the SGAFF may have played an important role in loan creation during the period 1994-2006, i.e. the fund may have reduced the problem of the occurrence of credit rationing. Moreover, since investment loans were an important part of financing of agricultural investments, the SGAFF significantly determined investment activity in Czech agriculture.

As we could see, farmers may have faced the credit rationing phenomenon during the period 1994-2006 and SGAFF may have reduced its occurrence, in the next parts of the paper we analyze and evaluate the impact of the occurrence of credit rationing on farmer's economic equilibrium in a different policy setting based on derived theoretical model.

4.2 Basic theoretical model

4.2.1 The derivation of the theoretical model

The derivation of the theoretical model stems from the following assumptions:

(i) Loans are an important part of the financing of investment (this assumption was confirmed to be true in the previous chapter).

(ii) Credit rationing determines the operational activity only through the investments.

Then, the theoretical model is based on a simple optimal dynamic investment model in which farmers solve the investment problem. However, in spite of the simple specification of the model, an upper limit on the investment was introduced and, thus, the financial constraint can be analyzed without explicit modeling the farmer's financial situation. This is the subject of many papers on this topic (as mentioned e.g. SCHWORM, 1980; STEIGUM, 1983). The basic features of the results are the same.

In the model it is assumed that economic agents (in this case farmers) are rational, i.e. we assume the rationality of economic agents who optimize. The economic agents base their business decisions on the solution of dynamic optimization problem in an infinite horizon. The model is general enough to comply with the characteristics of small farmers, as well as mid-sized and large agricultural enterprises. This feature of the model is very important because empirical analyses show that the aggregate supply in the Czech agriculture is significantly heterogeneous as far as the economic characteristics of economic agents are concerned (see e.g. ČECHURA, 2005).

Each farmer is endowed with capital k_0 and technology z at the beginning of the period, i.e. in time $t = 0$. It is assumed from the nature of the model that the nonnegativity constraint on the capital $k_t \geq 0$ is not binding in the interval $t \in (0;\infty)$. No assumption is placed on the terminal value of the capital, i.e. on $\lim_{t\to\infty} k_t$. The capital is employed in production, namely to produce output y_t. The transformation of the capital into the output is described by the Cobb-Douglas production function, $y_t = \alpha k_t^{\beta} z l_t^{1-\beta}$, with technology z and labor l_t. Technology is incorporated into the production function as a coefficient. It is assumed that the change of technology, which assures the farmers' competitiveness on the agricultural market for a given time period, is represented by a shift in the parameter z. The shift (increase) of the parameter z causes production to be more effective, i.e. it causes an upward shift of the production function. Labor is normalized to one without loss of generality, i.e. the production function can be written as $y_t = \alpha k_t^{\beta} z$. The production function is differentiable, strictly increasing and concave. Total profit, π_t, which is to be maximized, is the difference between the value of output, $p_t y_t$, and the investment cost. The price is assumed to be exogenously given and its variation does not influence the farmers' decision. However, the uncertainty might be incorporated by letting p_t follow the stochastic process (see e.g. ABEL, 1983). Investment costs are given by (1). That is, the farmer undertakes gross investment by incurring an increasing strictly convex cost of adjustment $c(I_t)$.

$$c(I_t) = \rho I_t + \sigma I_t^2 \tag{1}$$

The investment is financed from additional resources, especially from retain earnings and loans. Moreover, the farmer discounts his profit at a constant rate $r>0$.

It follows from the nature of the model that we can speak about the decision process of one farmer instead of all farmers without loss of generality. Thus, the result for one farmer also holds for other farmers till it is said otherwise.

Capital accumulation follows the differential equation $dk_t = (I_t - bk_t)dt$, where b states for a constant proportional rate of physical depreciation.

The financing of capital and investments is not modeled but is implicitly incorporated into the model by the introduction of the upper constraint on the investment I_t. Thus, the gross investment has both upper and lower bound. The upper bound represents the financial constraint (the credit rationing phenomenon as defined in the previous chapter) of the farmer in time t.

It follows from the model definition that credit rationing determines only investment financing. It is assumed that the capital k_t is always available. In other words, as the capital k_t is the sum of the loans L_t and the equity E_t, $k_t = L_t + E_t$, which states for the balance sheet identity, then the volume of the loan L_t, if $L_t>0$, is available. The failure of operational financing due to credit rationing is not the subject of the analysis.

To sum up, the farmer wants to maximize profit or the value of the firm (in this representation), respectively, subject to the state variable accumulation and its initial value, and the control variable constraint. The state variable is the capital (k_t) employed in the production of n agricultural outputs and the control variable is investment (I_t). Time is infinite. Thus, the problem can be written as follows.

$$\max_{I(\cdot)} \int_0^{\infty} e^{-rt}[p_t \alpha k_t^{\beta} z - c(I_t)]dt \tag{2}$$

$$\text{subject to} \quad dk_t = (I_t - bk_t)dt \text{ , k(0) = k}_0, \tag{3}$$

$$0 \le I_t \le B_t \tag{4}$$

where e^{-rt} is used to stand for discounting[1] with a discount interest rate *r*. B_t stands for financial constraint at time *t*.

Since the price p_t is exogenously given and its variation does not influence farmer's decision, for simplicity of the exposition it is assumed that price is constant for the optimization horizon, i.e. from now on the price is incorporated as a parameter into the model. It can be assumed in this situation that the farmer follows the price expectation based on the simple adaptive expectation.

We use a current value Hamiltonian to solve the problem. Employing the current value Hamiltonian we get an autonomous set of equations, which is easier to solve because it results in a pair of autonomous differential equations.[2]

The current value Hamiltonian for our problem (2)-(4) is as follows:

$$\mathcal{H}(k, I, m; \chi) = p\alpha k_t^{\beta} z - c(I_t) + m(I_t - bk_t)$$

$$\text{subject to } 0 \le I_t \le B_t \ , \tag{5}$$

where *m* is the current value multiplier.[3]

As the control variable is bounded ($0 \le I_t \le B_t$), we use the Kuhn-Tucker conditions to solve the problem. Thus, we append the constraints to the objective with multiplier w_1 and w_2. The resulting Langrangian for (5) is:

$$L = \mathcal{H} + w_{1t} I_t + w_{2t}(B_t - I_t) \text{ , that is}$$

$$L = p\alpha k_t^{\beta} z - \rho I_t - \sigma I_t^2 + m(I_t - bk_t) + w_{1t} I_t + w_{2t}(B_t - I_t) \tag{6}$$

From (6) we may obtain the necessary conditions for the solution of a constrained maximum with respect to I_t:

$$m_t' = m_t(r + b) - p\alpha\beta k_t^{\beta-1} z \tag{7}$$

$$k_t' = I_t - bk_t \tag{8}$$

and the optimality condition

$$\partial L / \partial I = -\rho - 2\sigma I_t + m_t + w_{1t} - w_{2t} = 0 \tag{9}$$

$$w_{1t} \ge 0 \ , \quad w_{1t} I_t = 0 \ ; \quad w_{2t} \ge 0 \ , \quad w_{2t}(B_t - I_t) = 0 \ ; \tag{10}$$

(9) and (10) imply[4] that

---

1 $\lim_{n \to \infty}(1 - r/n)^{nt} = e^{-rt}$, where the interest rate *r* is compounded *n* times per year.

2 The current value Hamiltonian is defined as $\mathcal{H} \equiv e^{rt} H = f(t,k,I) + mg(t,k,I)$.

3 $m(t) \equiv e^{rt} \lambda(t)$; $\lambda(t)$ is the marginal value of the state at *t*, which is discounted back to time zero, whereas the current value multiplier $m(t)$ gives the marginal value of the state variable at time *t* in terms of values at *t*. For further reference see KAMIEN et al. (1991).

4 Conditions (9) and (10) are equivalent to (11).

$$I_t = \begin{Bmatrix} 0 \\ ? \\ B_t \end{Bmatrix} \text{ when } m_t - \rho - 2\sigma I_t \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0 \qquad (11)$$

Moreover, it must hold for the optimal solution, that

$$\partial \mathcal{H} / \partial I \partial I = -2\sigma \leq 0 \quad , \qquad (12)$$

which is true as $\sigma > 0$,

and
$$\lim_{t\to\infty} e^{-rt} \mathcal{H} = 0 \quad . \qquad (13)$$

(13) stands for the transversality condition.

4.2.2 The solution of the theoretical model

The solution of the theoretical model shows us the optimal paths of the capital, investment and the farmer's supply in the conditions where the farmer is not financially constrained and where she/he faces a financial constraint, i.e. credit rationing occurs in our case. Then, the dynamic analysis is based on the solution.

As the control variable I_t is bounded, the farmer might face the following three situations according to (11):

A) $m_t < \rho + 2\sigma I_t \quad \Rightarrow \quad I_t = 0$ – if the marginal value of a unit of capital is less than its marginal cost, then no investment is carried out. This means that the capital decreases by the rate of physical depreciation *b*.

No investment might also be carried out in the situation when $B_t = 0$, i.e. in the situation when the farmer has no resources (both internal and external) to carry out the investment.

B) $m_t = \rho + 2\sigma I_t \quad \Rightarrow \quad I_t$ is inside the opened interval *(0; B_t)*, i.e. $0 < I_t < B_t$.

This situation indicates that if the investments are not binding, the farmer follows the well-known rule for capital accumulation, i.e. the farmer chooses the size of investment to equate the marginal value of a unit of capital and marginal costs.

C) $m_t > \rho + 2\sigma I_t \quad \Rightarrow \quad I_t = B_t$

The marginal value *m* of a unit of capital is higher than its marginal costs. It follows that the farmer is not able to raise the investment at time *t* as much as she/he would like (following the rule $m_t = \rho + 2\sigma I_t$) to equate marginal values. This situation represents the occurrence of credit rationing. That is, the farmer is financially constrained because she/he has no additional resources to finance the required level of investment. The theoretical analysis and numerical application are focused on this situation.

Ad C) The situation with financial constraints (credit rationing) – Solution

In this part, we show the solution to the situation when the investment is binding, i.e. the farmer faces credit rationing.

The solution to situation C follows the following proposition 1. Since the optimization problem is autonomous and the horizon is infinite, we inquire about a stationary state (see the following definition).

Definition 1: A stationary state (or steady state) is the state, in which $k' = I' = m' = 0$.

The volume of *k*, *I* and *m* in the stationary state is denoted by k_S, I_S and m_S.

Proposition 1: If the farmer's investment is bounded (financially constrained) in time t_i and $k_i < k_S$ then:

(i) the stationary state is approached by selecting $I_t = B_t$ on the interval $t_i \le t < t_j$, in which the farmer is financially constrained, and $I_t = \frac{m_t - \rho}{2\sigma}$ on the interval $t_j \le t < t_k$, in which she/he is not constrained, if the farmer follows the optimal path of capital given by $m_t = \rho + 2\sigma I_t$,

or

(ii) if the optimal solution for the farmer is to approach the stationary level of the state variable as quickly as possible then she/he chooses $I_t = B_t$, i.e. the following holds:

$$If \quad k_t \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} k_S \quad then \quad I_t = \begin{Bmatrix} B_t \\ I_S \\ 0 \end{Bmatrix}. \tag{14}$$

That is, if the optimal solution for the farmer is to approach the stationary level of state variable as soon as possible, then the following holds. Having $k_t < k_S$, then $I_t = B_t$ for $0 \le t \le T$, where T is to be determined and the aim is to minimize T.

However, part (ii) of the proposition 1 does not lead to the optimal path with respect to the solution of our optimization problem (2)-(4). Thus, we will solve our problem according to part (i).

Moreover, as B_t stands for the upper bound of the investment at time *t* and is assumed to be generated by the occurrence of credit rationing in the credit market, we assume that B_t is a function of the equity. Subsequently, we may approximate the increase in the equity and, thus, the increase in the potential collateral (which in fact increases the upper bound of investment) by the constant increase in B_t for some interval, i.e. $dB_t = (s)dt$, which means that $B_t = B_0 + s \cdot t,\ t \in (0, t_n)$. If the conditions in the equity change significantly, then the linear function changes as well.

Then, since the investment at time t_0 is the largest and then is decreasing, we assume that the investment is bounded on the first part of the optimization horizon, i.e. we assume that without loss of generality the following hypothesis holds.

Hypothesis for the problem solution

To find the solution we assume that the optimization horizon $t \in [0; \infty)$, during which the system reaches the stationary state **(if it is feasible)**, can be divided into 2 parts:

(i) $0 \le t < t_1$ – in this period the farmer is financially constrained and, thus, the investment I_t is equal to the upper bound B_t.

(ii) $t_1 \le t < \infty$ – from time t_1 the farmer is not financially constrained, i.e. the farmer's investment is inside the interval $0 < I_t < B_t$.

The time t_1 is determined by the condition:

$$w_{2t} = m_t - \rho - 2\sigma I_t = 0,$$

$$\text{or equivalently } I_t = \frac{m_t - \rho}{2\sigma} \tag{15}$$

To sum up, according to proposition 1 and the above-stated hypothesis the optimization horizon is divided into two parts: With and without financial constraints. The switching point from the first to the second period is given by (15) which can be used for finding the switching time t_1. The solutions to the optimization problem for period 1 and 2 are as follows.

Period 1 – The situation with financial constraints (credit rationing) – **Solution**

To find the solution for the period, in which the farmer is financially constrained, we solve our optimization problem according to the proposition (1) (part (i)) and the hypothesis for the problem solution. This means that when we substitute in the necessary condition (8) B_t for I_t, it results in (16). As the investment is bounded in this case, we get the solution to our optimization problem with the financial constraint by solving (16), i.e. we only solve the first order linear differential equation

$$k_t' = B_t - bk_t \quad . \tag{16}$$

The solution to (16) is

$$k_t = \frac{B_0}{b} + \frac{s \cdot t}{b} - \frac{s}{b^2} + e^{-bt} \cdot c_1 \quad , \tag{17}$$

where c_1 is the constant of integration, which can be determined knowing that $k(0) = k_0$ (see condition (3)). Thus, (17) can be rewritten

$$k_t^{\bullet} = \frac{B_0}{b} + \frac{s \cdot t}{b} - \frac{s}{b^2} + e^{-bt} \cdot (k_0 - \frac{B_0}{b} + \frac{s}{b^2}) \quad . \tag{17'}$$

Equation (17)' gives the optimal path of the capital when the farmer is financially constrained. Optimal path of I_t is given by B_t, i.e. $B_t = B_0 + s \cdot t$, see the above-given assumption.

The multiplier w_{2t} can be expressed by (18). The multiplier stands for the difference between the shadow price of the capital and its marginal costs.

$$w_{2t} = m_t - \rho - 2\sigma I_t \ , \tag{18}$$

where $I_t = B_t$ and m_t is determined according to (7) with the capital given in (17)'. The equation m_t is then used to determine the switching time t_1. In fact, (18) becomes our switching condition (15) when w_{2t} is equal to 0.

Period 2 – The situation without financial constraints (credit rationing) – Solution

According to the hypothesis, investment is not binding in the second period. That is, we face a standard dynamic nonlinear optimization problem. However, for the needs of the total solution to situation C and the following scenario analysis, the solution is closely exposed.

The necessary conditions (7)-(9) can be reduced to two ordinary differential equations in the variables (*k,m*) or (*k,I*). For the need of our analysis we choose the second possibility. That is, we solve two ordinary differential equations in the variables *k* and *I*. To get two differential equations in (*k,I*), we need to differentiate equation (9) with respect to time (note that if investment is not binding, then the multipliers w_{1t} and w_{2t} are equal to zero) to get:

$$-2\sigma I_t' + m_t' = 0 \quad . \tag{19}$$

Then, we may substitute (7) for m' in (19) that yields (20).

$$-2\sigma I_t' + m_t(r+b) - p\alpha\beta k_t^{\beta-1} z = 0 \quad . \tag{20}$$

Finally, we may eliminate m_t by the substitution $m_t = \rho + 2\sigma I_t$ from the equation (9). Solving for I_t' and together with (8) we get the system of ordinary nonlinear differential equations.

$$I_t' = \frac{(r+b)(\rho + 2\sigma I_t) - p\alpha\beta k_t^{\beta-1} z}{2\sigma} \tag{21}$$

and
$$k_t' = I_t - bk_t \quad . \tag{22}$$

The optimal paths $k_t^\bullet$ and $I_t^\bullet$ given time independent parameters $(\alpha, \beta, p, z, b, r, \rho, \sigma)$ satisfy (21) and (22).

To find the optimal paths of the capital and investment, we start with the stationary state solution of (21) and (22). According to definition 1, the stationary state solution is the simultaneous solution of (21) and (22) when $k_t' = I_t' = 0$. That is, we may get k_S and I_S if we solve the following pair of algebraic equations.

$$0 = \frac{(r+b)(\rho + 2\sigma I_t) - p\alpha\beta k_t^{\beta-1} z}{2\sigma} \quad , \tag{23}$$

$$0 = I_t - bk_t \quad , \tag{24}$$

which result in

$$I_S = \frac{p\alpha\beta k_S^{\beta-1} z}{(r+b)2\sigma} - \frac{\rho}{2\sigma} \quad , \tag{25}$$

$$k_S = \frac{I_S}{b} \quad . \tag{26}$$

Second, we need to examine the local stability of the stationary solution. As the system of the differential equations is nonlinear, we use the Jacobian matrix to deduce the local stability of the system in the stationary state, i.e. we evaluate it at $k_t' = I_t' = 0$.

The Jacobian matrix for our problem is as follows:

$$J_f(k_S, I_S) \overset{def}{=} \left.\begin{bmatrix} \frac{\partial k'}{\partial k} & \frac{\partial k'}{\partial I} \\ \frac{\partial I'}{\partial k} & \frac{\partial I'}{\partial I} \end{bmatrix}\right|_{\substack{k'=0 \\ I'=0}} = \begin{bmatrix} -b & 1 \\ \frac{-p\alpha\beta(\beta-1)k_S^{\beta-2} z}{2\sigma} & (r+b) \end{bmatrix} \quad . \tag{27}$$

From (27), $tr[J_t(k_S, I_S)] = r > 0$, it follows that the sum of eigenvalues of $J_f(k_S, I_S)$ is equal to the discount rate r. Thus, the eigenvalues do not have both negative real parts, which suggests that the stationary state is not locally stable. But (as shown in CAPUTO, 2005), since $\lim_{t\to\infty} e^{-rt} = 0$, $k_t^\bullet \to k_S$ and $m_t \to m_S$ as $t \to \infty$, if all admissible paths k_t are bounded, or $\lim_{t\to\infty} k_t$ exists for all admissible paths, then this means that $\lim_{t\to\infty} e^{-rt} m[k_t^\bullet - k_t] = 0$ and the limiting transversality condition is satisfied. Then $k_t^\bullet$ and $I_t^\bullet$ are a solution of the model. This means that a solution exists. The existence of the solution also immediately follows from the fact $\left|J_f(k_S, I_S\right| < 0$, which is evident from (28).

$$\left|J_f(k_S, I_S)\right| = \left[\underbrace{\frac{\partial k'}{\partial k}}_{-} \cdot \underbrace{\frac{\partial I'}{\partial I}}_{+} - \underbrace{\frac{\partial k'}{\partial I}}_{+} \cdot \underbrace{\frac{\partial I'}{\partial k}}_{+}\right]\Bigg|_{\substack{k'=0\\ I'=0}} < 0 \tag{28}$$

Therefore, at least one path to the stationary state must exist. Since $\left|J_f(k_S, I_S)\right| < 0$, the eigenvalues are real and have opposite signs. And since their sum is equal to *r*, the larger one must be positive. Thus, the Routh-Hurwitz condition is satisfied. Hence, the eigenvalues are real and of opposite sign, the stationary point is a saddle point, which is reached by two trajectories.

As the system of the differential equations (21) and (22) is nonlinear, it is difficult to find the explicit solution to this system. However, to be able to analyze and simulate the paths of capital and investment into the stationary state we may use the method of linearization of the system in the neighborhood of the stationary state. Thus, we use Taylor's theorem to linearize our system of nonlinear ordinary differential equations in the neighborhood of the stationary state. Because we assume that the higher order terms are small, the linearized system of (21) and (22) is as follows:

$$\begin{bmatrix} \Delta k' \\ \Delta I' \end{bmatrix} = \begin{bmatrix} -b & 1 \\ j_{21} & (r+b) \end{bmatrix} \begin{bmatrix} k_t - k_S \\ I_t - I_S \end{bmatrix} \quad , \tag{29}$$

where

$$j_{21} = \frac{\partial I'}{\partial k}\Bigg|_{\substack{k'=0\\ I'=0}} = \frac{-p\alpha\beta(\beta-1)k_S^{\beta-2}z}{2\sigma} \; , \; \Delta k' = k' \text{ and } \Delta I' = I' .$$

With theorem 25.1 of SIMON and BLUME (1994), (see CAPUTO, 2005), the general solution of (29) can be found by

$$\begin{bmatrix} k_t - k_S \\ I_t - I_S \end{bmatrix} = c_1 v^1 e^{\gamma_1 t} + c_2 v^2 e^{\gamma_2 t} \quad , \tag{30}$$

where c_1 and c_2 are constants of integration, v^1 and $v^2 \in \Re^2$ are eigenvectors of $J_f(k_S, I_S)$ corresponding to eigenvalues y_1 and y_2.

Finding v^1, v^2, c_1 and c_2, we may write the specific solution to the linearized system of differential equations (29), which describes the optimal path of the capital and investment to the stationary state, as follows:[5]

$$\begin{bmatrix} k_t^\bullet \\ I_t^\bullet \end{bmatrix} = \begin{bmatrix} k_S \\ I_S \end{bmatrix} + \left[k_0 - k_S\right] \cdot \begin{bmatrix} 1 \\ \dfrac{j_{21}}{\gamma_1 - r - b} \end{bmatrix} \cdot e^{\gamma_1 t} \quad , \tag{31}$$

where y_1 states for the negative eigenvalue.

[5] For further reference see CAPUTO (2005).

Finally, we may define the path for the farmer's supply. From the definition of the problem it is evident that the optimal path of farmer's supply is given by

$$y_t^{\bullet} = \alpha k_t^{\bullet \beta} z \quad . \tag{31'}$$

To sum up, the optimal paths of the capital and investment under financial constraints which are the subject of the study of the next section, are given by the equations (17)', $I_t = B_t = B_0 + s \cdot t$ and (31) (with the capital k_0 that is equal to the size of the capital in switching time t_1) and with the switching condition (15).

The solution, which in fact partly represents our scenario 0, can be demonstrated graphically. Recalling, scenario 0 represents the situation without any support. This means that the farmer may or may not be constrained. As the scenario 0 serves as a baseline, we show graphically both possibilities even if the analysis is aimed at the situation with financial constraints.

Firstly, the solution can be graphically represented by using the k-I plane[6]. To develop the k-I plane we need to find *k* and *I* nullclines or $k' = 0$ and $I' = 0$ isoclines, respectively. The $k' = 0$ isocline is derived from the equation (22), in which we let $k' = 0$. Thus the $k' = 0$ isocline is equal to

$$0 = I_t - bk_t \text{, i.e. } I_t = bk_t \tag{32}$$

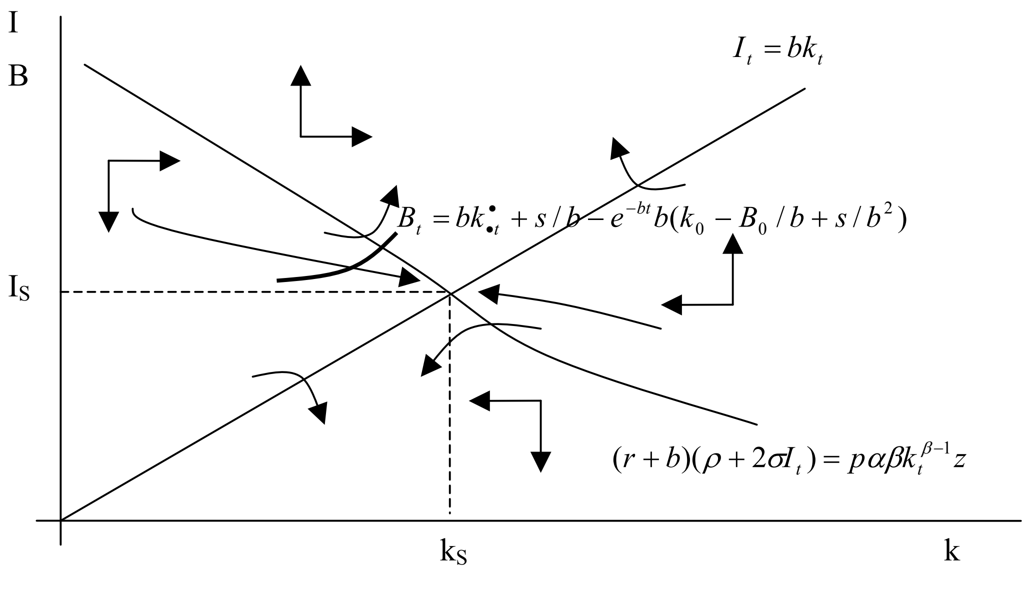
Now, we may consider $k' = 0$ isocline, that is, points satisfying (32). As (32) is a simple linear function without an intercept, we may conclude that the isocline is a straight line, which goes through the origin and increases with slope *b*. It is easy to verify that above the locus k' is positive, i.e. *k* is increasing, and vice versa (see Figure 1).

Next, the $I' = 0$ isocline results from (21) by letting $I' = 0$, i.e. we have

$$(r + b)(\rho + 2\sigma I_t) = p\alpha\beta k_t^{\beta - 1} z \quad . \tag{33}$$

We can verify the slope of $I' = 0$ isocline based on the definition of the production function. Since the production function is concave, the second derivative is negative. This implies that the isocline is decreasing. Above the $I' = 0$ locus, I' is positive and vice versa (see again Figure 1).

Figure 1: k-I plane



Source: Author's depiction based on KAMIEN et al. (1991).

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6 Or equivalently the k-m plane can be used.

From the derivation of isoclines it is evident that the intersection of the isoclines represents the fixed point of the system. The isoclines partition the phase plane into isosectors in which the trajectories of the system are monotonic as depicted in Figure 1. Moreover, Figure 1 shows the dynamics of the system and two optimal trajectories, i.e. trajectories leading to the stationary state. However, the optimal trajectory leading from left to right is feasible only if the farmer is able to carry out such an investment. In other words, it represents the optimal path when the farmer is not financially constrained. If the farmer is financially constrained, then she/he follows the solution in period 1 and 2 (see above).[7] That is, the farmer chooses the investment in the size of the upper bound B_t. As the upper bound increases with increased capital or collateral, respectively, which we approximated by a constant increase during the time, it can be depicted by an increasing convex function B_t as a function of $\dot{k}_t$ in Figure 1 (see the bold line). Then, the optimal path of the farmer with financial constraints is given by the bold line, $B_t = b\dot{k}_t + s/b - e^{-bt}b(k_0 - B_0/b + s/b^2)$, till the intersection with the optimal path without financial constraints. The farmer is not financially constrained from the intersection and follows the optimal path derived in period 2.

It can also happen that the stationary state is not feasible for the farmer. It is the situation when the farmer's financial constraint is very tough that the bold line does not intersect the optimal path. More precisely, the bold line lies below the stationary state. Thus, the farmer is not able to reach her/his economic equilibrium (of course in this case B_t is not a linear function of time, i.e. $B_t = B_0 + s \cdot t$, in the period $t \in [0;\infty)$).

The graphics of the solution are simple and logical. However, for further reference we will show the time paths of capital, investment and farmer's supply.

Figure 2a shows the paths of capital for both farmers with and without financial constraint. The farmer without financial constraint follows the solid line from the beginning. The farmer with financial constraint follows the dashed line till time t_1.[8] From time t_1 she/he also follows the solid line, which is below the solid line of the farmer without financial constraint. From the Figure it is evident that both paths have the same limit, i.e. both farmers reach the stationary value of capital. But the farmer who faces the financial constraints reaches the saddle point later. Figures 2b and 2c show the paths of investment and also the farmers' supplies. The depiction implicitly assumes that the stationary state is feasible for the financially constrained farmer. The paths of capital, investment and supply with and without a financial constraint depicted in Figures 2a,b,c represent our scenario 0.

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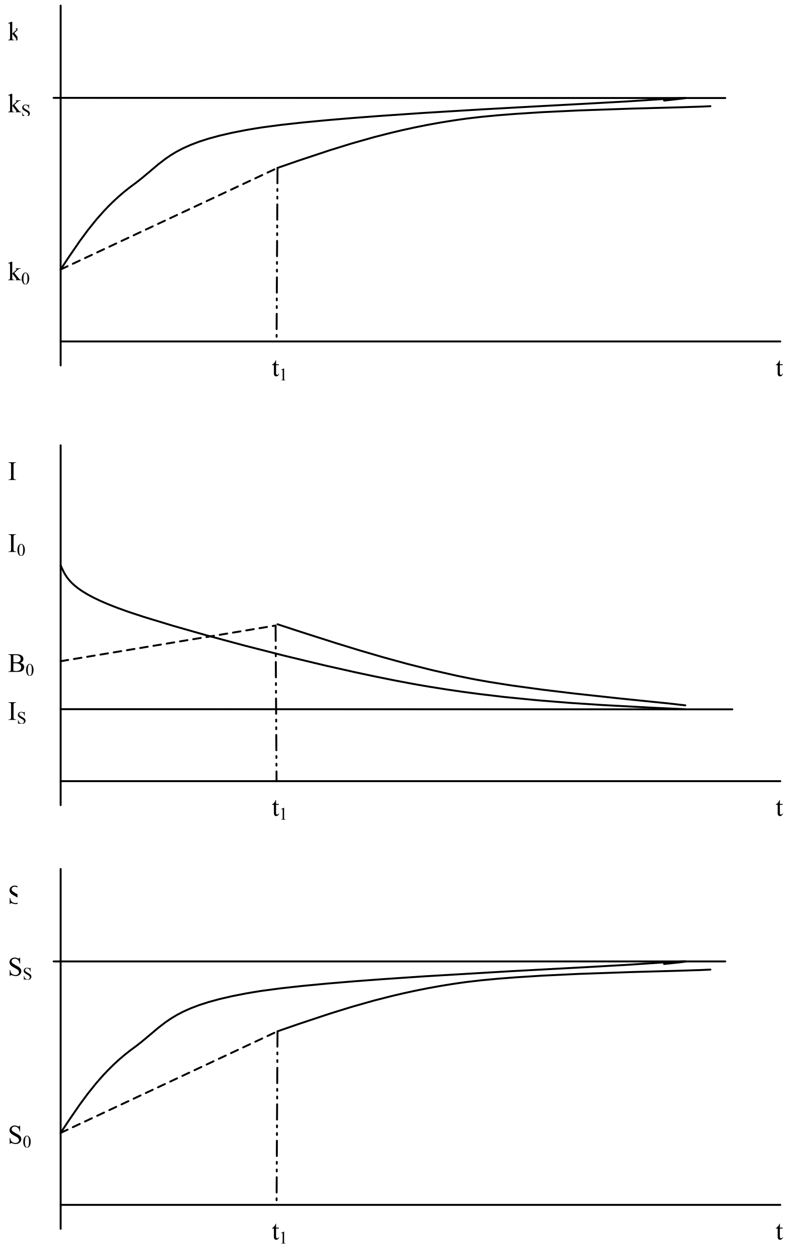
[7] Of course, it could happen that the farmer is financially constrained inside the interval. Then, the solution must be adapted by identifying two switching points. However, we assume for the reason presented above that our hypothesis for the solution holds.

[8] The dashed line is depicted here and in the next section as a straight line in Figures 2a,c for the simplicity of depiction even if it has in fact also a concave shape in these two Figures.

Figure 2a, b, c: The time paths of the capital, investment and farmer's supply



Source: Author's depiction.

4.2.3 Scenario analysis, comparative dynamic analysis with financial constraints

In this part of the paper, the comparative dynamic analysis of the defined scenarios 1 and 2 is carried out. Based on the comparative dynamic analysis, the defined scenarios are theoretically analyzed. Thus, different agricultural support methods are evaluated with respect to their impact on the farmer's economic equilibrium. Moreover, the results of this section serve for the purposes of the consequent numerical application.

For the subsequent analysis we assume that the farmer is financially constrained in time 0.

We start with scenario 1. Scenario 1 represents the support of the SGAFF (Supporting and Guarantee Agricultural and Forestry Fund). As the SGAFF offers different programs with different measures of support, the following support can be analyzed:

a. Loan guarantees;

b. Interest rate subsidies;

c. Loan guarantees and interest rate subsidies.

Firstly, for some programs the SGAFF offers loan guarantee only. The loan guarantee plays the same role as the collateral. It secures the loan and, hence, the bank is willing to grant a credit. Thus, the loan guarantee makes the farmer's financial constraint less tough. That is, the upper bound of the investment is higher, i.e. $B_{0G} > B_0$. The farmer reaches the optimal path to the stationary state without financial constraint faster, i.e. she/he reaches faster her/his economic equilibrium (see the definition of farmer's economic equilibrium). Graphically this situation is represented by the shift of the bold curve in Figure 1 upwards. The time t_1 is shorter. Figures 2a,b,c change according to this. t_1 is closer to the beginning and the dashed line is, in Figures 2a,c, steeper. In Figure 2b the dashed line shifts upwards.

Now, we can use Figures 2b,c for the evaluation of the loan guarantee effect on the farmer's supply path to the stationary state or to economic equilibrium, respectively.[9] We redraw Figures 2b,c by incorporating the effect of the loan guarantee. Thus, Figures 3a,b contain both the situation with and without the loan guarantee. That is, we may compare scenario 0 with scenario 1a. It is obvious from Figure 3a that the farmer's investment in scenario 1a is higher compared to scenario 0 because the upper bound of the farmer's investment is equal to B_{tG}. That is, the investment is bounded till time t_1' instead of t_1 as in scenario 0. Analogously in Figure 3b, the farmer's supply is higher in scenario 1a than in scenario 0 when the farmer is financially constrained. To evaluate the effect of the loan guarantee on the farmer's supply we may compute the loss in the farmer's supply when the farmer is financially constrained. The loss may be computed as the difference between the sum of supply during the time $[0;\infty)$ without and with financial constraint. Graphically it is the space between the optimal paths without and with financial constraint. The difference between the loss in scenario 1 and scenario 0 represents the gain or the effect of using the loan guarantee, respectively. The gain can be numerically approximated[10] by

$$\int_0^{t_1'} \alpha k_{\bullet Gt}^{\bullet\beta} z dt + \int_{t_1'}^{\infty} \alpha k_{Gt}^{\bullet\beta} z dt - \int_0^{t_1} \alpha k_{\bullet t}^{\bullet\beta} z dt - \int_{t_1}^{\infty} \alpha k_t^{\bullet\beta} z dt > 0 \quad , \tag{35}$$

where $k_{\bullet Gt}^{\bullet} = \frac{B_{0G}}{b} + \frac{s \cdot t}{b} - \frac{s}{b^2} + e^{-bt} \cdot (k_0 - \frac{B_{0G}}{b} + \frac{s}{b^2})$, $k_{Gt}^{\bullet} = k_S + (k_{t_1'} - k_S)e^{\gamma_1 t}$,

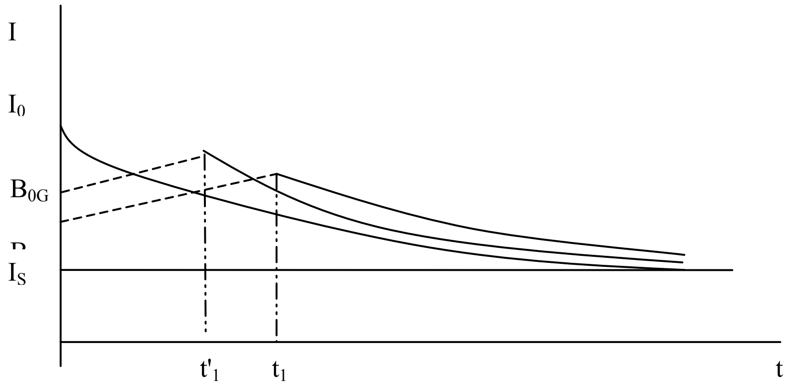
$$k_{\bullet t}^{\bullet} = \frac{B_0}{b} + \frac{s \cdot t}{b} - \frac{s}{b^2} + e^{-bt} \cdot (k_0 - \frac{B_0}{b} + \frac{s}{b^2}) \text{ and } k_t^{\bullet} = k_S + (k_{t_1} - k_S)e^{\gamma_1 t}.$$

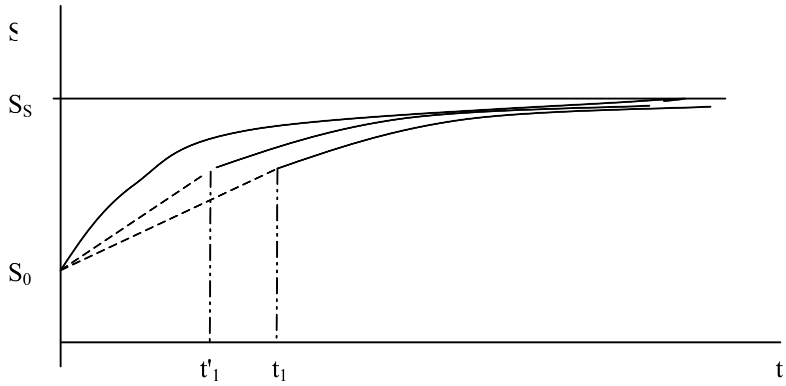
---

[9] It is evident from the definition of the problem and graphically from Figures 2a,c that the effect of the loan guarantee on the path of the capital is analogous to the effect on the path of the farmer's supply. However, to evaluate the effect of the loan guarantee we chose the farmer's supply for better economic interpretation.

[10] (35) is the approximation of the total gain due to the linearization of the solution (see the solution – part 4.2.2)

Figure 3a, b: The path of investment and the farmer's supply – Scenario 0 and scenario 1a





Source: Author's depiction.

Thus, the loan guarantee has a positive effect on the capital accumulation as well as on the farmer's supply if the stationary state is feasible. However, if the stationary state is only feasible with the support of SGAFF and then the farmer is not able to carry out at least the investment to the size of the amortization $bk_{t,}$ then it may be a case of the crowding-out effect of capital from the agricultural sector. However, this does not fully remove the positive effect of the loan guarantee in this case. The investment or the SGAFF's support can be always restored. The negative effect may, in this context, play the special purpose of the SGAFF's programs that may not allow the identified investment opportunity to be carried out by the farmer. In this case the farmer is either outside the economic equilibrium or the equilibrium may be distinct to the equilibrium of the first choice.

Second, if interest rate subsidy is only offered, it has the following effects on the farmer's economic equilibrium. The interest rate subsidy decreases the interest rate paid by the farmer. That is, it directly decreases the cost of investment. As the cost of investment is given by (1), we may simulate the effect of the interest rate subsidy by the decrease in ρ (we could decide for another parameter (e.g. σ or both) but for the simplicity of the exposition we chose ρ).

To evaluate the effect of the decrease in ρ we assume, again for the simplicity of the exposition but without loss of generality, that the farmer is in a stationary state in time of the parameter change and, thus, we evaluate the change in $k_0 = k_S$ (for further reference see CAPUTO, 2005).

Therefore, to analyze the effect of the decrease in ρ if the farmer is supposed to be in the stationary state at time t = 0 (that is in time of the change), we differentiate (31) with respect to ρ and evaluate it in $k_0 = k_S$, i.e.

$$\frac{\partial k_t^{\bullet}}{\partial \rho} = \frac{\partial k_S}{\partial \rho} + \left[k_0 - k_S\right] e^{\gamma_1 t} \cdot \frac{\partial \gamma_1}{\partial \rho} t - e^{\gamma_1 t} \frac{\partial k_S}{\partial \rho} \ ,$$

which results (evaluating in $k_0 = k_S$) in

$$\left.\frac{\partial k_t^{\bullet}}{\partial \rho}\right|_{k_0 = k_S} = \left[1 - e^{\gamma_1 t}\right] \cdot \frac{\partial k_S}{\partial \rho} \geq 0 \quad \forall t \in [0;\infty) \ , \tag{36}$$

$$\frac{\partial I_t^{\bullet}}{\partial \rho} = \frac{\partial I_S}{\partial \rho} + \left[k_0 - k_S\right] \cdot \left[\frac{j_{21}}{\gamma_1 - r - b} \cdot e^{\gamma_1 t} \cdot \frac{\partial \gamma_1}{\partial \rho} t + \frac{\partial\left(j_{21} / (\gamma_1 - r - b)\right)}{\partial \rho} \cdot e^{\gamma_1 t}\right] - \frac{\partial k_S}{\partial \rho}\left[\frac{j_{21}}{\gamma_1 - r - b}\right] \cdot e^{\gamma_1 t}$$

which results in

$$\left.\frac{\partial I_t^{\bullet}}{\partial \rho}\right|_{k_0 = k_S} = \frac{\partial I_S}{\partial \rho} - \frac{\partial k_S}{\partial \rho}\left[\frac{j_{21}}{\gamma_1 - r - b}\right] \cdot e^{\gamma_1 t} \quad \forall t \in [0;\infty). \tag{37}$$

From (36) it is evident that the result of the change in the parameter ρ on $k_t^{\bullet}$ in time 0 is equal to zero. That is, the parameter ρ does not have any effect on $k_t^{\bullet}$ immediately after its change. The capital $k_t^{\bullet}$ is influenced by the change in $I_t^{\bullet}$, which is equal to $\left.\frac{\partial I_t^{\bullet}}{\partial \rho}\right|_{k_0 = k_S} = \frac{\partial I_S}{\partial \rho} - \frac{\partial k_S}{\partial \rho}\left[\frac{j_{21}}{\gamma_1 - r - b}\right]$ at time 0. If we let t approach infinity, we get that the change in $k_t^{\bullet}$ is equal to $\lim_{t \to \infty} \left.\frac{\partial k_t^{\bullet}}{\partial \rho}\right|_{k_0 = k_S} = \frac{\partial k_S}{\partial \rho}$ and the change in $I_t^{\bullet}$ is $\lim_{t \to \infty} \left.\frac{\partial I_t^{\bullet}}{\partial \rho}\right|_{k_0 = k_S} = \frac{\partial I_S}{\partial \rho}$.

$\frac{\partial k_S}{\partial \rho}$ and $\frac{\partial I_S}{\partial \rho}$ represents the change in the stationary state caused by the change in ρ. This change can be calculated by differentiating the equations (25) and (26) with respect to ρ. To do that, we use the Jacobian matrix for the stationary state solution on k_S and I_S, i.e. the Jacobian matrix for equations (23) and (24). The Jacobian matrix for the stationary state is as follows:

$$J_S(k_S, I_S) = \begin{bmatrix} -b & 1 \\ -p\alpha\beta(\beta - 1)k_S^{\beta-2} z & (r+b)2\sigma \end{bmatrix} \tag{38}$$

$$\left|J_S(k_S, I_S\right| = \left[-b(r+b)2\sigma + p\alpha\beta(\beta - 1)k_S^{\beta-2}\right] < 0 \tag{39}$$

The determinant of the Jacobian matrix (39) is negative, which means that the sufficient condition for the steady state solution k_S, I_S to be locally well defined is satisfied.

Using the Jacobian matrix (38) for finding the solution gives

$$\begin{bmatrix} -b & 1 \\ -p\alpha\beta(\beta - 1)k_t^{\beta-2} z & (r+b)2\sigma \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial k_S}{\partial \beta} \\ \frac{\partial I_S}{\partial \beta} \end{bmatrix} = \begin{bmatrix} 0 \\ -\frac{1}{2\sigma} \end{bmatrix} \ . \tag{40}$$

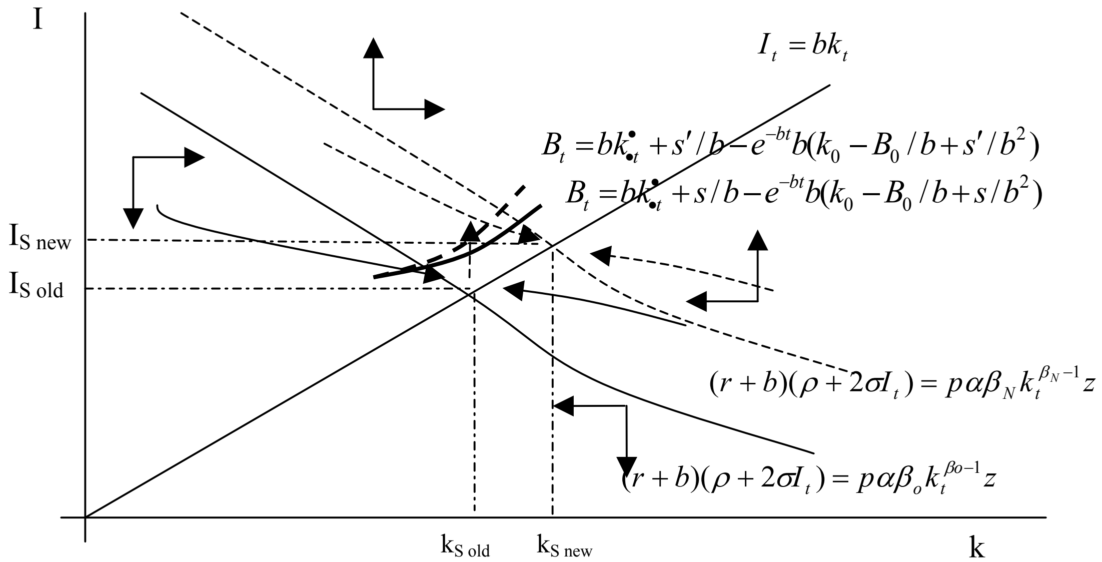
The solution to (40) can be found by using Cramer's rule, i.e.

$$\frac{\partial k_S}{\partial \rho} = \frac{\frac{1}{2\sigma}}{\left| J_S(k_S, I_S) \right|} < 0 \tag{41}$$

$$\frac{\partial I_S}{\partial \rho} = \frac{b\frac{1}{2\sigma}}{\left| J_S(k_S, I_S) \right|} < 0 \tag{42}$$

The inequalities in (41) and (42) say the effect of the change in the parameter ρ on the stationary state takes values of k_S and I_S. That is, (41) and (42) show that an increase in parameter ρ (i.e. the increase in the cost of investment) leads to a decrease in k_S and I_S and vice versa. In other words, the decrease in the cost of investment caused by the interest rate subsidy induces higher accumulation of the capital, higher investment and higher farmer's supply as well.

Figure 4: Graphical representation of comparative dynamic analysis

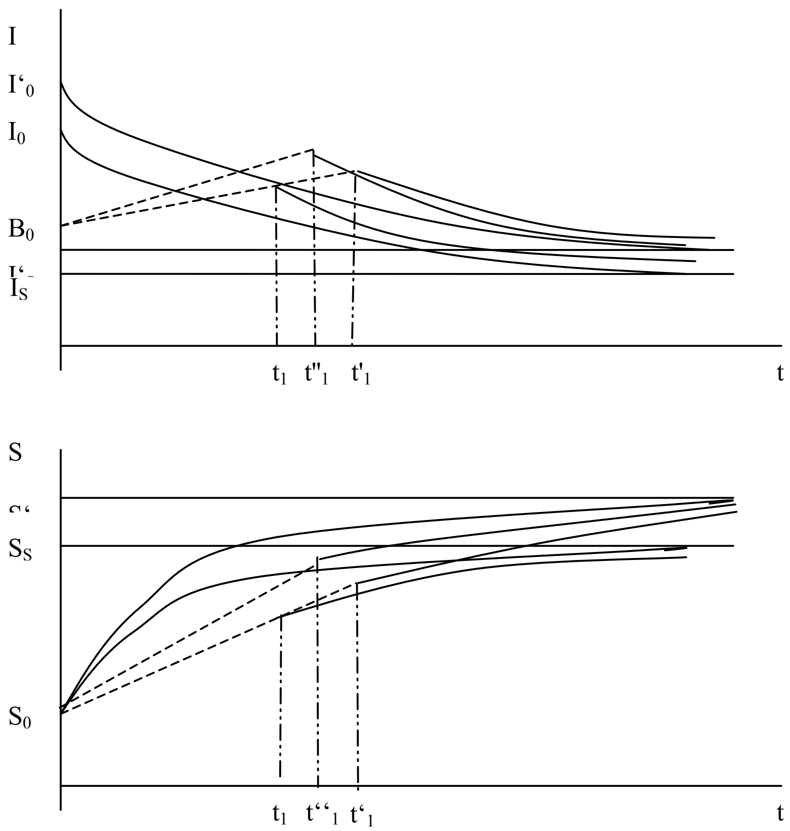


Source: Author's depiction.

This result can be shown graphically. The decrease in the parameter ρ results in the shift of $I' = 0$ isocline upwards as shown in Figure 4. Thus Figure 4 contains the old stationary state and the new stationary solution. As we have assumed that the farmer is in the stationary state at time 0, i.e. in the old stationary state in Figure 4, the farmer wants to get to the new one. The only two optimal paths to the new stationary state are shown by the dashed arrows. If the farmer wants to follow the optimal solution of the problem she/he should increase investment to get on the optimal path. This is depicted by the vertical dashed arrow in Figure 4. Thus the farmer reaches a new stationary state. But, till now we have implicitly assumed that the farmer is able to increase investment to get on the optimal path. The situation with the financial constraint has already been described and depicted in Figure 1. In Figure 4, the situation is analogousy. The bold line represents the path with a financial constraint and it is given by the equation $B_t = bk_t^{\bullet} + s/b - e^{-bt}b(k_0 - B_0/b + s/b^2)$. Thus the path in the new stationary state is given by the increase of the investment to the level of B_t. Then, the farmer is on the bold line till the bold line intersects the new optimal path without constraint. The farmer follows the new optimal path without constraint from the intersection. However, as the interest rate is a part of the costs, then the interest rate subsidy results in higher profit and thus it may result in higher retained earnings, which increase the upper bound of the investment by changing the slope *s* (see the approximation of B_t). Thus, the bold line may change the slope ($\uparrow s$ increases the slope of B_t). Then the farmer follows the new dashed bold line with the new parameter *s'* (see Figure 4).

So, we have analyzed the effect of the change in ρ when the farmer is in the stationary state at the time of the change. If the farmer is not in a stationary state, the above-presented analysis gives us a clue about what has happened with the farmer's path to equilibrium. Assuming now that we start at time 0 with k_0, the effect of the interest rate subsidy is visible from the above-presented. The interest rate subsidy decreases the cost of investment that causes an increase in the values of k_S, I_S and S_S. Thus the farmer has another optimal path to the stationary state compared to scenario 0. This new optimal path is above the old one and therefore asks for higher investment. If the interest rate subsidy changes the slope *s,* then also the path of the farmer's investment and supply (under financial constraint) change the slope and it is above the old one. The optimal path with financial constraint terminates at t_1''. The value of t_1'' depends on the change of *s*. But, if the interest rate subsidy does not change the slope *s*, then the optimal path with financial constraint conforms to the old one till t_1 and terminates at t_1'.[11] This can be graphically presented in Figures 5a,b.

Figure 5a, b: The path of investment and the farmer's supply – Scenario 1b and scenario 0



Source: Author's depiction.

[11] However, from the economic point of view it is reasonable to assume that the interest rate subsidy change the slope.

Consequently, if the farmer is financially constrained, then there are two possibilities: Either the new stationary state is not feasible or the stationary state is feasible but the farmer is financially constrained for a longer time compared to that in scenario 0 (we assume that the slope *s* does not change dramatically to cause $t_1 \geq t_1''$). The potential loss of production is higher in scenario 1b compared to scenario 0. But the total gain is positive. The calculation of the gain is analogical to (35) and therefore is not presented here. The gains in scenarios 1a and 1b depend on the change in B_0, *s* and ρ. So, we have not compared them.

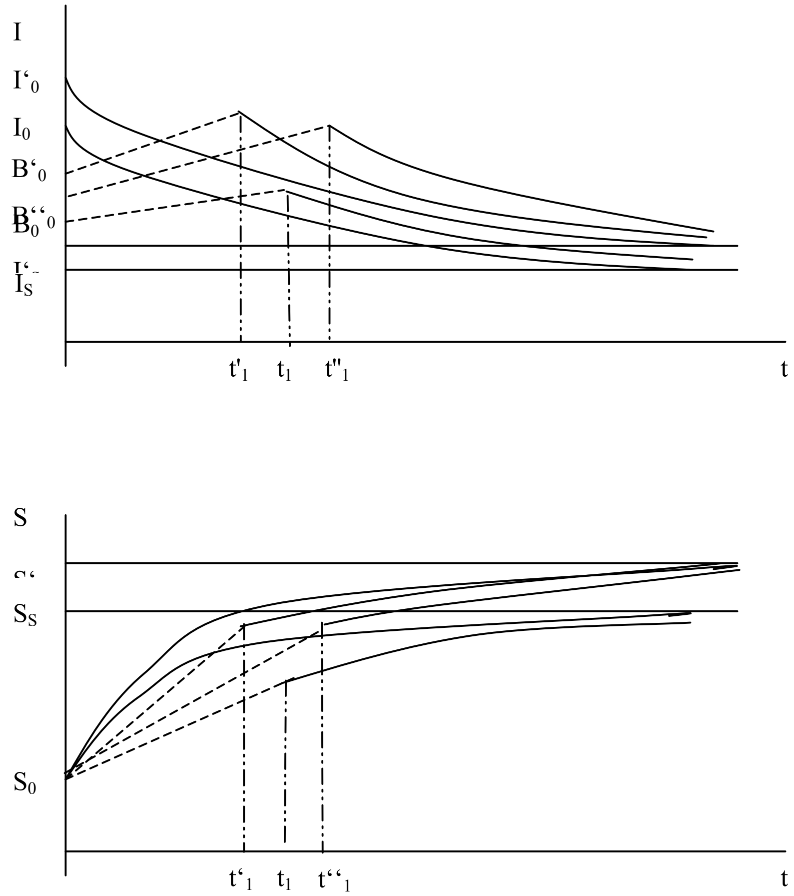
As the new stationary state is the result of the change in the cost of investment due to the interest rate subsidy it may not be maintainable. The cost of investment increases to the old level, i.e. before the change, after the termination of the SGAFF's program if the support is not restored and also the slope *s* decreases to the old level. Returning to the old level of the parameter means that the stationary state returns to the old one. Thus the farmer follows the optimal paths to the old stationary state. As we have two optimal trajectories to the stationary state we have also two possible situations for the farmer, i.e. either $S_t \leq S_S$ or $S_t > S_S$.[12] Having $S_t \leq S_S$, then, if the equality holds, then the farmer is in the stationary state, if inequality holds the farmer will follow the optimal path to the stationary state which is the same as before the change of interest rate. But the effect of the interest rate subsidy is that the optimal path without constraint (i.e. farmer's economic equilibrium) or the stationary state is reached faster compared to scenario 0, respectively. If $S_t > S_S$, then the farmer wants to decrease the supply and thus investment drops to 0; the capital decreases by a constant rate *b*. The capital is crowded-out from the agricultural sector this way.

That is, the interest rate subsidy does not decrease the external credit rationing but it decreases the internal credit rationing, given by the cost of financial resources. Then it increases the propensity to invest and may cause the external credit rationing or financial constraint to be tougher, respectively. In other words, the period with financial constraints is longer due to the higher saddle point. On the other hand, if the subsidy is not restored, the path to the farmer's equilibrium may be faster. Hence it suggests that support of credit rationed farmers is more efficient (from the agricultural policy point of view), compared to the non-credit rationed farmers. For non-credit rationed farmers this is the way to cheaper financial resources, which may be crowded-out (with higher probability) after the program.

Third, if both a loan guarantee and an interest rate subsidy are offered, then the effects of scenario 1a and 1b work together. That is, the loan guarantee causes the shift of B_t upwards due to the shift in B_0 and the interest rate subsidy changes the slope of B_t, i.e. the B_t curve is steeper. The interest rate subsidy also changes the stationary state. The new stationary state has values of k_S and S_S which are larger compared to the old ones. These changes can be depicted in Figures 6a,b. As the loan guarantee changes B_0 and the interest rate subsidy increases the slope *s* then the optimal path with a financial constraint (as depicted by the dashed line in Figure 6b) would be shorter than in the scenario 0, ceteris paribus. However, the interest rate subsidy also changes the stationary state. Thus, the new optimal path with the constraint terminates on the new optimal path without constraint which leads to the new stationary state S'_S. Now, it depends on the change in B_0, s and S'_S whether the optimal path with a constraint finishes before t_1 (see t'_1 in the Figures 6a and 6b) or after t_1 (see t''_1). The potential loss is also unclear. However, the total gain is higher for the farmer in scenario 1c compared to scenarios 1a and 1b.

12 We could also express the situation in terms of k_t and k_S.

Figure 6a, b: The path of investment and the farmer's supply – Scenario 1c and scenario 0



Source: Author's depiction.

As scenario 1c is a combination of scenarios 1a and 1b we do not need to analyze the changes in detail. Thus we may conclude that scenario 1c reduces both external and internal credit rationing. It increases the farmer's propensity to invest and the total gain may be larger compared to scenarios 1a and 1b. These results hold in general. However, the support has still further effects after the termination of the SGAFF's support. If the stationary state returns to its old values after the change in the parameter ρ, then having $S_t < S_S$ speeds up (in general) the farmer's path to equilibrium, but having $S_t > S_S$ causes the capital to be crowded-out from agriculture to the extent of $k_t - k_S$. In the case where the non-credit rationed farmer is granted, the crowding-out effect is reinforced. In other words, the non-credit rationed farmer crosses the old stationary value of S_S (or k_S) faster and thus after the return of the saddle point to the old place there is a higher probability that the non-credit rationed farmer is in the situation $S_t > S_S$. In real terms, for a non-credit rationed farmer it may be also (in addition to what was said above) a way to get cheap capital, which is crowded-out and may be used for non-agricultural activities which have a higher expected return. Thus, it may be considered as inefficient from the SGAFF's policy point of view.

Scenario 2 represents the support in the form of direct payments. We evaluated this scenario only qualitatively. As far as the farmer's financial constraint is concerned, direct payments have a similar initial effect on scenario 1b. The support in the form of direct payment can be imagined in our model as a shift in the price level *p*. It leads to an increase in the stationary values of capital and investment. Then the support results in a higher profit and may lead to higher retained earnings (ceteris paribus) which change the slope of B_t. The basic difference between scenario 1b and 2 is that the change is not temporary as in the case of the interest rate subsidy but it may be long-lasting. Thus, the final effect of the direct payment has higher stationary values of variables compared to scenario 0. That is, the total farmer's investment and supply are higher. However, it depends on the change in p and s if the period with the financial constraint is longer or shorter compared to scenario 0. In other words, the path of the farmer to her/his equilibrium may not be shorter.

We finish this section with the calculation of the effects of the change in other (time-independent) parameters on the stationary state that determine the farmer's paths to the equilibrium if the farmer is financially constrained.

Starting with β we differentiate (25) and (26) with respect to β. Using again the Jacobian matrix (38) for finding the solution it gives

$$\begin{bmatrix} -b & 1 \\ -p\alpha\beta(\beta-1)k_t^{\beta-2}z & (r+b)2\sigma \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial k_S}{\partial \beta} \\ \frac{\partial I_S}{\partial \beta} \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{p\alpha k_S^{\beta-1}z + p\alpha\beta k_S^{\beta-1}z\log(k_s)}{(r+b)2\sigma} \end{bmatrix} . \quad (43)$$

The solution to (43) can by found by using Cramer's rule, i.e.

$$\frac{\partial k_S}{\partial \beta} = \frac{-p\alpha k_S^{\beta-1}z - p\alpha\beta k_S^{\beta-1}z\log(k_S)}{(r+b)2\sigma \cdot |J_S(k_S,I_S)|} > 0 \quad (44a)$$

$$\frac{\partial I_S}{\partial \beta} = \frac{-b\left[p\alpha k_S^{\beta-1}z + p\alpha\beta k_S^{\beta-1}z\log(k_S)\right]}{(r+b)2\sigma \cdot |J_S(k_S,I_S)|} > 0 \quad (45a)$$

Since, the calculations with other parameters are standard, we show only the results.

For p:

$$\frac{\partial k_S}{\partial p} = \frac{-\alpha\beta k_S^{\beta-1}z}{(r+b)2\sigma \cdot |J_S(k_S,I_S)|} > 0 \quad (44b)$$

$$\frac{\partial I_S}{\partial p} = \frac{-b\alpha\beta k_S^{\beta-1}z}{(r+b)2\sigma \cdot |J_S(k_S,I_S)|} > 0 \quad (45b)$$

For z:

$$\frac{\partial k_S}{\partial z} = \frac{-p\alpha\beta k_S^{B-1}}{(r+b)2\sigma \cdot |J_S(k_S,I_S)|} > 0 \quad (44c)$$

$$\frac{\partial I_S}{\partial z} = \frac{-bp\alpha\beta k_S^{\beta-1}}{(r+b)2\sigma \cdot |J_S(k_S,I_S)|} > 0 \quad (45c)$$

For b:

$$\frac{\partial k_S}{\partial b} = \frac{-\frac{I_S}{b^2}(r+b)2\sigma + \frac{p\alpha\beta k_S^{\beta-1}z}{(r+b)^2 2\sigma}}{|J_S(k_S,I_S)|} < 0, \quad (44d)$$

the inequalities holds only if $p\alpha\beta k_S^{\beta-1} z > \frac{I_S}{b^2}(r+b)^3 4\sigma^2$.

$$\frac{\partial I_S}{\partial b} = \frac{b \cdot \frac{p\alpha\beta k_S^{\beta-1} z}{(r+b)^2 + 2\sigma} - \frac{I_S}{b^2} \cdot p\alpha\beta(\beta-1)k_t^{\beta-2} z}{\left|J_S(k_S, I_S)\right|} < 0 \qquad (45d)$$

For r:

$$\frac{\partial k_S}{\partial r} = \frac{p\alpha\beta k_S^{B-1} z}{(r+b)^2 2\sigma \cdot \left|J_S(k_S, I_S)\right|} < 0 \qquad (44e)$$

$$\frac{\partial I_S}{\partial r} = \frac{bp\alpha\beta k_S^{\beta-1} z}{(r+b)^2 2\sigma \cdot \left|J_S(k_S, I_S)\right|} < 0 \qquad (45e)$$

For α:

$$\frac{\partial k_S}{\partial \alpha} = \frac{-p\beta k_S^{B-1} z}{(r+b)2\sigma \cdot \left|J_S(k_S, I_S)\right|} > 0 \qquad (44f)$$

$$\frac{\partial I_S}{\partial \alpha} = \frac{-bp\beta k_S^{\beta-1} z}{(r+b)2\sigma \cdot \left|J_S(k_S, I_S)\right|} > 0 \qquad (45f)$$

For σ:

$$\frac{\partial k_S}{\partial \sigma} = \frac{\frac{p\alpha\beta k_S^{\beta-1} z - \rho(r+b)}{(r+b)2\sigma^2}}{\left|J_S(k_S, I_S)\right|} < 0 \qquad (44g)$$

$$\frac{\partial I_S}{\partial \sigma} = \frac{\frac{bp\alpha\beta k_S^{\beta-1} z - b\rho(r+b)}{(r+b)2\sigma^2}}{\left|J_S(k_S, I_S)\right|} < 0 \qquad (45g)$$

both inequalities holds only if $p\alpha\beta k_S^{\beta-1} z > \rho(r+b)$.

The solutions (44a)-(45g) can be summarized for presentational clarity in the Table (5). Thus, Table 5 shows the effects after the change of a parameter of interest on the stationary solution, i.e. on the values of k_S, I_S and S_S.

Table 5: Static comparative analysis

	β	p	z	b	r	α	σ
k_S	+	+	+	?-[13]	-	+	?-[7]
I_S	+	+	+	-	-	+	?-[14]
S_S	+	+	+	?-[11]	-	+	?-[7]

Source: Own calculations.

[13] Only if $p\alpha\beta k_S^{\beta-1} z > \frac{I_S}{b^2}(r+b)^3 4\sigma^2$.

[14] Both inequalities holds only if $p\alpha\beta k_S^{\beta-1} z > \rho(r+b)$.

4.3 The numerical application – Sensitivity analysis

The numerical application shows the microeconomic consequences of the occurrence of credit rationing in a different policy environment. In other words, we show in this part of the paper the sensitivity of the system to different parameters' changes which represent defined scenarios (see previews chapter) and other possible support mechanisms. The environment without any policy transfers serves as a baseline.

To be able to carry out the sensitivity analysis, firstly, we need to define the values of parameters and the initial values of k_0 and B_0 for scenario 0, i.e. for the environment without any supports.

Table 6 contains values of parameters and initial values of k_0 and B_0 for scenario 0. We decided for these values because of the following reasons. Parameters *α* and *β* represent the characteristics of big agricultural enterprises with 100 and more employees. The parameters were estimated based on the quarterly data for the period 1998-2002 (see ČECHURA, 2005). Price *p* and technology *z* were normalized to 1 for scenario 0 without loss of generality. The depreciation rate *b* in the height 5 % shall represent average depreciation rate of the big agricultural enterprises. The interest rate *r* was set 2 % higher than discount interest rate in the economy. Parameters *ρ* and *σ* of the cost function were chosen to approximate the convexity of investment costs with respect to the volume of investment spending. The initial value of k_0 was set arbitrarily on the level of 100 thousand CZK (the units correspond to the estimation of the Cobb-Douglas production function of big agricultural enterprises with 100 and more employees – see the setting of α and β). B_0 was chosen on the level of 10 % of k_0. Finally, the parameter *s* is the approximation of the average retain earnings rate.

Table 6: Parameters and initial values of k_0 and B_0

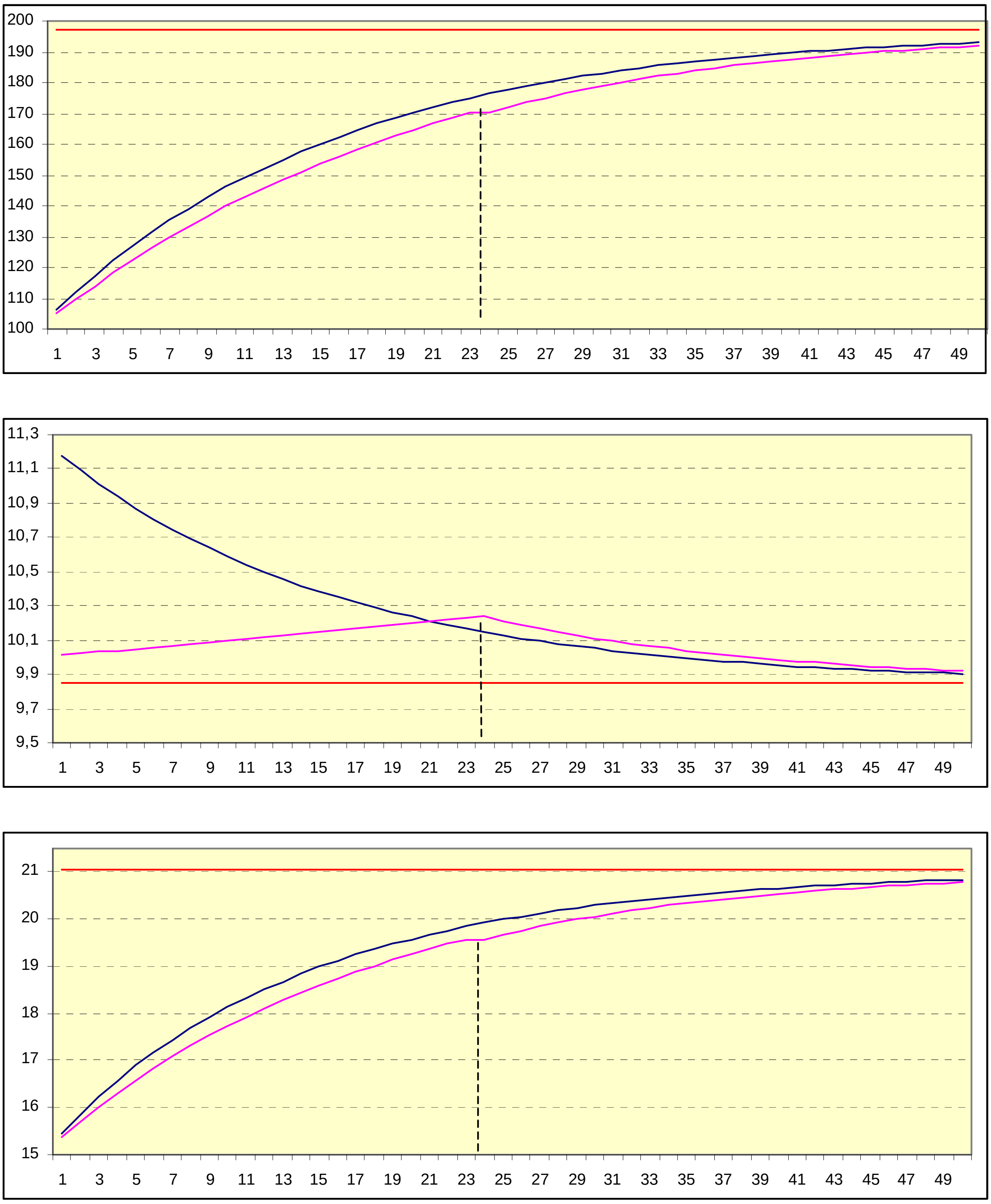
β	p	z	b	r	α	ρ	σ	k_0	B_0	s
0,5	1	1	0,05	0,04	1,5	0,06	0,03	100	10	0,01

Source: Own definition.

As we have defined the values of parameters and initial values of k_0 and B_0, we may show the paths of capital, investment and farmer's supply for this setting. The paths are computed based on equations (17)′, $I_t = B_t = B_0 + s \cdot t$, (31), (31)′ and (15) and are depicted in Figures 7a,b,c. The blue line in Figures represents the paths of capital, investment and farmer's supply when the farmer is not financially constrained. The pink line shows the paths of capital, investment and farmer's supply when the farmer is financially constrained during the period $0 \le t < t_1$. The switching time t_1 is depicted in Figures by the dashed line. Finally the red line represents the stationary values of capital, investment and farmer's supply to which the variables converge. Thus, scenario 0 shows that the paths of capital and farmer's supply are increasing concave curves. The paths of a financially constrained farmer lie bellow the paths of a farmer who does not face a financial constraint. The path of investment is, for a financially constrained farmer, a linearly increasing line till time t_1 and a convex decreasing curve from time t_1. That is, if the farmer is financially constrained, the investment rate is first lower than the investment rate of the farmer who does not face a financial constraint and then higher, ceteris paribus.

As Figures 7a,b,c show the same patterns as Figures in previous chapter, the graphical exposition of our numerical solution is sufficient and we only show the results of this chapter numerically. In other words, we present the consequences of the parameter change or of the change in initial value of k_0 or B_0 on the switching point and stationary values of the capital and investment. The results of the parameter change and of the change in k_0 and B_0 are presented in Table 7.

Figure 7a, b, c: Paths of capital, investment and farmer's supply – Scenario 0



Source: Author's depiction.

Table 7 contains values of switching point and stationary values of the capital and investments for scenario 0 and defined changes in initial values of k_0 and B_0 and changes in parameters of interest. Furthermore, Table 7 compares the resulting changes in switching point and stationary values to scenario 0. And, for purposes of comparison the resulting changes are recalculated on 1% change of k_0, B_0 or parameter of interest, respectively.

Table 7: Sensitivity analysis

		t_1	k_S	I_S	The change compared to scenario 0 (%)					
					t_1	k_S	I_S	t_1	k_S	I_S
Scenario 0		24	196.930	9.847	–	–	–	on 1% change of k_0, B_0 or parameter		
k_0	110	21	196.930	9.847	-12.500	0.000	0.000	-1.250	0.000	0.000
	150	14	196.930	9.847	-41.667	0.000	0.000	-0.833	0.000	0.000
B_0	9.5	48	196.930	9.847	100.000	0.000	0.000	20.000	0.000	0.000
	10.5	10	196.930	9.847	-58.333	0.000	0.000	-11.667	0.000	0.000
s	0.005	28	196.930	9.847	16.667	0.000	0.000	0.333	0.000	0.000
	0.02	18	196.930	9.847	-25.000	0.000	0.000	-0.250	0.000	0.000
	0.03	15	196.930	9.847	-37.500	0.000	0.000	-0.188	0.000	0.000
ρ	0.04	24	197.305	9.865	0.000	0.190	0.190	0.000	0.006	0.006
	0.08	22	196.406	9.820	-8.333	-0.266	-0.266	-0.250	-0.008	-0.008
σ	0.02	294	257.778	12.889	1125.000	30.898	30.898	33.750	0.927	0.927
	0.04	0	162.660	8.133	-100.000	-17.402	-17.402	-3.000	-0.522	-0.522
r	0.03	72	213.123	10.656	200.000	8.223	8.223	8.000	0.329	0.329
	0.05	6	183.478	9.174	-75.000	-6.831	-6.831	-3.000	-0.273	-0.273
p and z	1.1	60	209.935	10.497	150.000	6.604	6.604	15.000	0.660	0.660

Source: Own calculations.

Thus the results show that the switching point is mostly sensitive to the change in *σ*, *B_0*, *p*, *z* and *r*. In other words, the time during which a farmer is financially constrained is mostly sensitive to the initial bound of investment *B_0*, the parameter of the cost function *σ*, the price *p*, the level of technology *z* and the discount rate *r*. The stationary values of the capital and investment are sensitive to the change in parameters σ and r.

Taking the results of this chapter and previous chapter together it follows that the support in Scenario 1a may be more efficient than Scenario 1b. As far as the farmer's economic equilibrium is concerned, the most efficient support is represented by Scenario 1c and also 2. However, several other aspects of these supports must be considered (see conclusions).

4.4 Uncertainty

As uncertainty is part of the real world and it is a significant determinant of business decisions, we modify our model in this part of the paper and show the effect of uncertainty on the investment decision of the farmer. The basic characteristics of the model are the same and we introduce only the modifications of the model and the problem solution.

The first modification is the function of the investment cost. We replace the function (1) by (46). This form of investment cost (used by BOND et al., 1994) simplifies the solution.

$$g(I_t, k_t) = \frac{d}{2} \cdot \left[\left(\frac{I_t}{k_t} \right) - c \right]^2 \cdot k_t \qquad (46)$$

We suppose again that the farmer wishes to maximize her/his profit or the value of the firm, respectively. Thus the maximization problem is given by (47), subject to the capital accumulation equation, initial condition and the control variable constraint (48).

$$\max_I E\int_{t_0}^{\infty} e^{-rt}\left[p\alpha k_t^{\beta} z-\frac{d}{2}\cdot\left[\left(\frac{I_t}{k_t}\right)-c\right]^2\cdot k_t\right]dt \ , \tag{47}$$

$$\text{s.t. } dk_t=(I_t+bk_t)dt+\sigma k_t dz\ ,\ k(0)=k_0 \text{ and } 0\le I_t\le B_t , \tag{48}$$

where *dz* is a Wiener process with mean zero and unit variance. That is, we have incorporated the uncertainty into the model by letting k_t be a subject to stochastic disturbance. In other words, we have instead of the usual differential equation $dk_t=(I_t+bk_t)dt$ the stochastic differential equation $dk_t=(I_t+bk_t)dt+\sigma k_t dz$. The stochastic disturbance in k_t can be thought of as a result of the price variation in the market. We could model the situation letting *p* follow the stochastic process. But we decided for k_t for two reasons. First, we do not need to change the model structure and second, the effect on the farmer's decision is similar. Thus, in economic terms we may say that the price in our model represents the real price level and k_t states for the real capital, which is subject to the stochastic disturbances due to the real price variations.

As we have introduced the stochastic variable and have got the stochastic differential equation, we need to use stochastic calculus. So, we state the optimal control in closed-loop (feedback) form. That is, we have the form in terms of the state instead of time (see e.g. KAMIEN et al., 1991). The open-loop and closed-loop forms differ in the form but they produce identical values for the optimal control at each date of the planning horizon (see e.g. CAPUTO, 2005). Thus, to solve our dynamic optimization problem (47) subject to (48) we use a stochastic form of Hamilton-Jacobi-Bellman equation (i.e. we use the dynamic programming tools to solve our stochastic problem). We must solve (49).

$$rV(k_t)=\max_I\left(\left[p\alpha k_t^{\beta} z-\frac{d}{2}\left[\left(\frac{I_t}{k_t}\right)-c\right]^2 k_t\right]+V_k\cdot(I_t-bk_t)+\frac{1}{2}\sigma^2 k_t^2 V_{kk}\right) \tag{49}$$

Thus we differentiate (49) with respect to I_t to get the optimal I_t. The differentiation yields

$$I_t=\frac{V_k}{d}\cdot k_t+ck_t \ . \tag{50}$$

Then we substitute (50) to (49) to get after small simplifications

$$rV(k_t)=p\alpha k_t^{\beta} z+\frac{1}{2}\frac{1}{d}(V_k)^2 k_t+ck_tV_k-bk_tV_k+\frac{1}{2}\sigma^2 k_t^2 V_{kk} \ . \tag{51}$$

We obtained the nonlinear second order differential equation. As we put enough structure on the problem, we "try" the solution to this differential equation of the form:

$$V(k_t)=Ak_t^{\beta}+B \tag{52}$$

where *A* states for the coefficient and *B* for the constant to be determined. Now, we verify if the suggested solution holds and then we may determine *A* and *B*. To do that we compute the first and second derivatives of (52) with respect to k_t and together with (52) we substitute them from (51) to get after small simplification (53).

$$rAk_t^{\beta} + rB = p\alpha k_t^{\beta} z + \frac{1}{2}\frac{1}{d}A^2\beta^2 k_t^{2\beta-1} + cA\beta k_t^{\beta} - bA\beta k_t^{\beta} + \frac{1}{2}\sigma^2 A\beta(\beta-1)k_t^{\beta} \tag{53}$$

We might observe see that the suggested form of the solution holds for $\beta = 0.5$. As this specific solution is more straightforward compared to the general solution (i.e. for different values of β) and as it also complies with the value of β from the previous part (see the characteristics of agricultural enterprises with 100 and more employees), we show the solution for $\beta = 0.5$.

Thus solving for $\beta = 0.5$ we get

$$rA = p\alpha z + cA\beta - bA\beta + \frac{1}{2}\sigma^2 A\beta(\beta-1) \tag{54}$$

and it yields

$$A = \frac{p\alpha z}{r - 0.5c + 0.5b + 0.125\sigma^2} \quad . \tag{54$'$}$$

Furthermore, (53) implies that for $\beta = 0.5$ the constant B is equal to

$$B = \frac{1}{8rd}A^2 \quad . \tag{55}$$

Then the specific solution to our problem is

$$V(k_t) = \frac{p\alpha z}{r - 0.5c + 0.5b + 0.125\sigma^2}k_t^{\beta} + \frac{(p\alpha z)^2}{8rd(r - 0.5c + 0.5b + 0.125\sigma^2)^2} \tag{56}$$

and its first derivative

$$V_k = \frac{p\alpha\beta z}{r - 0.5c + 0.5b + 0.125\sigma^2}k_t^{\beta-1} \quad . \tag{57}$$

Using (57) in (50) we get the optimal control function (58) for the situation when the farmer is not financially constrained.

$$I_t = \frac{p\alpha\beta z}{d\cdot(r - 0.5c + 0.5b + 0.125\sigma^2)}k_t^{\beta} + ck_t \tag{58}$$

If the farmer is financially constrained the investment is equal to the upper bound, i.e. $I_t = B_t$.

Finally, we may convert the solution to open-loop form by solving of the following stochastic differential equation:

$$k_t' = (I_t + bk_t)dt + \sigma k_t dz = \left(\frac{p\alpha\beta z}{d\cdot(r - 0.5c + 0.5b + 0.125\sigma^2)}k_t^{\beta} + (c+b)k_t\right)dt + \sigma k_t dz \quad . \tag{59}$$

The solution to (59) is not exposed here because it is behind the scope of this part of the paper. But we shall examine the effect of uncertainty on the farmer's investment or capital accumulation, respectively.

Taking the first derivatives of (56) and (58) with respect to uncertainty (i.e. with respect to σ), we get equations (60) and (61). (60) and (61) show us that the effect of uncertainty on the farmer's capital accumulation and investment is negative. In other words, the higher uncertainty the farmer faces, the lower investment spending and capital accumulation she/he has.

$$\frac{\partial V(k_t)}{\partial \sigma} = -\frac{0.250\sigma p\alpha z}{(r-0.5c+0.5r+0.125\sigma^2)^2}k_t^{\beta} - \frac{0.5\sigma(p\alpha z)^2}{8rd(r-0.5c+0.5b+0.125\sigma^2)^3} < 0 \qquad (60)$$

$$\frac{\partial I_t}{\partial \sigma} = -\frac{0.250\sigma p\alpha\beta z}{d(r-0.5c+0.5b+0.125\sigma^2)^2}k_t^{\beta} < 0 \qquad (61)$$

5 CONCLUSIONS

In the analysis of agricultural loans and their institutional support it was shown that the SGAFF (Supporting and Guarantee Agricultural and Forestry Fund) may have played an important role in loan creation during the period 1994-2006 and that it significantly determined investment activity in Czech agriculture. That is, the SGAFF may have reduced the problem of the occurrence of credit rationing in Czech agriculture. To view the microeconomic consequences, the occurrence of credit rationing and the role of different agricultural support mechanisms were analyzed based on the derived theoretical model.

The derived theoretical model showed that the occurrence of credit rationing may significantly determine a farmer's economic equilibrium. That is, the farmer, who faces credit rationing, is for some time outside her/his economic equilibrium. Consequently, she/he reaches the saddle point later (if it is feasible) compared to the non-credit constrained farmer.

The loan guarantee makes the path to financial constraint shorter. That is, the loan guarantee decreases the problem of the occurrence of external credit rationing and the farmer reaches her/his economic equilibrium and also the saddle point faster. However, if the stationary state is feasible with the support of SGAFF and then the farmer is not able to carry out at least the investment to the size of the amortization bk_t, then, it may be a case of the crowding-out effect of capital from the agricultural sector.

Interest rate subsidy does not decrease external credit rationing but it decreases the internal credit rationing presented by the cost of financial resources. Then it increases the propensity to invest and may cause external credit rationing or financial constraint to be tougher, respectively. Since the SGAFF's programs are open for all farmers, the interest rate subsidy may produce overinvestment. In other words, for non-credit rationed farmers this is the way to cheaper financial resources, which may be crowded-out (with higher probability) after the program termination.

If both a loan guarantee and an interest rate subsidy are offered, then the effects work together. That is, this form of support reduces both the external and internal credit rationing. However, if the non-credit rationed farmer is granted, then the overinvestment or the crowding-out effect may be reinforced, respectively. Direct payments also result in higher farmer's investment and supply and, thus, may also support overinvestment (but indirectly).

The numerical application shows that the farmer's economic equilibrium is mostly sensitive to the initial bound of investment, the parameter of the cost function, the price, the level of technology and the discount rate.

As far as the farmer's economic equilibrium is concerned, the theoretical analysis and numerical application suggest that the most efficient support is represented by Scenario 1c and also 2. However, if we evaluate the effectiveness of analyzed scenarios from both farmer and agricultural policy point of view, scenario 1a seems to be the most effective way of support.

Finally, if uncertainty is introduced into the theoretical framework, it was demonstrated that the farmer's investment spending and capital accumulation is lower.

To sum up, we may conclude that, in general, the hypotheses of the paper holds.

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