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**Firms' Fixed Capital Investment under
Restricted Capital Markets**

November 2004

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1 Introduction

The determinants of firms' fixed capital investment play an important role in growth and business cycle theories. They are crucial in designing optimal fiscal policy. Hence, study aimed at the identification of the major impediments to the optimal level of investment at firm level, has not only academic interest, but also provides practical implications for economic policy. Many previous studies acknowledged the existence of the 'financial hierarchy', when firms rely heavily on the internal sources of financing of capital investment (see section Literature Review). Asymmetric information, agency costs and transaction costs are often mentioned as the primary reasons of the financial hierarchy. This study hypothesizes that the investment behavior of any firm at a given period of time can be explained by one of the two mutually exclusive and exhaustive regimes: constrained or unconstrained. In particular, investment of a 'constrained firm' is the minimum of the optimal level and internally available funds, regardless of the source of the financial constraint. Application of the switching regression technique makes possible the estimation of the parameters for each of the regimes. This study differs from the vast literature in the field in several dimensions. First of all, in contrast to the widely used Tobin's Q models of investment equations our methodology does not require extensive stock market data. Therefore this approach has potential applicability to a large set of countries and industries, in many of which stock market data may be unavailable or unreliable. Second, the model is not related to a particular type of financial constraint (e.g. source of external financing, capital intensity, growth rates, age, etc.) in contrast to some of the empirical models¹. Thus, it is possible to model a wide range of different situations without making specific assumptions about the source of the constraint itself. This although comes at a cost of some simplifications, which might be strong in some cases. Third, proposed methodology allows exact (to the extent of the precision of the estimation procedure itself) identification of the constrained and unconstrained firms, that is, it estimates how the sample is separated into constrained and unconstrained firms. Thus, it is possible not only to make inferences about the presence of financial constraints, but also to identify firms that are subject to such constraints. Finally, although in the present study we used a number of simplifying assumptions to derive the investment equation in a

¹ This approach may be viewed as a close one to the "non-negativity of dividends" way of introducing financial constraints, although these views employ different methodologies.



traditional way, this should in no way be seen as a weakness of the approach itself. Indeed, more realistic settings (e.g. monopolistic competition, stochastic environment, different adjustment cost functions, etc.) can be used to construct alternative (probably more complicated) models with better fit and explanatory power.

2 Literature review

Economic literature contains several basic approaches to the modeling of capital investment. The most widely used 'traditional' investment models are generalized accelerator, cash flow (often combined with accelerator), neoclassical (and its modified versions), Q-theory (also known as securities value) models, etc. Many recent empirical studies of investment behavior focused also on the direct estimation of the first order conditions (Euler equations) derived from a dynamic optimization problems. This study uses the model from the later subset.

Much of the earlier investment literature does not consider cash flow and other financial variables in the investment function.² According to the neoclassical theory, a firm's desired capital stock is determined by factor prices and technology and cash flow or other financial variables play no direct role in this theory. Thus, it was assumed that any desired investment project can be financed. Recently, many authors developing theories of capital market imperfections point in an opposite direction.³ Over the past two decades many authors attempted to extend traditional investment models to account for external financial constraints.⁴ Theoretical models studying internal sources of investment financing versus external ones are generally based on an information asymmetry between borrowers and lenders. This asymmetry may significantly increase the cost of external funds through excessive risk premiums in the interest rates charged to borrowers. The availability of internal finance enhances the firm's ability to raise outside funding by providing a signal to investors about the performance of the company under imperfect information environment. An alternative view on the information imperfections gave rise to the "agency costs" models, which emphasize conflicts of interests between managers and external shareholders. In particular, extensive monitoring and reduced managerial flexibility resulting from the attempts of outside shareholders to control managers may lead to the direct increase in the associated costs of "control" as well as to foregone profit opportunities. Similar approaches relate the financial hierarchy to the conflict of interests between incumbent shareholders and outside investors. Other models point towards the

² Sometimes this proposition is also referred to as "Modigliani-Miller Theorem".

³ With respect to R&D investments, however, the importance of internal finance was greatly acknowledged in early studies as well due to Schumpeter's view of monopoly profit as a resource for innovative activity (see Schumpeter, 1942).

⁴ It would be definitely incorrect to date the beginning of the investigating the role of financial constraints to the 1980s. The early studies raised this problem as far as about 40 years in the past. However, an increasingly varying approaches and successful their application to the available data certainly appear relatively recently.



importance of transaction costs. For instance, the difference between the costs of internal and external funds may be due to registration fees, underwriting discounts, and the selling expenses related to the procedure of bonds and stocks issuance. Also, the existence of financial hierarchy may be supported by the difference in taxation of dividends and capital gains. An excellent survey of the early and recent theoretical models of investment and their empirical counterparts can be found in Chirinko (1993). The problem of external versus internal financing is discussed from a variety of theoretical perspective in Myers and Majluf (1984), Hubbard (1988), Bernstein and Nadiri (1988), Sinai and Eckstein (1983), Kopcke (1985), and Fazzari and Mott (1986).

Below we focus on the recent empirical literature investigating the impact of financial constraints on the firms' fixed capital investment. Hubbard (1998) in his review article particularly admits that "the principal findings of these studies are that: (1) all else being equal, investment is significantly correlated with proxies for changes in net worth or internal funds; and (2) that correlation is most important for firms likely to face information related capital-market imperfections" (p. 193). There are several ways of modeling financial constraints. At the same time the vast majority of these methods use the idea of sensitivity of investments to the changes in cash flows or other internal worth variable. This approach is traditionally implemented by including additional financial variables in a theory-driven investment equation. Under the null hypothesis of no financial constraints, coefficients for these variables should not be statistically significant. Rejection of the null is used as an indication of financial hierarchy. For example, this approach was employed in a Fazzari and Athey (1987) by using two variables capturing the financing constraints: flow of internal finance and interest expense. The results supported the hypothesis of the importance of financial constraints for firms' investment. Hence, the authors conclude that "[t]o predict a firm's investment, it is not sufficient to know only the firm's desired path of capital accumulation in the absence of financial constraints. One must also determine whether all desired investment can be financed." (p. 482). However, it is worth noting that such methodology has a significant flaw, which was recognized by many authors. In particular, it is unclear "whether the investment cash-flow sensitivity is a signal of financial constraints or merely a signal of expected profit" (Chatelain, 2002, p.6). Indeed, even if financial markets are perfect and there is no difference in the costs of external and internal financing, the future profitability of capital is likely to be reflected by the financial variables Fazzari, Hubbard and Petersen (1988) in their seminal paper provide an elegant solution to the problem by estimating an investment equation with financial variables for two separate groups of firms, classified by their dividend behavior. The results show that although "financial effects were generally important for investment in all firms, [b]ut the results consistently indicated a substantially greater sensitivity of investment to cash flow and liquidity in firms that retain nearly all of their income" (p. 184). Calomiris and Hubbard (1995) use the firm-level dataset for 1933-38 providing "a rare opportunity to measure the shadow price differential between internal and external finance" (p. 476) due to a surtax on undistributed profits. The authors find that firms with a high shadow value on internal funds also revealed much greater sensitivity of investments to internal funds. As it is



shown by Lamont (1997) in his study of non-oil subsidiaries of oil companies, a decrease in cash flow and collateral value may lead to the decrease in investments. Oliner and Rudebusch (1992) provide added support to the hypothesis of information asymmetry as a major source of the financial hierarchy.⁵ Finally, the approach in this paper can be motivated by the following citations: “in any period a subset of firms may be in a regime in which their investment expenditure is constrained by the availability of internally generated funds” (Bond and Meghir, 1994). Also, as it was admitted in Greenwald, Stiglitz, and Weiss (1984, p. 198), “[i]t is the availability of capital and not its cost that determines the level of investment”.

3 Definitions and basic model

Our theoretical model of investment is based on the set of relatively standard assumptions. Particularly, each industry is represented by N identical firms. A fixed capital stock depreciates at a constant rate δ . The interest rate is exogenously determined and is denoted by r . The capital stock is built upon investment goods, which can be purchased and sold at a given price normalized to one. Firm j uses a constant return to scale Cobb-Douglas technology. Thus, the real profit of firm j is linear in capital: $\pi_{jt} = \beta k_{jt}$, where $\beta > 0$ is the marginal profitability of capital. Firms can be broadly divided into two groups. The first one relies on their current profits only as a source for investments. The maximum amount of investment for this group is thus capped from above by some constant fraction of the current year profit $i_{jt} \leq s \cdot \beta k_{jt}$ (plus outside funds if available minus adjustment costs), with $0 \leq s \leq 1$. The second group can have access to external funds and is able to invest the optimal amount. Finally, we assume that adjustment of the capital stock is costly. The adjustment cost depends on both the level of investments i plus the current capital stock. Thus, adjustment costs are given by $c(i_{jt}, k_{jt})$, where

$$c(0, k_{jt}) = 0, \frac{\partial c(0, k_{jt})}{\partial i_{jt}} = 0, \frac{\partial^2 c(\bullet)}{\partial i_{jt}^2} > 0 \text{ and } \frac{\partial c(\bullet)}{\partial k_{jt}} < 0 \text{ for positive levels of } k_{jt}.$$

The basic approach to the modeling of investment behavior was borrowed from Bond and Meghir (1994). A firm is assumed to maximize its net present value:

$$V_t(K_{t-1}) = \max_{I_t} \{ \Pi(K_t, I_t) + \rho_{t+1} V_{t+1}(K_t) \},$$

where capital evolves according to the equation of motion $K_t = (1 - \delta)K_{t-1} + I_t$, $\Pi(K_t, I_t) = \beta K_t - I_t - C(I_t, K_t)$, and the symmetric

⁵ Interestingly, that using panel data of U.S. firms covering the late 1970s and early 1980s the authors find that while information asymmetry is definitely an important factor determining firms' capital investment, they have failed to find evidence to the transaction costs argument.



adjustment cost function is defined as $\frac{1}{2}bK_t[(I/K)_t]^2$. Using the envelope theorem, the Euler equation characterizing the optimal path of investment is determined by

$$\lambda_t = (1-\delta)\left(\frac{\partial \Pi_t}{\partial K_t}\right) + (1-\delta)\rho'_{t+1}\lambda_{t+1},$$

where $\lambda_t = \frac{\partial V_t}{\partial K_{t-1}}$ is the shadow value of capital. From the first-order condition for investment we can also obtain

$$(1-\delta)\left(\frac{\partial \Pi_t}{\partial I_t}\right) + \lambda_t = 0$$

Combining these two equations we can express an Euler equation in terms of observables:

$$-(1-\delta)\rho'_{t+1}\left(\frac{\partial \Pi_{t+1}}{\partial I_{t+1}}\right) = -\left(\frac{\partial \Pi_t}{\partial I_t}\right) - \left(\frac{\partial \Pi_t}{\partial K_t}\right)$$

Now to derive the empirical equation, we proceed as follows:

$$\Pi = \beta K_t - I_t - \frac{1}{2}bK_t\left(\frac{I_t}{K_t}\right)^2, \quad \text{then} \quad \frac{\partial \Pi_t}{\partial I_t} = -1 - bK_t\frac{I_t}{K_t^2} = -1 - b\frac{I_t}{K_t}, \quad \text{and}$$

$\frac{\partial \Pi_t}{\partial K_t} = \beta + \frac{1}{2}b\left(\frac{I_t}{K_t}\right)^2$. Substituting back to the Euler equation and rearranging we can get:

$$-(1-\delta)\rho'_{t+1}\left[-1 - b\frac{I_{t+1}}{K_{t+1}}\right] = 1 + b\frac{I_t}{K_t} - \beta - \frac{1}{2}b\left(\frac{I_t}{K_t}\right)^2 \Leftrightarrow$$

$$\frac{I_{t+1}}{K_{t+1}} = \frac{1}{(1-\delta)\rho'_{t+1}}\left[\frac{1}{b} - \frac{\beta}{b} + \frac{I_t}{K_t} - \frac{1}{2}\left(\frac{I_t}{K_t}\right)^2\right] - \frac{1}{b}$$

$$\frac{I_{t+1}}{K_{t+1}} = \left(\frac{1}{b} - \frac{1}{b(1-\delta)\rho'_{t+1}}\right) - \frac{\beta}{b(1-\delta)\rho'_{t+1}} + \frac{1}{(1-\delta)\rho'_{t+1}}\left[\frac{I_t}{K_t} - \frac{1}{2}\left(\frac{I_t}{K_t}\right)^2\right]$$



Finally by denoting $i_t = \frac{I_t}{K_t}$, $\alpha_0 = -\left(\frac{1}{b} - \frac{1}{b(1-\delta)\rho_{t+1}^t}\right)$, $\alpha_1 = \frac{1}{b(1-\delta)\rho_{t+1}^t}$, $\alpha_2 = -\frac{1}{(1-\delta)\rho_{t+1}^t}$, we can rewrite the empirical (reduced-form) version of the Euler equation as follows:

$$i_{j,t+1} = \alpha_0 + \alpha_1 \beta_{j,t-1} + \alpha_2 (i_{j,t-1} - 0.5 * i_{j,t-1}^2) \quad (*)$$

where j denotes firm's subscript.

Constrained firm behavior at a given time can be explained by the binding constraint itself plus some function of cash-flow variable to account for limited access to the outside funds. We assume that this function is linear in proxy for cash flow: $g\left(CF_t^+\right) = \gamma * CF_t$. Then the constraint becomes:

$$I_t = s\beta K_t - \frac{1}{2} b K_t \left(\frac{I_t}{K_t}\right)^2 + \gamma * CF_t$$

where s is some share of profit devoted to investment. It is easy to recognize a simple quadratic equation. Then the investment equation for the constrained firm can be written as follows:

$$I_t = s\beta K_t - \frac{1}{2} b K_t \left(\frac{I_t}{K_t}\right)^2 + \gamma * CF_t \Leftrightarrow \frac{1}{2} b \left(\frac{I_t}{K_t}\right)^2 + \frac{I_t}{K_t} - s\beta - \gamma \frac{CF_t}{K_t} = 0 \Leftrightarrow$$

$$\theta_1 i_t^2 + i_t + \theta_2 = 0$$

$$i_t = \frac{-1 \pm \sqrt{1 - 4\theta_1\theta_2}}{2\theta_1} = -\frac{1}{2\theta_1} + \sqrt{\frac{1}{4\theta_1^2} - \frac{\theta_2}{\theta_1}} = -\frac{1}{b} + \sqrt{\frac{1}{b^2} + 2\frac{s\beta}{b} + 2\gamma \frac{1}{b} \frac{CF_t}{K_t}} =$$

$$= -1/b + \sqrt{1/b^2 + 2s\beta/b + (2\gamma/b)(CF_t/K_t)}$$

And its reduced form is represented by the equation below:

$$i_{jt} = \varphi_1 + \sqrt{\varphi_1^2 + \varphi_2 \beta_{jt} + \varphi_3 CF_{jt}} \quad (**)$$

4 Econometric model

In the previous section we derived two equations that describe optimal behavior of the firm under constrained and non-constrained regimes. Under



the assumption that any firm in the industry at a given period of time operates in one and only one of the regimes, it is possible to estimate parameters of both equations using a switching regression technique. Assuming a random disturbance terms we can rewrite the two regimes (*) and (**) as follows:

$$\text{Constrained: } i_t = \varphi_1 + \sqrt{\varphi_1^2 + \varphi_2\beta + \varphi_3CF_t} + \varepsilon_{jt}^C$$

$$\text{Unconstrained: } i_{jt+1} = \alpha_0 + \alpha_1\beta_{j,t} + \alpha_2(i_{j,t} - 0.5 * i_{j,t}^2) + \varepsilon_{jt}^{NC}$$

Let ε_C and ε_{NC} be vectors of disturbance terms, which appear as a result of stochastic errors in the investment decision. For simplicity in this application we assume that ε^C and ε^{NC} are independently normally distributed: $\varepsilon^C \sim N(0, \sigma_C^2)$ and $\varepsilon^{NC} \sim N(0, \sigma_{NC}^2)$.

The data generating process is assumed to be described by $i_{jt} = \min\{i_{jt}^C, i_{jt}^{NC}\}$, then for each observation we can derive the following Likelihood Function:

$$LF_{jt} = P(i_{jt}^C > i_{jt}^{NC})f(\varepsilon_{jt}^{NC}) + [1 - P(i_{jt}^C > i_{jt}^{NC})]f(\varepsilon_{jt}^C)$$

$$\begin{aligned} P(i_{jt}^C > i_{jt}^{NC}) &= P(\varphi_1 + \sqrt{\varphi_1^2 + \varphi_2\beta + \varphi_3CF_t} + \varepsilon_{jt}^C > \alpha_0 + \alpha_1\beta_{j,t} + \alpha_2(i_{j,t} - 0.5 * i_{j,t}^2) + \varepsilon_{jt}^{NC}) = \\ &= P(\varepsilon_{jt}^{NC} - \varepsilon_{jt}^C < \varphi_1 + \sqrt{\varphi_1^2 + \varphi_2\beta + \varphi_3CF_t} - \alpha_0 - \alpha_1\beta_{j,t} - \alpha_2(i_{j,t} - 0.5 * i_{j,t}^2)) = \\ &= F\left(\frac{\varphi_1 + \sqrt{\varphi_1^2 + \varphi_2\beta + \varphi_3CF_t} - \alpha_0 - \alpha_1\beta_{j,t} - \alpha_2(i_{j,t} - 0.5 * i_{j,t}^2)}{\sqrt{\sigma_C^2 + \sigma_{NC}^2}}\right) \end{aligned}$$

where $F(\cdot)$ is normal *cdf*. Then the likelihood function for the problem can be written as follows:

$$LF = \prod_{jt} [F(\bullet)f(\varepsilon_{jt}^{NC}) + (1 - F(\bullet))f(\varepsilon_{jt}^C)]$$

This likelihood function belongs to the class of exogenous selection models with undefined sample separation. Certainly, the estimation procedure places sufficiently strong requirements on the data, which implies that the results should not be expected to be very good in terms of precision of estimated parameters and behavior of the likelihood function. At the same time it is worth noting that several authors acknowledge that "the frequency with which 'good' results are reported with this method are indeed surprising" (Maddala, p.1642).

Before discussing the estimation results it is necessary to mention that in the equations above we specify marginal productivity of capital as a



constant for firms within the same industry. Being a consequence of theoretical assumptions this result produce no problems for the model so far. However, it is obvious that the value of the marginal profitability of capital depends on the definition of industry, which becomes crucial for the empirical estimations. In order to take into account difference between marginal productivity of capital in different industries, we use estimates of β at 5-digit industry level.⁶ This allows us to introduce additional flexibility to the model, where, while estimating coefficients at a relatively broad definition of industry (2-digit), we still control for different parameters of narrower sub-industries. Finally, we impose theory-driven restrictions on parameters.

5 Data

In order to test the model we used data from the Ukrainian industrial register for 1993-1998. The values of gross investment spending were adjusted for inflation using the PPI at 3-digit disaggregation level. All numbers thus are represented in terms of 1995 prices. In the table below we convert the summary statistics into USD 1995 for representational purposes. Overall the industrial register covers more than 10,000 individual enterprises (this number slightly varies depending on the year). The following table outlines descriptive statistics for the data.

Table 1
Summary statistics for firms within 2-digit industries for 1993-1998

Capital, USD 1995				
Industry	Min	Max	Average	St.Dev.
Power	5,855.98	121,746,454.07	3,633,053.72	7,244,251.16
Ferrous Metallurgy	53,555.66	92,244,910.99	7,737,990.68	14,313,780.34
Chemical	1,609.43	46,256,509.19	3,056,507.22	6,953,177.72
Machinery	357.82	35,634,255.05	766,786.17	2,037,027.31
Woodworking	1,074.74	4,057,499.79	202,169.57	396,022.00
Construction materials	367.92	7,073,673.58	308,184.73	573,228.27
Light	250.94	6,547,951.84	201,382.83	545,148.03
Food	128.30	61,343,502.27	184,544.30	714,847.38
Investment, USD 1995				
Industry	Min	Max	Average	St.Dev.
Power	0.00	1,471,397.94	17,286.56	66,947.44
Ferrous Metallurgy	0.00	429,374.34	21,485.46	48,742.33
Chemical	0.00	630,503.14	7,902.22	38,936.74
Machinery	0.00	484,754.72	1,398.74	8,917.24
Woodworking	0.00	52,558.30	605.17	3,013.02
Construction materials	0.00	93,727.99	790.80	3,852.13

⁶ Estimation of the MPK was done using constant-less OLS regression across firms within narrow definition of industry (5-digit) and for each year.


Table 1 (cont.)

Summary statistics for firms within 2-digit industries for 1993-1998

Light	0.00	203,598.11	563.20	5,499.54
Food	0.00	434,875.47	1,547.86	9,919.25
Estimated marginal profitability of capital				
Industry	Min	Max	Average	St.Dev.
Power	-0.036	0.284	0.003	0.019
Ferrous Metallurgy	-0.004	0.025	0.005	0.005
Chemical	-0.002	14.590	0.103	1.155
Machinery	-0.431	0.425	0.005	0.024
Woodworking	-0.016	0.291	0.008	0.027
Construction materials	-0.036	0.730	0.005	0.033
Light	-0.079	0.957	0.014	0.068
Food	-0.142	12.744	0.020	0.301
Cash flow per unit value of capital				
Industry	Min	Max	Average	St.Dev.
Power	0.000	2.495	0.040	0.168
Ferrous Metallurgy	0.000	0.256	0.024	0.023
Chemical	0.000	6.041	0.046	0.257
Machinery	0.000	2.239	0.023	0.089
Woodworking	0.000	2.573	0.046	0.181
Construction materials	0.000	2.009	0.028	0.112
Light	0.000	6.182	0.046	0.221
Food	0.000	8.157	0.094	0.395

Source: Ukrainian manufacturing enterprise register, own calculations

Data for both capital and investment is collected by the Ministry of Statistics of Ukraine and comes from individual enterprise balance sheets. Capital data is represented by book value capital adjusted for depreciation. Investment data is given in terms of gross capital investment. As a proxy for cash flow variable we used output in monetary equivalent.⁷

6 Results

At this stage we estimated the switching regression model described above for 8 two-digit industries, including power, ferrous metallurgy, chemical, machinery, woodworking, construction materials, light, and food processing industries. Results of the estimation are listed in the Table 2 below. Estimation was performed using module MAXLIK Version 5.0.2 for Gauss. It

⁷ Definitely, the use of output instead of profit or sales as a proxy for cash flow deserve a rational critique. However, a number of missing observations on alternative variables and great concerns about the quality of the reported data as well as our belief that output volume is highly correlated with the 'true' financial performance of the enterprise lead us to the choice of this proxy.



is worth noting that in all cases normal convergence was achieved, however, in case of Machinery the number of iterations was considerable (about 1,000). Test for robustness of the results was done by selecting different starting values for the maximization procedure. It revealed that in most cases coefficients remained the same up to the fourth decimal point. Upon the availability of time, more formal grid search methods will be used to test robustness of the results.

Theoretical restrictions on the parameters allow us to estimate smaller number of them. In particular, we denote $\theta_1 = \frac{1}{b}, \theta_2 = \frac{1}{(1-\delta)\rho_{t+1}^t}, \theta_3 = s, \theta_4 = \gamma, \theta_5 = \sigma_C,$ and $\theta_6 = \sigma_{NC}$. Estimation results are listed in the table below:

Table 2
Results of the estimation of switching regression model for 9 two-digit industries

	Power (11)	Fer. Met. (12)	Chemical (13)	Machinery (14)	Woodwork (15)	Constr.m. (16)	Light (17)	Food (18)
Number of observations	1670	600	795	6430	1315	3665	2765	9220
θ_1	3.797	26.463	6.973	2.723	0.712	3.630	0.916	2.452
<i>p-value</i>	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
θ_2	1.209	0.995	1.134	1.093	1.038	1.155	1.031	1.199
<i>p-value</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
θ_3	0.773	0.995	0.258	0.079	0.164	0.188	0.086	0.214
<i>p-value</i>	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.000
θ_4	0.006	0.274	0.001	0.001	0.001	0.0001	0.0002	0.002
<i>p-value</i>	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
θ_5	0.003	0.029	0.001	0.0004	0.001	0.001	0.0004	0.003
<i>p-value</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
θ_6	0.071	0.002	0.074	0.095	0.108	0.096	0.093	0.120
<i>p-value</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D.F.:								
$\frac{1}{(1-\delta)\rho_{t+1}^t}$	1.209	0.995	1.134	1.093	1.038	1.155	1.031	1.199
b	3.797	26.463	6.973	2.723	0.712	3.630	0.916	2.452
s	0.773	0.995	0.258	0.079	0.164	0.188	0.086	0.214
γ	0.006	0.274	0.001	0.001	0.001	0.0001	0.0002	0.002
Average Prob(Constr)	0.80	0.39	0.60	0.65	0.51	0.51	0.65	0.76

Source: own calculations

First of all, in the theoretical model real discount factor $\frac{1}{(1-\delta)\rho_{t+1}^t}$ should be positive and greater than one, which is the case for all industries. It is difficult to comment on the estimates of the parameter b entering the

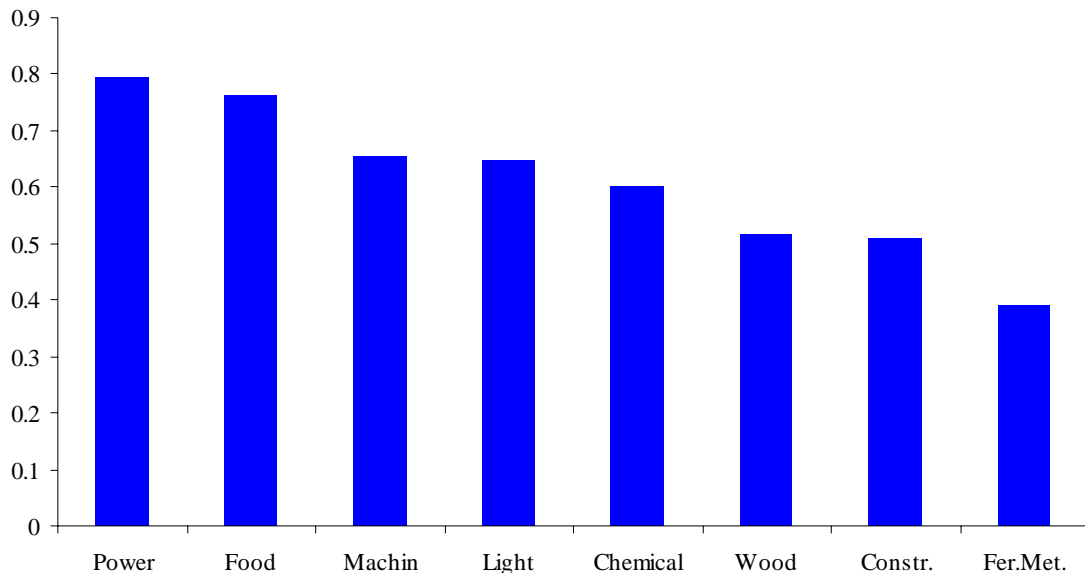


assumed quadratic adjustment cost function. Indeed, cross-industry comparison makes not much sense given broad definition of industry and, thus, completely different technologies of production. It would be definitely interesting to compare estimates of this parameter for different branches within the same industry, say for 3-digit sub-industries within 2-digit ones. Therefore we leave this issue for further research and at this stage we skip discussion of the parameter's values. Estimates of the parameter s (share of gross profits directed to investment) are within the expected range $[0,1]$. According to the results constrained firms in ferrous metallurgy industry devote the largest share of gross profits to investment (about 100%). The lowest parameter of the current profit directed toward investment was found in machinery (about 8%). This is not completely unexpected result given that ferrous metallurgy in Ukraine represents one of the export-oriented industries. It is possible that combination of profitable opportunities and high capital intensity forces constrained firms to invest merely all of their profits. Machinery in turn includes enterprises with different scale of production as well as different prospective for further development. Many of the enterprises in machinery industry were represented by small stagnating workshops facing reduction in demand and hence constant surplus in labor and capital. Cash flow variable has expected positive effect on the level of investment in all industries having the highest impact in ferrous metallurgy.

The Graph below represents average probability of constraints for all 8 industries.

Graph 1

Average probability of constraints for 8 industries



Source: own calculations

As it can be seen from the figure, the lowest share of constrained firms was found in ferrous metallurgy and the highest in power industry. Highest probability of constrained regime in power sector in Ukraine seems reasonable given extremely high level of non-payments from both business



and residential consumers. According to the estimation results, food industry has second highest share of constrained firms after the power industry. One of the possible explanations is that enterprises representing food industry belong to the food processing branch rather than trading one. Vast majority of these enterprises are located in regions and serve local agricultural farms. Empirical evidence suggests that agricultural enterprises during the period under considerations experienced severe liquidity constraints and conduct high rate of so-called non-monetary transactions (toll schemes and barter operations). Hence, the liquidity constraints are likely to be passed on the food processing enterprises, thus, reducing their internal resources for investment and harming general creditworthiness of the industry. As to the rest of the industries, we believe that the figure conveys sufficient information about the degree of importance of investment constraints across industries and since the detailed discussion of the reasons of this particular ranking goes beyond the scope of this paper, we left it for further research which will be conducted at less aggregated level and would be particularly devoted to the study of Ukrainian investment climate and major obstacles for its development in 1992-2000. At the same time, we have to admit that the average probability of constrained regime is very high for the manufacturing sector of Ukrainian economy, which is not surprising given that during the period under consideration Ukraine was in the last quintile of the investor ratings.

One of the benefits of the switching regression approach is that it identifies the subset of constrained firms. A brief analysis of the characteristics of the constrained firms is presented below. Characteristics of the constrained and unconstrained firms are obtained by weighting average of firm-level indicators using probability of constrained/unconstrained regimes as weights.

First of all, according to the estimates, constrained firms on average have higher marginal profitability of capital. At the same time, in absolute amounts profits of constrained firms are smaller than those of unconstrained ones. Besides, unconstrained firms have much larger sales volumes. Together these observations suggest that constrained firms that are likely to be more productive and generate higher return on investments. However, small own resources (current profits) and turnovers (as signals for potential investors) for such firms may represent obstacles for optimal investment behavior, which results in unrealized profit opportunities.

Using data on total power capacities installed and electricity consumed in a given period, we are able to construct proxy variable standing for capacity utilization ratio.⁸ Estimation results suggest that unconstrained firms have smaller capacity utilization ratio. It is not surprising given that excess capacities are likely to be associated with lower optimal levels of investment.

Firms oriented towards international markets traditionally have better access to liquidity both in terms of larger and more stable cash flows as

⁸ It is worth noting however, that the ratio is likely to underestimate capacity utilization ratio since total power capacities installed often include resources for social infrastructure on balance of the firm.

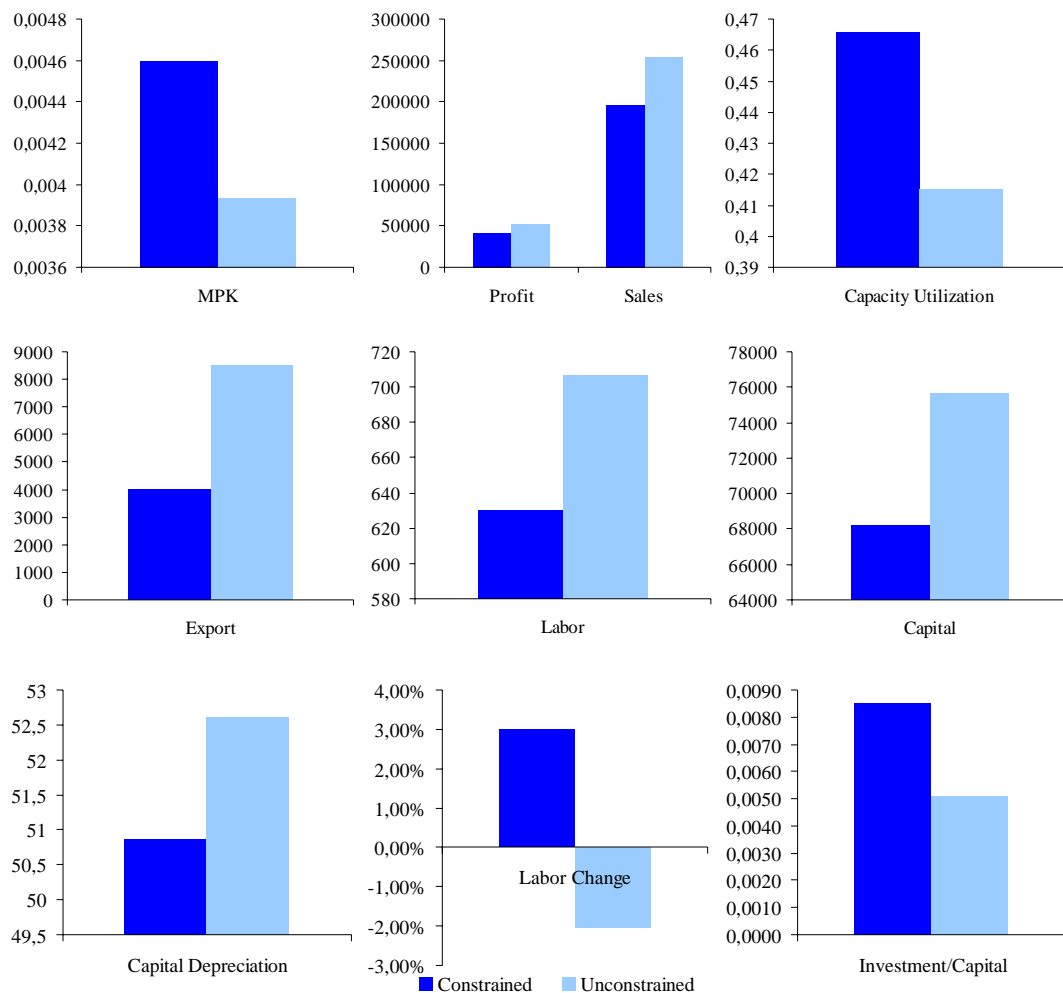


well as in terms of available outside finance. Hence it is not surprising that unconstrained firms have significantly higher share in exports.

One can expect that larger enterprises are less likely to be financially constrained. On the one hand, larger enterprise is more likely to have sufficient (sometimes excess) capacities given reduction in demand. On the other, financial institutions require collateral in terms of capital assets of the enterprise. Therefore, larger enterprises may demand less investment and they also much easier obtain desired financial resources. On the picture above it can be seen that constrained firms are smaller in terms of both capital and labor employed. Furthermore, constrained enterprises have relatively modern equipment, i.e. have smaller capital depreciation ratio.

Graph 2

Characteristics of constrained versus unconstrained firms



Source: own calculations

Finally, constrained enterprises are likely to have higher growth rates as compared to unconstrained. This can be inferred from the average labor

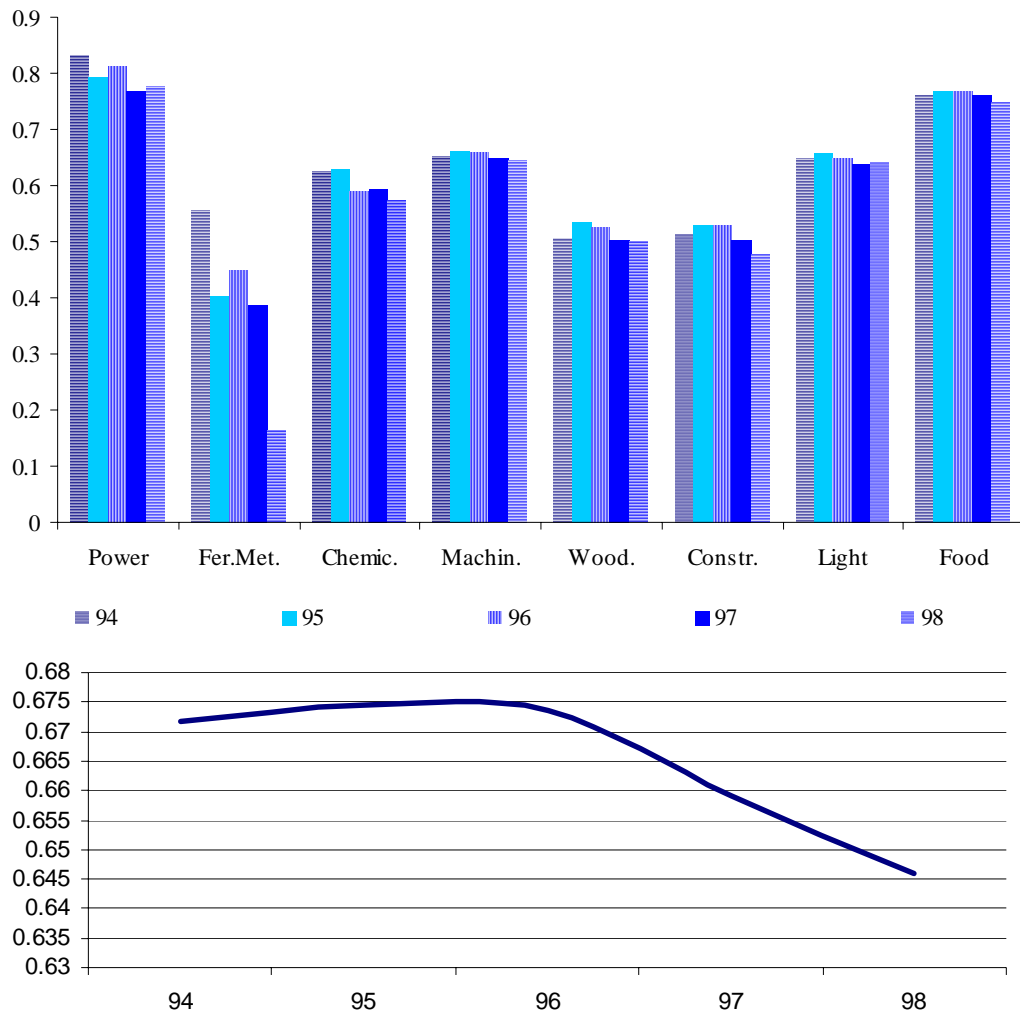


change (percentage change in the labor force as compared to the previous year) and average investment per capital.

Hence, results of the estimation are in line with the theoretical and empirical predictions by other authors. In particular, typical constrained firm is small, young and fast growing entity.

Graph 3

Dynamics of the probability of constrained regime



Source: own calculations

It might be interesting to look at the dynamics of the probability of constrained regime. The figure below represents dynamic of the average probability of constrained regime for each of the 8 industries. As it can be seen, all of the industries exhibit decline in the probability of constrained regime, with the greatest change in ferrous metallurgy industry.⁹ One of

⁹ Export orientation of the industry may be the key determinant of the change.



the possible explanations may be in the strict monetary policy related to the introduction of new currency in Ukraine in autumn 1997.¹⁰

7 Conclusions

In this study we develop a simple theoretical model of firm's investment under restricted capital market. Particularly, it is assumed that investment behavior of any firm within given industry in a given year can be explained by one of the two regimes: constrained or unconstrained. Technically this result is due to the introduction of additional feasibility constrained to the dynamic optimization problem of the firm, which when binding by itself represents investment equation. In case of the non-binding constrained Euler equation is used to trace the optimal path of investment. Switching regression technique from the class of exogenous sample selection models with undefined sample separation is used to estimate the parameters of the model. We used the data from Ukrainian manufacturing enterprise register to test the model and to draw some conclusions about the investment behavior of firms in a transition economy.

The results of the estimation confirm theoretical predictions to a large extent. Particularly, overall quantity of constrained firms in Ukrainian manufacturing sector was very high in 1994-98, which is consistent with the qualitative indicators of investment climate in Ukraine according to major worldwide business and NGO ratings. The most constrained industries were found to be power and food processing and the least constrained – ferrous metallurgy. As to the comparison of constrained versus unconstrained subsets of the firms within manufacturing sector it is possible to make some conclusions, which seems to be logically consistent. In particular, constrained firms on average have higher marginal profitability of capital, which nevertheless cannot be realized due to low absolute value of retained earnings. Besides, access to the external finance for such firms may be restricted due to their smaller size and turnover. With respect to other characteristics of constrained versus unconstrained firms several interesting observations can be made. First of all, export-oriented enterprises having better access to liquidity are more likely to work in unconstrained investment regime. Secondly, capacity utilization ratio is higher for constrained firms, which can be considered as indirect indicator of necessity to increase level of productive capital. Average size of constrained firm measured by absolute value of capital and labor force employed is smaller than that of unconstrained one. Finally, "typical" constrained firm is "younger" and grows faster than unconstrained one, which is perfectly in line with the theoretical and empirical finding discussed in the section "Literature Review" above.

As to the dynamic prospective of the investment constraints, for the Ukrainian economy overall intensity of investment constraints was found to be declining in 1997-98, which coincides with the period of relative macroeconomic stabilization.

¹⁰ Preliminary measures directed towards stabilization of macroeconomic situation including control over exchange rate were made as early as 1996.



In general, the results of the estimation given data limitation and the simplicity of the investment model itself can be considered as encouraging ones. However, in the present paper we left many issues for further research. Particularly, estimation of the model for less aggregated data (e.g. 3-digit industry level) will be particularly interesting in terms of more precise evaluation of investment behavior and its determinants within major sectors of the Ukrainian economy. Besides, a slightly more complicated analysis can be done at the level of theoretical model to account for monopolistic competition. Finally, larger in terms of time-series observations dataset can be used to analyze the most recent developments in the Ukrainian investment climate, taking into account economic recovery and growth.

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Appendix 1

Derivation of the Euler equation

$$\begin{aligned}
 V_t(K_{t-1}) &= \max_{I_t} \{ \Pi(K_t, I_t) + \rho'_{t+1} V_{t+1}(K_t) \} \\
 FOC[I_t]: \quad & \frac{\partial \Pi_t}{\partial K_t} + \frac{\partial \Pi_t}{\partial I_t} + \rho'_{t+1} \frac{\partial V_{t+1}}{\partial K_t} = 0 \Leftrightarrow \rho'_{t+1} \frac{\partial V_{t+1}}{\partial K_t} = -\frac{\partial \Pi_t}{\partial K_t} - \frac{\partial \Pi_t}{\partial I_t} \\
 \frac{\partial V_t}{\partial K_{t-1}} &= \left[(1-\delta) + \frac{\partial I_t}{\partial K_{t-1}} \right] \frac{\partial \Pi_t}{\partial K_t} + \frac{\partial \Pi_t}{\partial I_t} \frac{\partial I_t}{\partial K_{t-1}} + \left[(1-\delta) + \frac{\partial I_t}{\partial K_{t-1}} \right] \rho'_{t+1} \frac{\partial V_{t+1}}{\partial K_t} \\
 &= \left[(1-\delta) + \frac{\partial I_t}{\partial K_{t-1}} \right] \frac{\partial \Pi_t}{\partial K_t} + \frac{\partial \Pi_t}{\partial I_t} \frac{\partial I_t}{\partial K_{t-1}} + \left[(1-\delta) + \frac{\partial I_t}{\partial K_{t-1}} \right] \left[-\frac{\partial \Pi_t}{\partial K_t} - \frac{\partial \Pi_t}{\partial I_t} \right] = \\
 &= (1-\delta) \frac{\partial \Pi_t}{\partial K_t} + \frac{\partial \Pi_t}{\partial K_t} \frac{\partial I_t}{\partial K_{t-1}} + \frac{\partial \Pi_t}{\partial I_t} \frac{\partial I_t}{\partial K_{t-1}} - (1-\delta) \frac{\partial \Pi_t}{\partial K_t} - \frac{\partial \Pi_t}{\partial K_t} \frac{\partial I_t}{\partial K_{t-1}} - (1-\delta) \frac{\partial \Pi_t}{\partial I_t} - \frac{\partial \Pi_t}{\partial I_t} \frac{\partial I_t}{\partial K_{t-1}} = \\
 &= -(1-\delta) \frac{\partial \Pi_t}{\partial I_t} \Rightarrow \frac{\partial V_t}{\partial K_{t-1}} = -(1-\delta) \frac{\partial \Pi_t}{\partial I_t} \Rightarrow -(1-\delta) \rho'_{t+1} \frac{\partial V_{t+1}}{\partial I_{t+1}} = -\frac{\partial \Pi_t}{\partial K_t} - \frac{\partial \Pi_t}{\partial I_t}
 \end{aligned}$$



Appendix 2

Gauss code

```

new;
cls;
library maxlik;
#include maxlik.ext;
maxset;
path="C:\\Documents and
Settings\\Alexander\\Desktop\\Data_File\\dta_new.xls";
range="A2:L27416";
data_raw=xlsreadm(path, range, 1, 0);
id=unique(trunc(data_raw[:,3]/10),1);
declare string matrix h[1,12] = "Industry" "#firms" "#constr"
"%constr" "df" "b" "s" "Var(C)" "Var(NC)" "Exit code" "CF-coef"
"F-n Value";
declare string matrix outp[30,12] = "";
outp[1,]=h;
k=1;
data_out=zeros(1,10);
betareport=zeros(1,4);
for pntr(6,rows(id),1);
dt=selif(data_raw, trunc(data_raw[:,3]/10) .eq id[pntr]);
dataf=matalloc(rows(dt),10);
dataf[:,1:3]=dt[:,1:3];
dataf[:,4]=zeros(rows(dt),1);
dataf[:,5]=dt[:,5]; //inv
dataf[:,6]=dt[:,6]; // const
dataf[:,7]=dt[:,7]; // mpkt
dataf[:,8]=dt[:,8]; // mpktml
dataf[:,9]=dt[:,9]; // X3
dataf[:,10]=dt[:,12]; // 10-profit, 11-output, 12-sales
clear dt;
start=ones(6,1);
start[1]=3;
start[2]=1;
start[3]=0.5;
start[4]=0.5;
start[5]=0.5;
start[6]=0.5;

//_max_Algorithm = 5 ; /* see MAXLIK manual, p. 42 */
//_max_LineSearch = 1 ; /* see MAXLIK manual, p. 45 */
_max_CovPar = 1 ; /* see MAXLIK manual, p. 42 */
_max_gradtol = 1e-5 ; /* see MAXLIK manual, p. 43 */
_max_GradMethod = 2 ; /* see MAXLIK manual, p. 43 0
is opt */
_max_MaxIters = 2000 ; /* see MAXLIK manual, p. 45 */
//_max_Switch = {4, -10, 500, 0.001};

screen off;

```



```

{beta,f,g,cov,ret}=fastmax(dataf,0,&llf,start);
screen on;
call maxprt(beta,f,g,cov,ret);
stop;
if rows(cov) lt 2;
    cov=ones(6,6);
endif;
beta_se = sqrt(diag(cov));
beta_z = beta./beta_se;
beta_p = 2*cdfn(abs(beta_z));
betareport = betareport|beta~beta_se~beta_z~beta_p;
df=beta[2];
b=beta[1];
s=beta[3];
perc_C=sumc(round(dataf[.,4]))/rows(dataf);

fnum = rows(dataf);
fmat = "%*.*lf";
field = 1;
prec = 0;
outp[k+1,1] = ftos(id[pntr],fmat,field,prec);
outp[k+1,2] = ftos(fnum,fmat,field,prec);
outp[k+1,3] = ftos(sumc(round(dataf[.,4])),fmat,field,prec);
prec = 2;
outp[k+1,4] = ftos(perc_C,fmat,field,prec);
prec = 5;
outp[k+1,5] = ftos(df,fmat,field,prec);
outp[k+1,6] = ftos(b,fmat,field,prec);
outp[k+1,7] = ftos(s,fmat,field,prec);
prec = 8;
outp[k+1,8] = ftos(beta[5]^2,fmat,field,prec);
outp[k+1,9] = ftos(beta[6]^2,fmat,field,prec);
outp[k+1,10] = ftos(ret,fmat,field,prec);
outp[k+1,11] = ftos(beta[4],fmat,field,prec);
outp[k+1,12] = ftos(f,fmat,field,prec);
k=k+1;
cls;
screen on;
print outp;
pause(1);
data_out = data_out|dataf;

ret = xlswritesa(outp,"C:\\Documents and
Settings\\Alexander\\Desktop\\Results\\out_screen.xls","a2",1,"
");
print ret;
ret = xlswritem(betareport,"C:\\Documents and
Settings\\Alexander\\Desktop\\Results\\out_beta.xls","b2",1,"")
;
print ret;
ret = xlswritem(data_out,"C:\\Documents and
Settings\\Alexander\\Desktop\\Results\\out_data.xls","a2",1,"")
;
print ret;
stop;

```



```

endfor;
//=====Documenting results=====
ret = xlswritesa(outp,"C:\\Documents and
Settings\\Alexander\\Desktop\\Results\\out_screen.xls","a2",1,"
");
print ret;
ret = xlswritem(betareport,"C:\\Documents and
Settings\\Alexander\\Desktop\\Results\\out_beta.xls","b2",1,"")
;
print ret;
ret = xlswritem(data_out,"C:\\Documents and
Settings\\Alexander\\Desktop\\Results\\out_data.xls","a2",1,"")
;
print ret;
//=====
end;

proc llf(theta,d);
    local y, x1, x2, x3, x4, x5, x6, sigm0, sigmaC, sigmaNC,
pC, pNC, eC, eNC, loglf, NC_K, C_K, a1, a2, a3, a4, b1, b2, b3,
b4;
    loglf=matinit(rows(d),1,0);
    sigmaC=theta[5];
    sigmaNC=theta[6];

        sigm0=sigmaC^2+sigmaNC^2;
        y=d[.,5];
        x1=d[.,6]; //
constant
        x2=d[.,8]; // MPK(t-
1)
        x3=d[.,7]; // MPK(t)
        x4=d[.,9]; // i(t-
1)-0.5i(t-1)^2
        x5=d[.,10]; // CF

//----prameters

        a1=-((1/theta[1])-theta[2]/theta[1]); // times
column of ones
        a2=-theta[2]/theta[1]; // times
beta (MPK)
        a3=theta[2]; // times
i(t)

        b1=-1/theta[1]; // times
column of ones
        b2=1/(theta[1]^2); // times
column of ones
        b3=2*theta[3]/theta[1]; // times
beta (MPK)
        b4=2*theta[4]/theta[1]; // times
CF/K
        eNC=y-x1*a1-x2*a2-x4*a3;
        eC=y-x1*b1-sqrt(abs(x1*b2+x3*b3+x5*b4));

```



```

pC=cdfn((eC-eNC)/sqrt(sigm0));
dataf[.,4]=pC;

NC_K = (1/(sqrt(2*pi*(sigmaNC^2))))*exp(-
.5*((eNC.*eNC)/((sigmaNC)^2)));
C_K = (1/(sqrt(2*pi*(sigmaC^2))))*exp(-
.5*((eC.*eC)/((sigmaC)^2)));
retp(
ln(pC.*C_K + (1-pC).*NC_K)
);
endp;

```
