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WITH MORAL HAZARD

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Neoclassical Investment with Moral Hazard

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Abstract

This paper takes the neoclassical model of the investment decision of the firm and adds a Moral Hazard problem to it. The Moral Hazard problem, which arise due to the separation between ownership and control, induces empirical results from sample splits which are usually interpreted as a sign of financial constraints. These results are a consequence of the departure from the benchmark linear framework of the Neoclassical model. In short, curvature can be a result of either adjustment costs, credit constraints, or of a Moral Hazard problem if the manager has a concave utility function. In addition, the Moral Hazard problem is greatly exacerbated in the presence of a compensation structure with limited liability. This induces volatility in the firm, and depending on the model parameters can generate large losses for the firm coupled with generous compensation outcomes for management.

JEL Classification: E22, G34

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1 Introduction

A pervasive theme in the investment literature is the study of the nature of adjustment costs.[1] The particular nature of the technology of investment affects its dynamic properties and therefore the response to shocks and policies. Here, the literature has found evidence of lumpiness and inaction at the plant level, but also a smoother behaviour at the firm level, which has supported the widespread use of quadratic adjustment costs in models of the investment decision of the firm.

A second theme in this literature is whether we can detect imperfections in credit markets from the observed investment behaviour of different firms. These credit market imperfections again affect the way economies react to shocks and to economic policies. The investment literature has uncovered a firm level pattern of sensitivity of investment to cash flow which has typically been taken as evidence of the presence of financial constraints. Recent criticism, however, has pointed out that measurement error and/or model mispecification can generate the patterns of sensitivity of investment to cash flow observed in empirical exercises.[2]

The present paper fits in the mispecification literature. I ask the question: can we mistakenly infer from empirical exercises the existence of credit constraints and/or investment adjustment costs, when in fact the true structural model has a Moral Hazard problem at the firm level? The model in this paper is a standard neoclassical model of investment with output subject to diminishing returns. To this structure I add in turn adjustment costs, credit constraints, and a Moral Hazard problem. The Moral Hazard problem is imposed on it by having the investment decision be taken by a manager who maximizes an objective function which differs from shareholder value. The model is very stylized and is a reduced form for incentive problems.[3] I explore several possibilities for the objective function of the manager. Curvature in the optimal decision function, and therefore a behaviour like that under adjustment costs and credit constraints, arises due to the fact that the manager has a concave objective function.

The model is then simulated under a calibrated set of parameter values, and a series of moments from artificial data is compared to a set of moments taken from a cut of the Compustat data - including moments from standard sample splits. A "good" model will have moments of its artificial data that are close to the moments of the real data. On this score the Moral Hazard models can outperform either the credit constraints or the adjustment costs

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[1] Cooper and Haltiwanger (2004), Hall (2002).

[2] See Gomes (2000), Erickson and Whited (2000), Cooper and Ejarque (2001).

[3] See work by Covas (2004), Phillipon (2004), and a survey by Andrade et al. (2001).

model, depending on the metric used.

Finally, the paper explores different compensation structures, showing that Moral Hazard problems which arise due to the separation between ownership and control are exacerbated by a compensation structure with limited liability. This induces volatility in the firm's output, and depending on the model parameters can generate large losses for the firm coupled with generous compensation outcomes for management.

2 The Data

The data is a cut from Compustat used in Gilchrist and Himmelberg (1995). Some summary statistics of the data are presented here.[4] There are 428 firms and 12 years of data from 1978 to 1989.

2.1 Basic Moments

For each firm and each variable I compute its mean, standard deviation, first order autocorrelation (by regressing the variable against a constant and its lag and getting the OLS coefficient on the lag), and the ratio of its standard deviation to its mean over the 12 period sample. This yields a distribution of 428 means (μ), standard deviations, (σ), AR1 coefficients, (ρ), and ratios. The following table shows the cross sectional mean (CSM) of these firm level moments for five variables.[5]

CSM	I/K	S/K	OI/K	CF/K	V/K
μ	0.1724	3.1425	0.3775	0.2464	**2.5121**
σ	**0.0922**	0.6309	0.1365	**0.0938**	0.9680
ρ	**0.2374**	0.6533	0.5626	**0.5083**	0.6131
σ/μ	0.5241	0.2017	0.4369	0.1434	0.3682

Additional moments of interest are the relationships between standard deviations and persistence of different variables. The next table again shows cross sectional means (CSM) and standard deviations (CSSD) over the 428

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[4]See their paper for details. I: investment, K: capital, S: sales, CF: cash flow, OI: operating income, and V/K is Tobin´s (average) Q.

[5]One remark on the standard deviation of investment: if we just take one long column with the I/K data for all firms and periods, and take its mean we get the same (obviously) but if we take the standard deviation of this long variable we get 0.1230, slightly higher than the cross sectional average of firm level standard deviations which is 0.0922.

firms of two ratios:

	$\sigma(I/K)/\sigma(CF/K)$	$\rho(I/K)/\rho(CF/K)$
CSM	1.2761	0.9865
$CSSD$	0.9881	10.448

Any representative firm model we study must be able to reproduce some key aspects of these tables.

2.2 Q Regressions

Next, I present a series of regression results with different estimators on this data. I do not try to reproduce the regressions of Gilchrist and Himmelberg (1995) but rather present a series of regressions that can be easily reproduced by the reader, and that are suggestive of the effects we want to look at later. The basic equation *in levels* contains a trend and is

$$\frac{I_t}{k_t} = \alpha_1 + \alpha_2 T + \alpha_3 \frac{V_t}{k_t} + \alpha_4 \frac{cf_t}{k_t} + \alpha_5 \frac{cf_t}{k_t} D_t + e_t$$

and for this equation I use a simple pooled OLS estimator in levels wich has 12 observations for each firm, and 428 firms for the full sample.[6]

But while the model will not have fixed effects, it is conceivable that the data might have such type of heterogeneity among firms, which it is typically assumed to be correctly removed by first differencing. The above regression in first differences is

$$\Delta \frac{I_t}{k_t} = \alpha_1 + \alpha_3 \Delta \frac{V_t}{k_t} + \alpha_4 \Delta \frac{cf_t}{k_t} + \alpha_5 \Delta \left(\frac{cf_t}{k_t} D_t \right) + u_t$$

For this equation I show two estimators. First, a simple pooled OLS estimator in first differences which has 11 observations for each firm (and no trend). Finally a basic pooled Instrumental Variables estimator, where the instruments are the second lag of the explanatory variables.[7] This regression

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[6] We must note that this equation is not ad-hoc, but rather, it arises from the Euler equation of the hayashi linear quadratic model, which is the baseline in the literature. Here the baseline deviates from it in two ways: there are no quadratic adjustment costs and revenues are not linear since $\alpha < 1$. The concavity of revenues alone is sufficient to make cash flow significant in the standard regression so that is not the point here.

[7] Standard errors are just the square root of the covariance matrix, which here is given by $(X'Z(Z'ee'Z)^{-1}Z'X)^{-1}$, where Z is the instrument matrix and e is the error from the first stage regression.

has 9 observations in the time dimension for each firm.

EST	α_1	α_2	α_3	α_4	α_5	R^2
$POLS$	0.1165	−0.0015	0.0153	0.1056	0.0173	0.1433
	(28.4)	(3.11)	(12.7)	(7.1)	(1.39)	
$POLSD$	0.0043		**0.0362**	**0.1439**	0.1924	**0.1206**
	(2.2)		(18.6)	(3.6)	(**1.26**)	
PIV	0.0037		0.0198	0.0530	1.4445	0.0694
	(8.2)		(8.1)	(2.62)	(0.80)	

The dummy variable is an indicator of a sample split. In this case I use only one criterion, which is a rank of dividend payments.[8] This is in fact the main aspect of the literature on credit constraints, and while typically different regressions are run on the different subpanels, here I simply introduce a dummy indicator with a value of 1 if the firm is a low dividend paying firm. We expect the sign of α_5 to be positive indicating a higher sensitivity to cash flow for such firms, in line with the literature. This is a simpler exercise which will allow for an easier comparison with the artificial data since only one regression is necessary.

There are a few important outcomes to note here. First, the low values for the R squared. Second, the fact that the coefficients on the dummy variable are positive but not significant. Third, the fact that cash flow is very significant and its coefficent is one order of magnitude higher than the coefficient on Q.

2.3   Volatility Regressions.

Here I run a simple cross section regression by OLS in the spirit of Cantor (1990). The dependent variable is, for each firm (j), the standard deviation of the investment to capital ratio ($\sigma^j_{i/k}$) and the right hand side variables are a constant (with coeficient α_1), a dummy that qualifies the sample, (α_2), a size measure, (α_3), and the standard deviation of the sales to capital ratio ($\sigma^j_{s/k}$), (α_4). The dummy here splits the sample between high and low dividend paying firms, exactly the same way as above, and has a value of 1 for a low dividend paying firm. The size measure is the capital stock in 1984, which

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[8]There are two sample splits in the empirical regressions of Gilchrist and Himmelberg (1995) that can be replicated with artificial data. One is between small and large firms, and another is between high and low dividend firms. Low dividend firms are those below the 25th cross section percentile of the 1984 ratio of dividends to operating income. Small firms are the firms that are below the 25th cross section percentile of capital in 1984. Big firms are above the 25th percentile. Later, with the artificial data I use period 7 sample capital stock and sample dividends over revenues for each firm.

is the size measure available in this cut of the Compustat. Again, there are $j = 1 : 428$ firms/observations. The equation is

$$\sigma^j_{i/k} = \alpha_1 + \alpha_2 \left[D^j \right] + + \alpha_3 \left[k^j_{1984} \right] + \alpha_4 \left[\sigma^j_{s/k} \right] + u_t$$

The result of this regression is in the following table with T statistics in the bottom row:

	α_1	α_2	α_3	α_4	R^2
$Value$	0.1293	-0.0488	-0.0070	0.0163	0.1056
$Tstat$	10.90	2.05	4.48	2.76	

According to Cantor we expect the sign of α_2 to be positive. While in Cantor´s paper that is true, in this sample that is not the case.[9] A positive sign would imply that "constrained" firms display higher volatility of investment over and above what is structurally implied by its volatility of sales, after controlling for size. Note also that smaller firms have slightly higher - but significant - volatility.

2.4 Moment Selection.

For the exercise that follows in this paper we need to select a set of moments which will be used to test the models developed below. The appropriate moments are related to the structural parameters of the model we are interested in. For example, if matching the value of average q is a key criterion, we must be very careful in choosing the curvature of revenues since it directly determines profitability. Likewise, if volatilities and persistence of investment are the main moments we are interested in, the parameters of the stochastic process as well as the parameters of adjustment costs are key factors affecting our target moments. Of course all components of the model affect these different moments, but some have more direct impact on them. The moments used in this paper are set in bold type in the previous tables.

Some discussion of the moments **not** included is in order. The average of I/K is not used because the depreciation rate is a calibrated parameter which will not be estimated. Averages of cash flow, operating income and sales are not used because the mapping from these data concepts to our

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[9]This regression is the one that can be reproduced with artificial data. In the model there is no bond rating variable. Using a dummy to qualify the sample according to a bond rating, the dummy comes out positive but not statistically significant. If we use the dummy (D) in a multiplicative way by adding the variable product $D \times \sigma(S/K)$, the results change again and in some cases the dummy is then positive and significant.

revenues variable in the model is imperfect. Instead, the average Q is used since it maps directly into the curvature of profits. On the other hand, the fact that operating income and cash flow have reasonably close standard deviations and close to the standard deviation of investment, *while their persistence parameter is double that of investment* seems to be a pattern we should want to replicate. The coefficient on the dummy in the Q regression is not included because the dummy is not significant in this data. Ironically, its T statistic is low, and that is significant. The robust features here seem to be the higher order of magnitude of the cash flow coefficient and the low R squared. The low R squared is included despite the fact that it is hard to get low R squared with artificial data. The volatility regressions are also not considered because they yield mixed results. We will look at these type of moments later, but they will not be used for estimation and statistical model comparison. Clearly the choice of moments affects our outcome in terms of choice of model. However, I believe the selection criteria have been agnostic with respect to the outcomes.

Additionally, the Neoclassical model cannot generate the relative patterns of volatility of investment and Q. No internal structural source of volatility can generate enough volatility in the value function without increasing even more the volatility of investment and output. Several things seem to be incompatible: high average Q´s imply curvature because profits are required. But curvature implies a smoothing of volatility. Therefore, the standard deviation of Q cannot be a moment we want to match without adding some external source of noise to the model. That is straying away from the research strategy but it does have some useful implications: it reduces the coefficient and significance of the Q variable in the regressions with artificial data and of course their R squared, and, in the Moral Hazard problems, a given source of market noise in Q may have implications for what severity of Moral hazard we may recover from the data.

Finally, in the appendix I show the distribution of I/K which does not point towards the existence of fixed costs of adjustment at the firm level in this sample. There is no significant incidence of very low or very high investment ratios, but rather a unimodal distribution with most of the mass concentrated around the mean.

3   Model

Consider a firm which produces using only capital (k). The firm´s profits/dividends are discounted at the factor $\beta = 1/(1 + r)$, and are given by revenues less investment expenditures:[10]

$$\Pi\left(A_t, k_t, k_{t+1}\right) = A_t k_t^\alpha - I_t$$

where $0 < \alpha < 1$. A is a technology shock with persistence parameter ρ and standard deviation σ. Capital obeys $k_{t+1} = (1 - \delta) k_t + I_t$. There are two components which are added (separately) to this basic model.

One component is simply a non negativity (credit) constraint on dividends, which delivers the model:

$$\Pi\left(A_t, k_t, k_{t+1}\right) = A_t k_t^\alpha - I_t \geq 0$$

The other component is the standard quadratic adjustment cost function which sets dividends to:

$$\Pi\left(A_t, k_t, k_{t+1}\right) = A_t k_t^\alpha - I_t - \frac{\gamma}{2} k_t \left(\frac{I_t}{k_t}\right)^2$$

In this case no restrictions are imposed on Π. In all of these three versions the value of the firm is simply the present value of dividends under the optimal decision. The parameters of the model so far are $\alpha, \beta, \delta, \gamma, \rho, \sigma$.

3.1   Moral Hazard

Suppose decisions in this firm are taken by a manager who has a different objective function than that of the owners of the firm. Dividends are:

$$\Pi\left(A_t, k_t, k_{t+1}\right) = y_t - I_t = A_t k_t^\alpha - I_t$$

The fact that the manager and the firm have different objective functions is the source of the Moral Hazard (MH) problem. The manager will maximize

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[10]See page 231 of Gilchrist and Himmelberg (1998). Here sales, operating income and cash flow are essencially the same and equal to revenues $(A_t k_t^\alpha)$. This is because in the data we subtract the cost of goods sold (and other expenses) from sales to get operating income, but our revenues are already net of the wage bill and of variable factors. Then from operating income to cash flow we subtract taxes and interest payments, neither of which exists in this simple framwork - although both of them are easy to include.

By the same reasoning, profits and dividends are the same in the model, whereas in the data dividends are often unrelated to current performance. The present model trivializes dividends.

a utility function, and the respective dynamic programming problem is given by

$$S\left(A_t, k_t\right) = \max_{k_{t+1} \geq 0} \left[u\left(A_t, k_t, k_{t+1}\right) + \beta E_t S\left(A_{t+1}, k_{t+1}\right)\right]$$

Now, once the optimal policy $k_{t+1} = g\left(A_t, k_t\right)$ is found, we can compute the market value of the firm $W\left(A_t, k_t\right)$, mechanically as

$$W\left(A_t, k_t\right) = \Pi\left(A_t, k_t, g\left(A_t, k_t\right)\right) + \beta E_t W\left(A_{t+1}, k_{t+1}\right)$$

where for simplicity we assume all agents (and the market) have the same discount factor, β. Naturally, this market value (W) will differ from the first best value of the firm (denoted $V\left(A_t, k_t\right)$) where we simply maximize profits.

This simple problem is interesting for several reasons. First, it allows us to measure - in a calibrated implementation of the problem - how different objective functions for the manager affect the market value of the firm relative to the first best. Second, it allows us to model, by choosing the utility function, the particular type of Moral Hazard we have in mind. Third, this simple structure is a reduced form for a more general problem where an incentive contract is implemented to minimize the MH problem, and is therefore not necessarily restrictive in this area.[11]

Throughout we will use the CRRA utility function as a reduced form for the MH problem which implies the manager does not like fluctuations.[12] The first formulation of the problem is simply:

$$u\left(\Pi\right) = \frac{1}{1-\eta}\Pi^{1-\eta}$$

and an alternative formulation will have a two part compensation,

$$u\left(w + \phi\Pi\right) = \frac{1}{1-\eta}\left[w + \phi\Pi\right]^{1-\eta}$$

The Euler equation of the problem of the manager has a deterministic steady state given by $r + \delta = \alpha A k^{\alpha-1}$. Note that in the second MH case, none of the parameters (w, ϕ) affects the steady state. One key characteristic of the solution to the dynamic programming problem (DPP) is that, in the baseline problem, the policy functions $k_{t+1} = g^{FB}\left(A_t, k_t\right)$, are horizontal in the (k_{t+1}, k_t) space, that is, they are independent of current capital, $g^{FB}\left(A_t, k_t\right) = g^{FB}\left(A_t\right)$. However, with constraints, adjustment costs, or

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[11]One difference that may result from an endogenous incentive contract is that the manager may face a borrowing constraint, as capital structure is used for incentive purposes.

[12]See Reiche (2004) for a discussion of the amount of hedging top executives do on the option component of their compensation. This is suggestive of risk aversion.

Moral Hazard, the policy functions are no longer horizontal but rather concave and upward sloping in current capital. The key corollary of this fact is that we may think we measure physical adjustment costs to investment, and/or financial constraints, when in fact we are seeing the outcome of a Moral Hazard problem and vice versa.

4   Experiments

We study one calibration taken from the literature and some deviations from it. It is worth emphasizing that we are using a one shock model so that we deliberately limit our ability to match the data in this way. Ingram, Kocherlakota and Savin (1994) make the simple point that all models are essencially unidentified, with the reverse point that, given enough shocks, we can match any characteristic of the data. I note also that we are not estimating the model, although, for the credit constraint model and the adjustment cost model we are in fact using a calibration that results from estimation.[13]

4.1   Calibrated outcomes

Before estimating these models we look at a calibrated outcome for the four models we have described. The following parameter values are loosely taken from the literature:[14]

α	γ	r	δ	η	$\hat{w}$	ϕ	A	ρ	σ
0.72	0.10	0.065	0.17	0.01	0.01	0.005	1	0.111	0.856

The five models are implemented numerically. The first step is to solve the dynamic programming problems and obtain the optimal decision rules. For the benchmark unconstrained problem - without constraints, adjustment costs or moral hazard - the decision rules (or policy functions) in (k_{t+1}, k_t) space are horizontal. Figure 1 shows the four deviations from this benchmark. The top left figure shows the policy functions when we add the nonnegativity constraint. The top right figure shows the case of adjustment costs. The bottom left figure shows the first case of moral hazard, and the bottom right

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[13]Note also, that models (FM,AC,MH,MH2) can be nested so that we could actually estimate one single model to ascertain the relative contribution of each component.

[14]See Cooper and Ejarque (2001). The parameter gama is estimated by CE to be 0.16. Here I use 0.10 for graphical purposes, but it affects the G statistics below. The second Moral Hazard formulation has $\phi = 0.005$, and a constant w calibrated such that fixed compensation averages 1% of profits, $w = \hat{w}\Pi^* = 0.01 \times \Pi^*$. But it is only the relative weight of the fixed and variable compensation that matters.

figure shows the second case of Moral Hazard with a fixed compensation component. Clearly all deviations from the first case deliver curvature in the policy function.

In the first moral hazard case, the remarkable point is the amount of curvature we get from a negligible amount of concavity in the utility function. Part of the reason is the fact that even with minimal concavity, negative dividends are immediately ruled out, so that at the bottom end of the state space the optimal decision becomes severely constrained. In the second MH case, the extent of induced curvature in the policy function is lower.

Armed with these policy functions, I generate n (equal to 300) artificial panels of 428 firms and 12 periods using n artificial draws for a panel of shocks.[15] The same shocks are used in the five models within a replication. I generate artificial versions of the same data used to compute the moments of choice discussed in the data section of the paper.[16] The test statistics then sum over the vector of moments from actual data (D) and its artificial counterpart (D^A) which is itself an average over n replications.[17] The measure of closeness to the data is given by G, and I have weighed and unweighed versions:

$$
\begin{aligned}
D^A &= \frac{1}{100} \sum_{n=1}^{100} D_n^A \\
G^1 &= \left(D^A - D \right)' * V^{-1} * \left(D^A - D_m \right) \\
G^2 &= \left(D^A - D \right)' * \left(D^A - D \right) \\
V &= \frac{1}{100} \sum_{n=1}^{100} \left(D_n^A - D \right) \left(D_n^A - D \right)'
\end{aligned}
$$

Numerical results

[15] The shock process is an AR1 process which is discretized into a first order Markov process using Tauchen´s method with 11 points in the support of the state space for A.

[16] There is one difference in the Q regression which arises from the timing assumptions for investment. In GH investment becomes productive within the period. Thus, their measure of average Q is (with their notation) current beggining of period observed $V(A_t, K_{t-1})/K_{t-1}$, whereas in the regressions with artificial data the measure is (with my notation) $E_t V(A_{t+1}, K_{t+1})/K_{t+1}$.

[17] For each model there are 9 moments. Each artificial moment is computed n times and then averaged. See the indirect inference approach of Gourieroux, Monfort and Renault.

- These two columns show the G statistic for each model.[18]

	$G1$	$G2$
FM	8.233	2.486
CC	8.268	2.444
AC	8.251	**1.236**
MH	10.18	4.414
$MH2$	**8.002**	1.413
$MH3$	10.14	2.324

We can see that the Adjustment Cost model beats the credit constraint model in the ability to match the data. This is of course in line with previous work that shows that for this dataset the credit constraint adds little to an adjustment cost model. Surprisingly, the second Moral Hazard model does very well also. The third Moral hazard Model is the object of the next section.

- I show now averages over the 300 replications for the moments and models.

	$\sigma_{i/k}$	$\rho_{i/k}$	$\sigma_{\pi/k}$	$\rho_{\pi/k}$	Q	$\hat{\alpha}_3$	$\hat{\alpha}_4$	$T_{\hat{\alpha}_5}$	R^2
$Data$	**0.092**	**0.237**	**0.094**	**0.508**	**2.51**	**0.036**	**0.144**	**1.26**	**0.12**
FM	0.446	-0.395	0.315	-0.175	2.70	-0.411	0.394	0.474	0.85
CC	0.296	-0.294	0.147	0.153	2.67	-0.376	0.422	0.217	0.92
AC	**0.106**	-0.186	0.189	0.142	2.62	-0.425	0.099	0.970	0.90
MH	0.243	-0.194	**0.106**	**0.526**	2.68	-0.131	0.724	3.032	0.93
$MH2$	0.269	-0.252	0.139	0.317	2.66	-0.293	0.507	0.795	0.91

This table raises a number of questions.But first we note an interesting possibility, which is that of combining the Moral hazard curvature with the adjustment cost curvature to get a better overall match of the standard deviations and first order serial correlations.

- Why do adjustment costs tend to make the dummy significant? In the appendix we see that as gama increases the T statistic on the dummy also increases.[19] Shocks are essencially iid, and desired investment does

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[18]Here, the π in the model that matches the cash flow in the data is given by $R_t - I_t$, or $R_t - I_t - AC_t$, if apropriate. Revenues are of course $R_t = A_t k_t^\alpha$.

[19]Recall that the dummy here is a rank of the firms according to their period 7 value of profits (equal dividends). But profits are already in the regression without the dummy and they are certainly correlated with their own value in period 7. So, this is still hard to understand. There is a deeper point here, and that is that this sample split with dividends does not make much sense here. But neither does it make sense in the data, as the theory underlying that sample split is shallow at best.

not vary so much with A. But revenues vary.a lot with A. Then a shock implies some adjustment in capital is desired, but of a smaller order of magnitude than the variation in profits. But the whole thing rests on depreciation. Smaller firms (low K which happens after a history of low A´s) want to grow for any mildly positive shock, and so cannot count on depreciation to save on adjustment costs as big firms do. And low K also lowers profits. So, low profits implies a desire to grow, which implies the dummy comes out positive and significant since the dummy has value one for low dividend firms.

- Why is the dummy not significant with credit constraints? There are several points to the answer here. First remember that all firms are constrained in this sample, just that some should be more constrained if they are paying low dividends. This is how all models work in the literature: whether you are constrained or not depends on where you are. So, low dividends could be a proxy for being constrained. But apparently they are not when they should be. Here we note two observations from the literature: Gomes (2000) notes that the value function has all the information, including that of constraints. So, the dummy and the cash flow variable can be significant only if V/K is the wrong measure of Q, which is the case because of $\alpha < 1$. Second, Cooper and Ejarque (2001) show that a firm *without* credit constraints will have significant cash flow as long as $\alpha < 1$. Here, cash flow is already significant, and since cash flow equals profits in the model, the dummy adds little explanatory power. But then again, this should be true also in the data, which is the case of course!

- Why is the dummy so significant in the first MH problem? I repeat the argument here (although this is an incomplete explanation): In the first moral hazard case we get a lot of curvature from a negligible amount of concavity in the utility function, since negative dividends are ruled out so that at the bottom end of the state space the optimal decision becomes very constrained. The curvature we get seems to have a similar effect to the curvature we get from adjustment costs. Note that no credit constraints are involved.

- What happens to the value of the firm relative to the first best? In MH1 the first best V/K is 0.94% higher than the market value V/K, and in MH2 the first best V/K is 0.71% higher than the market value V/K.

- *So, since we still cannot explain these regularities in a satisfactory way,*

does this mean we cannot make any inference from this exercise? Not really: they suggest that if we see a significant sample split. we should be inferring the existence of curvature from either adjustment costs or Moral Hazard, and not from credit constraints.

5 Moral Hazard, Size Distortions, Takeover Probabilities

Consider now a further variation on the Moral Hazard problem we just saw. Suppose the objective function of the manager is now

$$u\left(\Pi\right) = \frac{1}{1-\eta}\left[\Pi + \lambda k\right]^{1-\eta} = \frac{1}{1-\eta}\left[A_t k_t^{\alpha} + (1-\delta)k_t - k_{t+1} + \lambda k_t\right]^{1-\eta}$$

where curvature arises from utility and lambda measures a preference for size. The rationale for lambda comes from the divestments that occur after takeovers. The fact that we simply add $\Pi + \lambda k$ is purely for convenience.

There is an additional twist to this model. There is a takeover probability $q = 0.02$ every period. The takeover probability is taken from Andrade et al (2003). Lambda is set at 0.02. Lambda must be of a smaller order of magnitude than delta. The metric for lambda must come from the size of divestitures after takeovers, and of course from the difference in market value in the firm, when we get rid of bad managers. But there we have also the curvature parameter taking a role. In case a takeover happens the manager gets zero and it is "game over". His problem is

$$S\left(A_t, k_t\right) = \max_{k_{t+1} \geq 0} u + \beta(1-q)E_t S\left(A_{t+1}, k_{t+1}\right)$$

We see that the probability of takeover shortens the horizon for the manager. This acts in the direction of reducing the capital stock, whereas lambda acts in the direction of increasing the capital stock. In the event, with these parameter values capital is lower than in the baseline.

In addition, a simplifying assumption is that in case a takeover happens, shareholders do **not** get any rents from it, but rather get only the current market value of the firm. This implies we can still write

$$W\left(A_t, k_t\right) = \Pi\left(A_t, k_t, g\left(A_t, k_t\right)\right) + \beta E_t W\left(A_{t+1}, k_{t+1}\right)$$

which makes the problem much easier.[20]

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[20] Alternatively we could have the shareholders capturing some of the rent from the takeover. This could be written: $W = \Pi + \beta(1-q)W' + \beta q\left[W' + \phi\left(V - W'\right)\right]$ with V denoting the first best value of the firm.

	$\sigma_{i/k}$	$\rho_{i/k}$	$\sigma_{\pi/k}$	$\rho_{\pi/k}$	Q	$\hat{\alpha}_3$	$\hat{\alpha}_4$	$T_{\hat{\alpha}_5}$	R^2	K
Data	**0.092**	**0.237**	**0.094**	**0.508**	**2.51**	**0.036**	**0.144**	**1.26**	**0.12**	
FM	0.446	−0.395	0.315	−0.175	2.70	−0.411	0.394	0.474	0.85	187.7
CC	0.296	−0.294	0.147	0.153	2.67	−0.376	0.422	0.217	0.92	184.7
AC	0.106	−0.186	0.189	0.142	2.62	−0.425	0.099	0.970	0.90	176.1
MH	0.243	−0.194	0.106	0.526	2.68	−0.131	0.724	3.032	0.93	181.9
MH2	0.269	−0.252	0.139	0.317	2.66	−0.293	0.507	0.795	0.91	183.8
MH3	0.245	−0.205	0.112	0.501	2.71	−0.163	0.674	2.301	0.93	177.2

In this third Moral Hazard model the capital stock is lower than in the baseline. The lesson is that even a small takeover probability can successfully counteract one of the Moral Hazard components, namely the size distortion. Of course, given the presence of large divestitures in the aftermath of a merger or takeover, this points in the direction of a different model of size distortion, or simply a much bigger lambda.

The overall fit is not too bad in the unweighed statistic and the T statistic on the dummy is again high. The standard deviations and serial correlations seem quite good, which suggests this framework can fit the data.

6   Limited Liability

In this section I move away from the credit constraints literature, and from trying to match the moments in the Gilchrist and Himmelberg dataset. Rather, I want to explore other implications of Moral Hazard and compensation structure. Consider now an additional Moral hazard model, still with exogenous takeover probabilities. The manager now has an objective function with a truncated payoff:

$$U = \frac{1}{1 - \eta} \left[w + \phi \Pi \left(\Pi > 0 \right) \right]^{1-\eta}$$

where

$$\Pi = A_t k_t^\alpha + (1 - \delta) k_t - k_{t+1}$$

which implies that he has complete insurance from the flat wage w, plus a proportional upside in case of positive profits.

The shock A is again an AR1 process with persistence parameter ρ and standard deviation σ. There is also, as above, a takeover probability q every period. The probability of takeover shortens the horizon for the manager. In

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case a takeover happens the manager gets zero. His problem is

$$S\left(A_t, k_t\right) = \max_{k_{t+1} \geq 0} \left[u + \beta(1-q)E_t S\left(A_{t+1}, k_{t+1}\right)\right]$$

As usual, in case a takeover happens, shareholders do **not** get any rents from it, but rather get only the current market value of the firm. This implies we can still write

$$W\left(A_t, k_t\right) = \Pi\left(A_t, k_t, g\left(A_t, k_t\right)\right) + \beta E_t W\left(A_{t+1}, k_{t+1}\right)$$

What is the impact of designing a contract for management with strong limited liability? As we will see, the impact is dramatic. In this simple framework, with moderate concavity in utility, the manager has an incentive to invest a very large amount one period, and then sell it all the following period, creating a cycle of growth and destruction, and cashing in every second period when accounting profits are high. In order to avoid such extreme fluctuations, we impose a "borrowing constraint" on the manager,

$$\Pi = A_t k_t^\alpha + (1-\delta)\, k_t - k_{t+1} \geq -B$$

where B is some exogenous borrowing limit. We can justify this by arguing that large debt decisions must be taken with board aproval, and assume the board is not captured by management. With this constraint there is a slower build-up phase, followed by an abrupt sale of capital.

Some companies such as Enron and World Com experienced enourmous growth, only to collapse later. Here, the optimal decision rule of the manager implies a cycle. At low levels of capital it is optimal for the manager to invest very large amounts, and then reap the benefits of selling all the capital again. The compensation structure implies a large cyclicality in the company. Furthermore, whereas here there is no capital loss in the sale of used machines, it is also easy to see that introducing a wedge between the buying and the selling price of capital will not change the behaviour of the model, while implying large losses for the firm. This framework easily induces the collapse of the company. Introducing adjustment costs - quadratic adjustment costs will imply large losses when selling too much capital - will smooth the behaviour of the firm, but will not eliminate the incentive for this cyclical pattern of overinvestment followed by asset sales. Note that observed output volatility is high, but not because the firm is in any way adopting a risky strategy. In the appendix I discuss an extension where the manager can choose how risky its assets are, in a setting where shareholders will prefer a less risky investment, but managers can choose the high risk investment due to the limited liability in their compensation.

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So, what do we learn from this framework? Moral Hazard problems which arise due to the separation between ownership and control are exacerbated by the compensation structure with limited liability. This induces volatility in the firm's output, and depending on the model parameters can generate large losses for the firm coupled with generous compensation outcomes for management. Note also that the high output volatility occurs, even if the manager has substantial concavity in the utility function, because, again, the manager has a lower bound on compensation.

7 Conclusion

This paper explores a variety of investment models trying to identify the different effects of adjustment costs, credit constraints, and distortions arising from the separation between ownership and control of the firm. I calibrate these different models, generate artificial data for each of them, and with the artificial data construct a set of moments which are compared to the same set of moments taken from a cut of the compustat dataset.

The different models show a variety of interesting outcomes. Of note is the fact that models without credit constraints, but where curvature arises either from adjustment costs or from the Moral Hazard problems will generate significant sample split outcomes typically associated with the identification of credit constraints. Thus the answer to one of the main questions in this paper is positive. But other significant patterns emerge. The model with adjustment costs and the model with credit constraints do equivalently well matching the data. Some of the Moral Hazard models explored here perform worse - they were not estimated - although they do generate a strong significance of the sample split dummy - an outcome interesting in its own right. The model with takeover probabilities suggests that even small values for this probability can go a long way in counteracting the size distortion part of Moral Hazard.

There are many reasons for a poor fit of the MH models, the main one being that the dataset of GH 1995 is not the best suited cut of the compustat for such an exercise. Being surviving firms, suggests that they should have less of a problem with governance than others. Being a sample which has been cleaned of all episodes of mergers, takeovers, or large changes, it is also unlikely to be suited to the analysis of the last model with a takeover. Still, the exercise allows a first exploration of the behaviour of these types of models. And, more importantly, the MH models are not yet estimated.

More substantially, and in the direction of this work, is the study of the way to model the governance problem in the firm. A concave objective

function for the manager - a framework suggested by observations of hedging of stock options - seems to run counter another observation, namely that of the higher riskyness of portfolios of firms which end up bankrupt. This contradictory intuition may be just apparent. Compensation with limited liability will induce managers to overinvest and then sell capital cyclically, even when having a concave objective function. This behaviour can result in large losses for the firm, coupled with generous compensation outcomes for management.

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8 Data Appendix

The data is the cut from Compustat used in Gilchrist and Himmelberg (1995). Some summary statistics of the data are presented here.[21] There are 428 firms and 12 years of data from 1978 to 1989. For each firm and each variable I compute its mean, standard deviation, first order autocorrelation (by regressing the variable against a constant and its lag and getting the OLS coefficient on the lag), and the ratio of its standard deviation to its mean over the 12 period sample. This yields a distribution of 428 means (μ), standard deviations, (σ), AR1 coefficients, (ρ), and ratios. The following table shows the cross sectional standard deviation of these firm level moments:

STD	I/K	S/K	OI/K	CF/K	V/K
μ	0.0605	1.6953	0.1986	0.1275	1.6609
σ	0.0634	0.5410	0.0905	0.0633	0.8411
ρ	0.3078	0.4300	0.2985	0.3303	0.3495
σ/μ	0.2538	0.1062	0.4510	6.8848	0.1694

Next, I present a series of regression results with different estimators on this data. I do not try to reproduce the regressions of Gilchrist and Himmelberg (1995) but rather present a series of regressions that can be easily reproduced by the reader, and that are equally indicative of the effects we want to look at later. The basic equation is

$$\frac{I_t}{k_t} = \alpha_0 + \alpha_1 T + \alpha_2 \frac{V_t}{k_t} + \alpha_3 \frac{cf_t}{k_t} + e_t$$

and I show regression results for three estimators. A simple OLS estimator in levels wich has 12 observations for each firm, and 428 firms for the full sample. A simple OLS estimator in first differences (but with a constant and a time trend just the same) which has 11 observations for each firm. Finally a basic Instrumental Variables estimator in first differences also with constant and trend, where the instruments are the second lags of the explanatory

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[21]More details of the data can be found in their paper and on the website: http://www.columbia.edu/~cph15/panel/panel.html.

variables.[22]

EST	full OLS	full OLSD	full IV
n	428	428	428
α_0	0.1166	0.0066	0.0220
	(28.5)	(1.57)	(3.13)
α_1	-0.0015	-0.0003	-0.0070
	(3.11)	(0.62)	(3.30)
α_2	0.0153	0.0362	0.0256
	(12.8)	(18.7)	(7.85)
α_3	0.1092	0.1885	0.2447
	(7.50)	(10.2)	(6.92)
R^2	0.143	0.120	0.085

EST	small OLS	small OLSD	small IV	big OLS	big OLSD	big IV
n	106	106	106	322	322	322
α_0	0.1045	0.0098	0.0193	0.1193	0.0057	0.0230
	(11.6)	(1.01)	(1.22)	(25.9)	(1.25)	(2.95)
α_1	-0.0010	-0.0006	-0.0059	-0.0016	-0.0003	-0.0074
	(0.97)	(0.41)	(1.24)	(3.23)	(0.52)	(3.15)
α_2	0.0141	0.0357	0.0263	0.0163	0.0366	0.0249
	(6.47)	(10.3)	(5.01)	(11.1)	(15.2)	(5.69)
α_3	0.1018	0.2239	0.2412	0.1134	0.1677	0.248
	(4.09)	(6.36)	(3.93)	(6.15)	(7.66)	(5.54)
R^2	0.127	0.154	0.127	0.156	0.103	0.064

8.1   Investment spikes

This table shows the distribution of I/K in this data. The first column shows the fraction of all observations in a bin (neighborhood). There are 5136 observations. The second column shows the cumulative density. The last

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[22]There are two sample splits. One is between small and large firms, and another is between high and low dividend firms. These are the actual empirical regressions that can be replicated with the artificial data. Small firms are in this data the firms that are below the 25th percentile of capital in 1984. Big firms are above the 25th percentile. Low dividend firms are those below the 25th cross section percentile of the 1984 ratio of dividends to operating income. This is just like in Gilchrist and Himmelberg (1995). Later, with the artificial data I use mean sample capital stock and mean sample dividends over revenues for each firm.

column shows the mid point of the histogram bin.

N	NS	X
0.0199	0.0199	0.0167
0.0715	0.0913	0.0480
0.1396	**0.2309**	**0.0794**
0.1649	**0.3958**	**0.1107**
0.1620	**0.5578**	**0.1420**
0.1314	**0.6893**	**0.1734**
0.0964	**0.7856**	**0.2047**
0.0586	0.8442	0.2361
0.0430	0.8873	0.2674
0.0292	0.9165	0.2987
0.0195	0.9359	0.3301

If we define inaction as investment in the lower two bins we have inaction less than 10% of the time. If we define a spike as investment in excess of one standard deviation higher than the mean, we have spikes around 10% of the time. This data does not seem to support modelling fixed costs of adjustment at the firm level. For that matter, it does not point to fixed costs of raising external finance either.

9   Estimation: Changing gama

This is what happpens to our moments and statistics as we increase gama from the benchmark of the AC model

γ	$\sigma_{i/k}$	$\rho_{i/k}$	$\sigma_{\pi/k}$	$\rho_{\pi/k}$	Q	$\hat{\alpha}_3$	$\hat{\alpha}_4$	$T_{\hat{\alpha}_5}$	R^2
Data	**0.092**	**0.237**	**0.094**	**0.508**	**2.51**	**0.036**	**0.144**	**1.26**	**0.12**
0.10	0.106	-0.186	0.189	0.142	2.62	-0.43	0.099	0.97	0.90
0.15	0.081	-0.155	0.206	0.070	2.63	-0.42	0.081	1.85	0.89
0.20	0.065	-0.134	0.217	0.039	2.64	-0.41	0.078	2.44	0.88
0.30	0.048	-0.110	0.232	0.011	2.67	-0.39	0.069	3.13	0.87
$*$	$*$	$*$	$*$	$*$	$*$	$*$	$*$	$*$	$*$
0.60	0.028	-0.071	0.256	-0.014	2.77	-0.29	0.061	3.97	0.83

γ	$G1$	$G2$
0.10	8.25	1.23
0.15	8.24	1.53
0.20	8.24	2.58
0.30	8.47	4.69
*	*	*
0.60	8.75	8.48

First, overall the model gets **worse** as there is more curvature (above $\gamma = 0.2$) as measured by the G statistics. This is of course in line with the estimation results of Cooper and Ejarque. Q increases, investment volatility falls (as capital adjustment costs increase. This implies that for a given A distribution, the volatility of profits must increase to take up the slack. Interestingly, the coefficient on the dummy variable in the Q regression becomes significant. Note that the coefficient is positive implying the inference that low dividend firms are now significantly "constrained" - which we know is false since there are no constraints in the model.

10   Estimation: Changing alfa

This is what happpens to our moments and statistics as we increase alfa: the top three rows are for the credit constraint model. the bottom three rows are for the adjustment costs model.

α	$\sigma_{i/k}$	$\rho_{i/k}$	$\sigma_{\pi/k}$	$\rho_{\pi/k}$	Q	$\hat{\alpha}_3$	$\hat{\alpha}_4$	$T_{\hat{\alpha}_5}$	R^2
$Data$	**0.092**	**0.237**	**0.094**	**0.508**	**2.51**	**0.036**	**0.144**	**1.26**	**0.12**
0.65	0.2382	-0.3563	0.1676	**0.3432**	3.0884	-0.4758	0.0562	0.5907	0.908
0.72	0.2693	-0.3264	0.1450	**0.2380**	2.4906	-0.3524	0.4588	0.8597	0.901
0.80	0.2869	-0.2636	0.1263	**0.0898**	1.9840	-0.3191	0.7215	-1.088	0.937
0.65	0.0754	-0.1725	0.2387	**0.0596**	3.2189	-0.3181	0.0875	2.1192	0.861
0.72	0.0807	-0.1532	0.2058	**0.0760**	2.6295	-0.4199	0.0856	1.7538	0.891
0.80	0.0881	-0.1332	0.1726	**0.0908**	2.0823	-0.5637	0.0789	1.8132	0.929

α	$G1$	$G2$
0.65	8.084	2.071
0.72	**8.062**	**1.441**
0.80	8.852	7.365
0.65	8.563	2.312
0.72	**8.014**	**1.419**
0.80	8.096	1.831

Both the credit constraints model and the adjustment cost model get worse as we move away from the 0.72 benchmark.The behaviour of serial correlation for profits is one moment that has a clear different behaviour between the two models.

11 Limited Liability. Part 2, variance choice.

Consider now an additional Moral hazard model, still with exogenous takeover probabilities. The manager now has an objective function with a truncated payoff:

$$U = \frac{1}{1-\eta} \left[w + \phi \Pi \left(\Pi > 0 \right) \right]^{1-\eta}$$

which implies that he has complete insurance from the flat wage w, plus a proportional upside in case of positive profits.

In addition, the manager can choose today between two distributions of A with equal mean but different variances for next period. This choice has a cost, which for simplicity is an increase in the current depreciation rate. The shock $A = \tilde{A}\varepsilon$ is now a combination of an AR1 process $\tilde{A}$, and an iid process ε. $\tilde{A}$ is a technology shock with persistence parameter ρ and standard deviation σ. There will be a mean preserving spread over the iid shock. The metric for the variance comes from the high risk nature of the portfolios of bankruptcy-bound firms. The aim here is to link such high risk to a Moral Hazard problem, rather than a survival theory of the Jovanovic type.

There is also, as above, a takeover probability q every period. The probability of takeover shortens the horizon for the manager. In case a takeover happens the manager gets zero. His problem is

$$S\left(A_t, k_t\right) = \max \left\{ \begin{array}{l} \max_{k_{t+1} \geq 0} \left[u^H + \beta(1-q)E_t^H S\left(A_{t+1}, k_{t+1}\right) \right] \\ \max_{k_{t+1} \geq 0} \left[u^L + \beta(1-q)E_t^L S\left(A_{t+1}, k_{t+1}\right) \right] \end{array} \right.$$

where

$$u^H\left(w + \phi\Pi^H\right) = \frac{1}{1-\eta} \left[w + \phi\Pi^H \left(\Pi^H > 0\right) \right]^{1-\eta}$$
$$\Pi^H = A_t k_t^{\alpha} + \left(1 - \delta^H\right) k_t - k_{t+1}$$

and similarly for the low variance choice.

As usual, in case a takeover happens, shareholders do **not** get any rents from it, but rather get only the current market value of the firm. This implies we can still write

$$W\left(A_t, k_t\right) = \Pi\left(A_t, k_t, g\left(A_t, k_t\right)\right) + \beta E_t W\left(A_{t+1}, k_{t+1}\right)$$

The key idea is that the higher depreciation cost today, by reducing current profits will counter the potential future benefit to the decision maker, from choosing higher variance. There is a reduced mean payoff today, and a shift in probability mass of the future payoff to the positive tail. The economic question is which effect dominates and under what circumstances - how does the decision depend on current state variables K and A.

What is the economic intuition? Different projects have different risks but these risks have equal means. Whereas shareholders should generally prefer the low risk investment, the manager, due to his truncated payoff contract, may prefer the higher variance and lower mean project. What project choice can the model refer to? Perhaps the idea is more of a product choice nature. The firm has one plant with a collection of machines, and these machines depreciate more in the high market risk product. Clearly some or all of the investment decisions within the firm have option characteristics. Ideally we could disaggregate the capital stock into vintages which would correspond to the different options exercised by management each period. The model constructed is a proxy for these ideas.

Kt+1(Kt), credit constraint
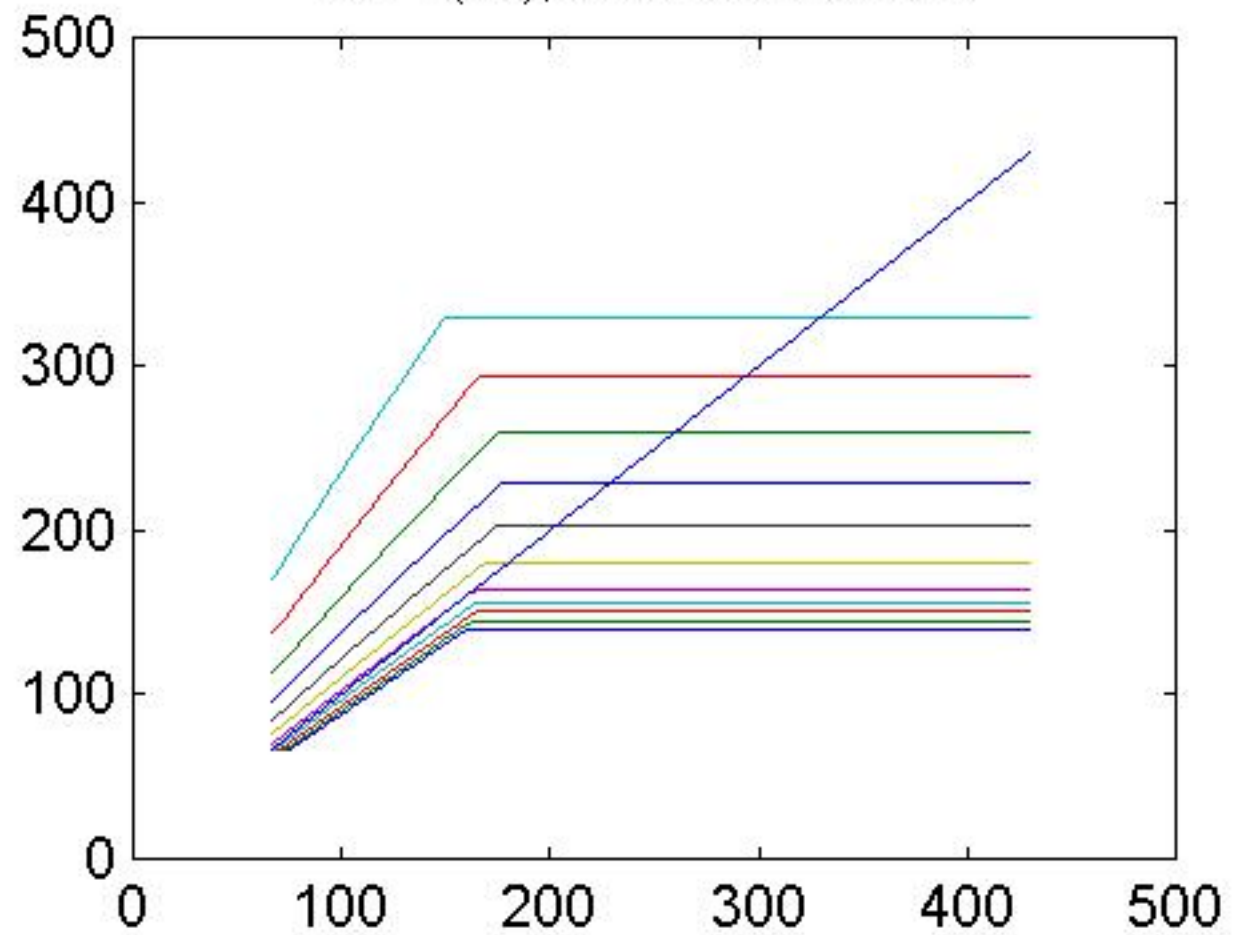
Kt+1(Kt), adjustment costs
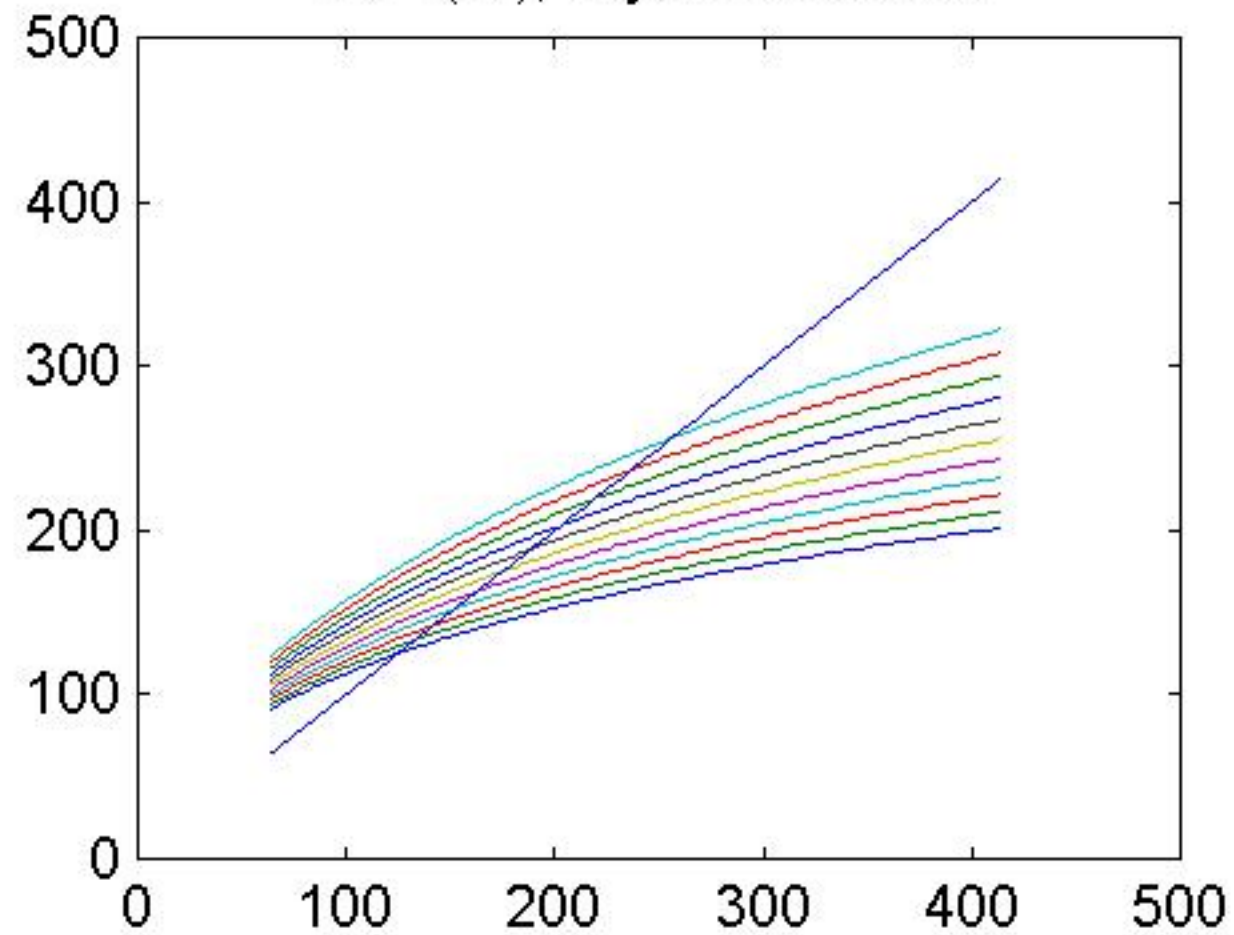
Kt+1(Kt), moral hazard
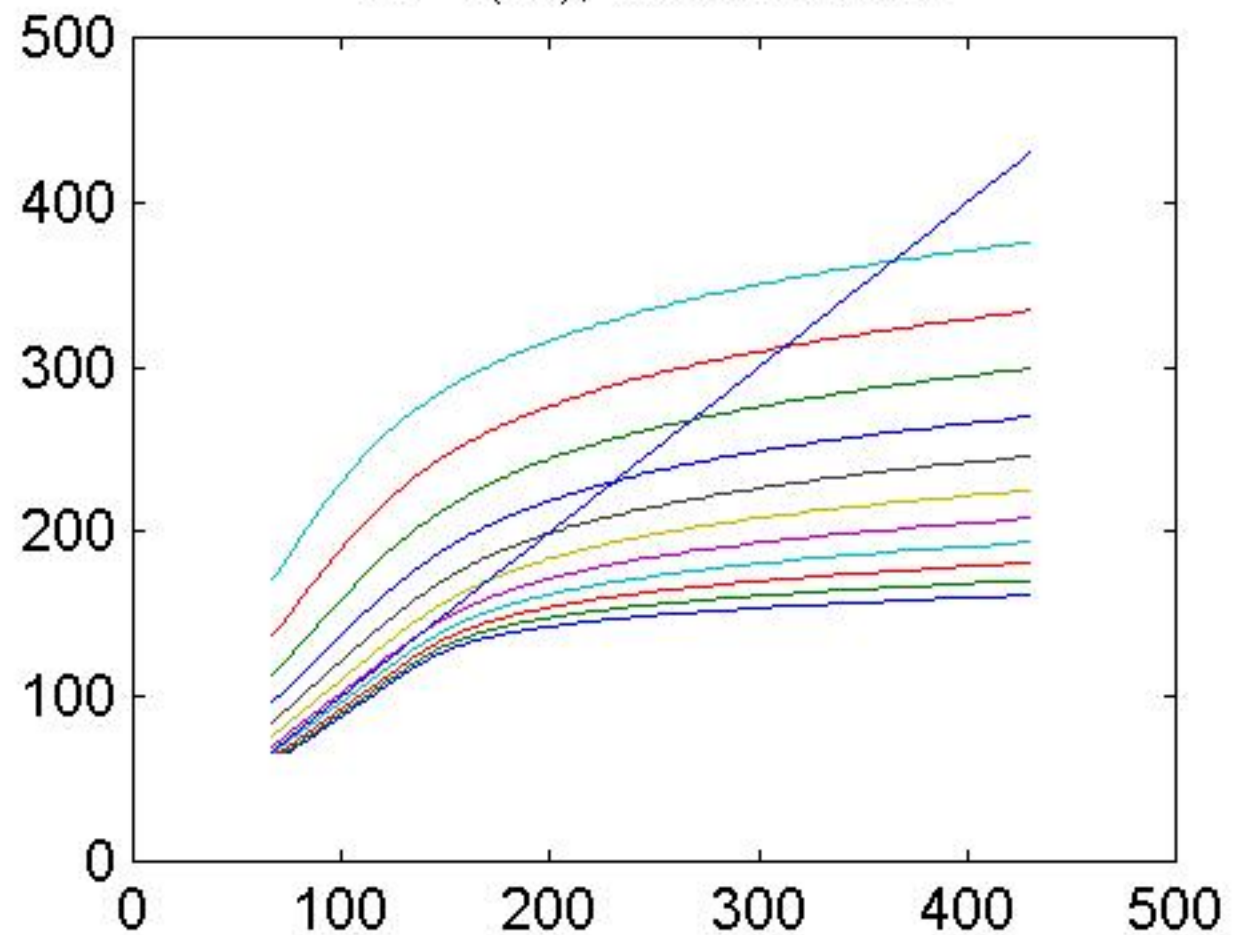
Kt+1(Kt), moral hazard 2
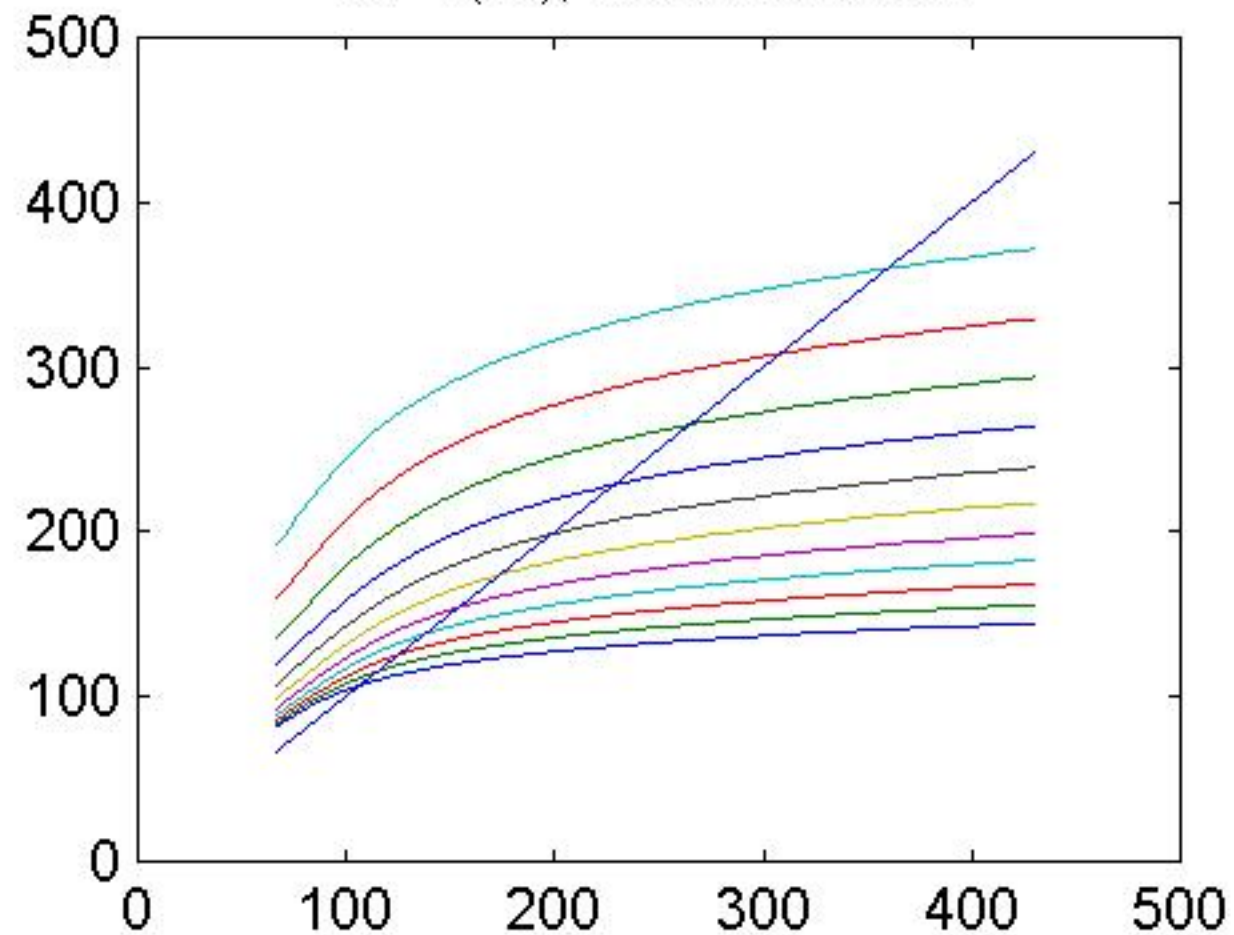
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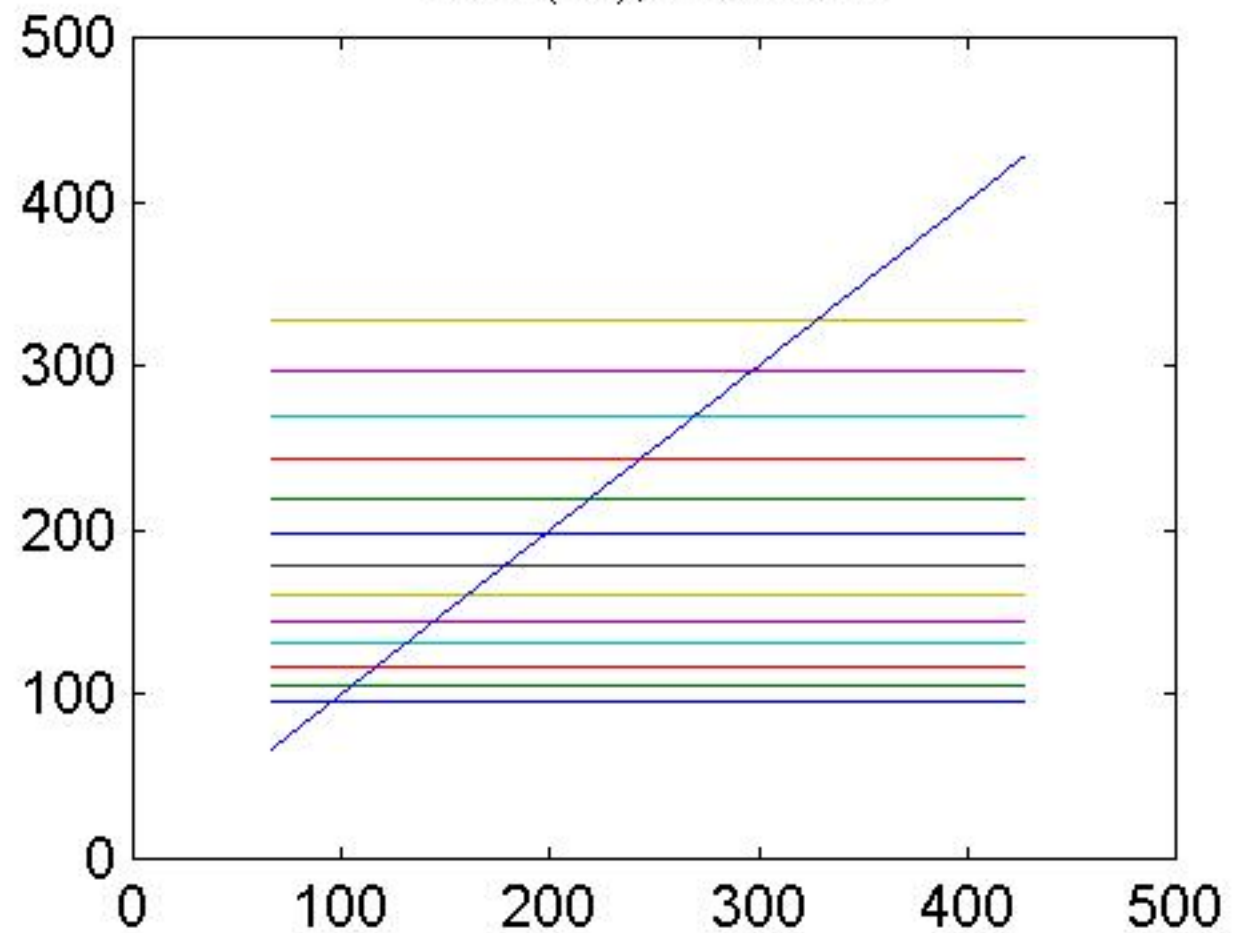
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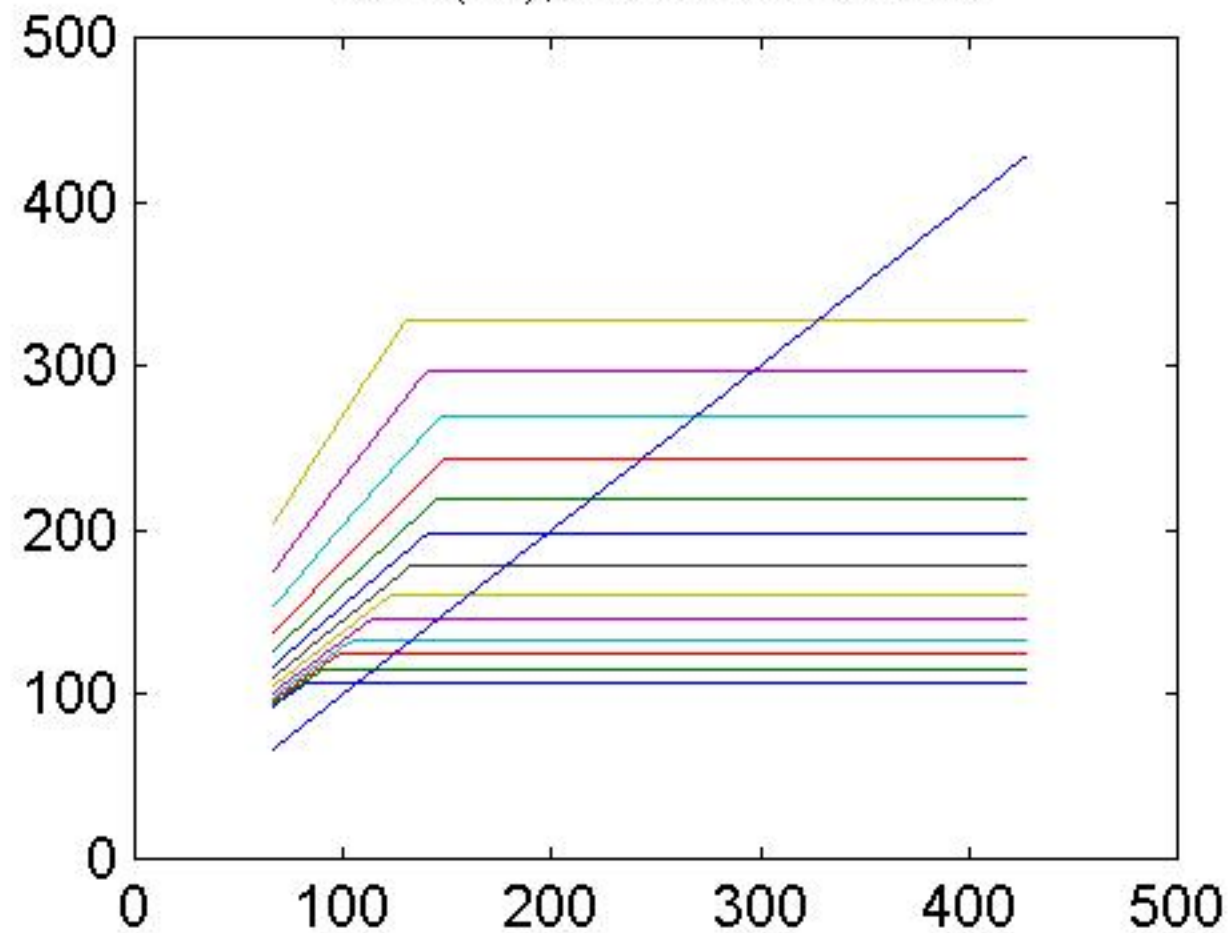
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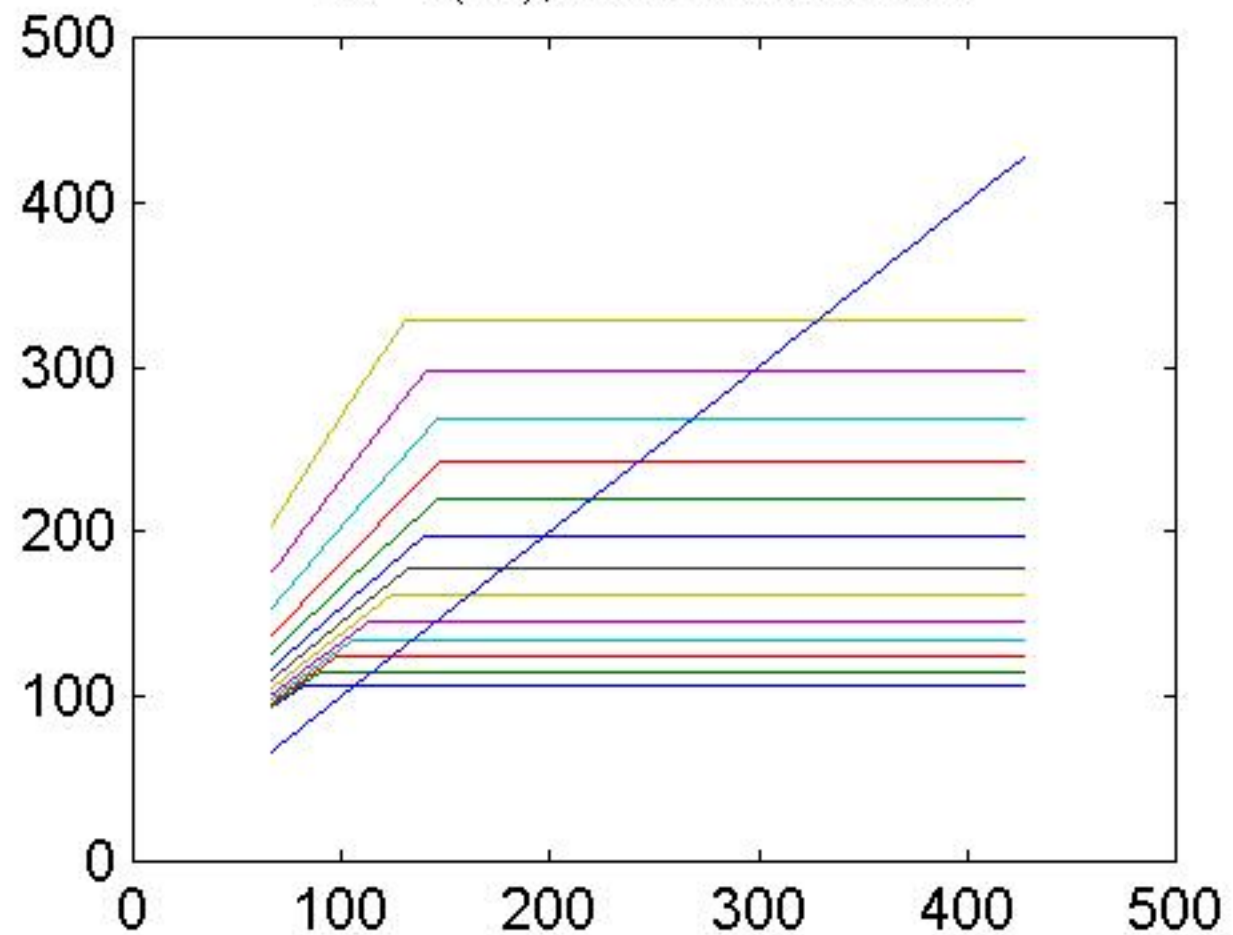
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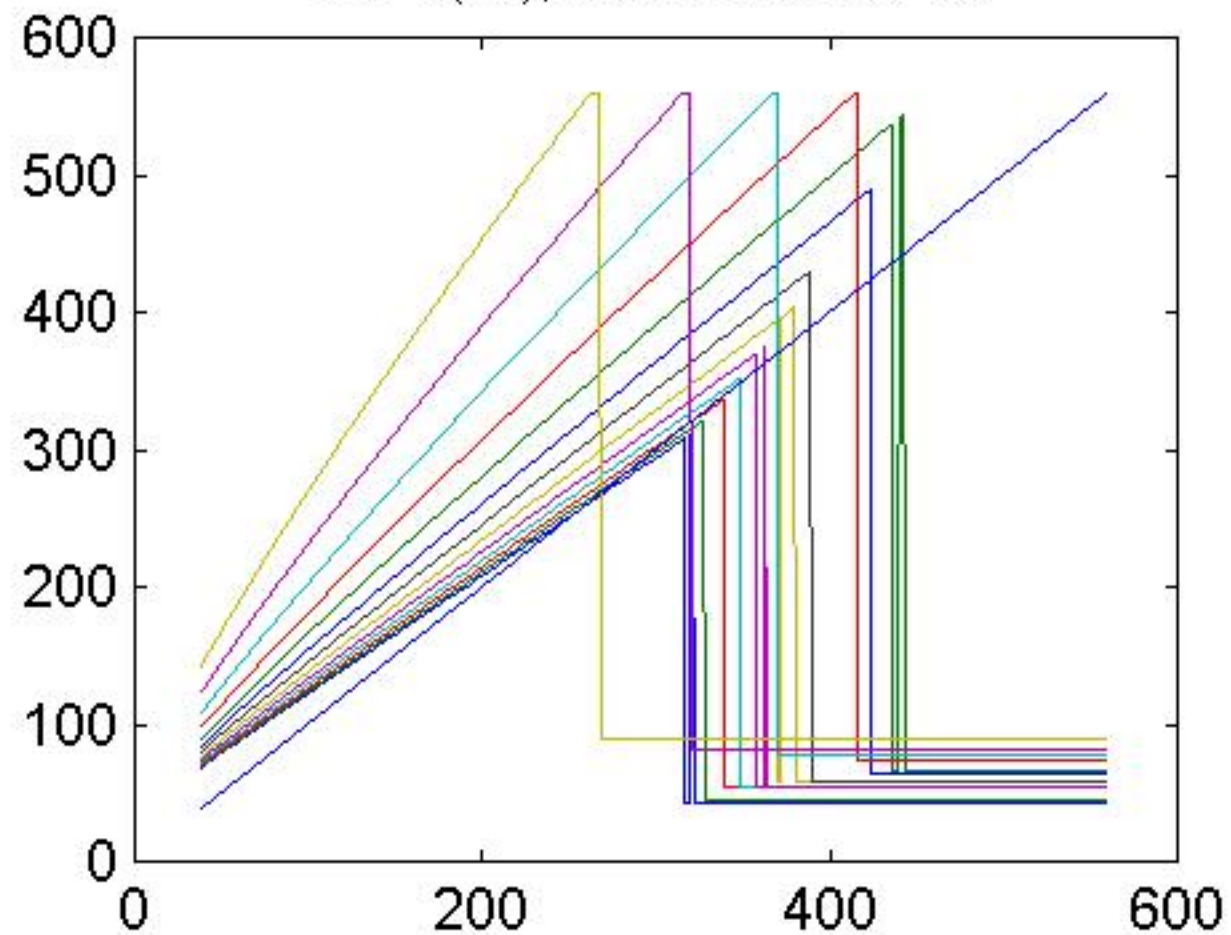
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