Appreciating Depreciation: A Note on Physical Capital Depreciation in a Developing Country*

Matthias Schündeln

Abstract

Little is known about the nature of physical capital in less developed countries. This note seeks to address the lack of empirical work related to depreciation rates, which are a neglected but important ingredient of both micro and macro analyses. Using a straightforward econometric approach, I estimate depreciation rates of physical capital invested in manufacturing enterprises in Indonesia based on establishment-level survey data. I estimate the depreciation rate to be between 8% and 14%. Comparing these to published estimates for the U.S., the results therefore provide some support for the typically used assumption of constant depreciation rates across countries. I also investigate differences across types of firms, and find evidence for significant heterogeneity across industries, age and size groups. Finally, I find evidence that suggests that financially constrained firms use less durable investment goods.

JEL classification: O14, D92, E22, L6
Keywords: Depreciation rate, capital stock, investment, manufacturing, Indonesia

---

*I am grateful to Ulrich Doraszelski, Nicola Fuchs-Schündeln and Marcelo Moreira for comments. Address: Department of Economics, Harvard University, Littauer Center, 1875 Cambridge Street, Cambridge, MA 02138. Email: schuendeln@harvard.edu

1 Introduction

Does physical capital depreciate faster or slower in developing countries than in other regions of the world? More generally, are there important differences with respect to depreciation across countries? Knowledge about this question is surprisingly scarce while at the same time fairly important for both macro and micro economists. This note seeks to address the lack of empirical work in this area and approaches the question about the existence of differences in depreciation rates across countries in the context of one particular part of a country's physical capital stock, namely the capital stock of manufacturing enterprises. To this end, I provide estimates for depreciation rates of physical capital in the Indonesian manufacturing sector, based on a rich establishment-level data set.[1]

From a macro perspective, the importance of depreciation is illustrated by a consideration of depreciation rates in the growth literature: The rate of depreciation is an important determinant of steady state capital per effective unit of labor in the standard Solow growth model and other standard growth models. For example, in the Solow model, a 1% change in depreciation has the same effect on steady state capital and steady state income per capita as a 1% change in labor or a 1% change in technology, i.e. variables that receive considerably more of attention. Differences in depreciation rates may therefore account for a significant part of observed differences in incomes per capita across countries. Nevertheless, in studies that are based on calibrations as well as on empirical growth studies, the standard approach is to assume away differences in depreciation rates and focus on heterogeneity along other

[1] To estimate depreciation rates survey data is needed, as opposed to accounting data. What is relevant is the resale value or replacement value of the capital stock, not the book value.

dimensions, e.g. population growth, or savings rates (e.g. Mankiw et al. 1992, p. 410, Islam 1998, p. 327).

Similarly, at the micro level knowledge about depreciation rates in developing countries is important, for example, for studies of the returns to capital in which depreciation needs to be taken into account to adjust the gross returns to capital (e.g. de Mel et al. 2006) and, relatedly, studies that try to find evidence for the existence or quantify the extent of financing constraints based on estimated returns to capital (e.g. Udry and Anagol 2006). Depreciation rates can also directly be used to investigate important theoretical questions that at first appear less related to depreciation. Udry and Anagol (2006) show theoretically that financially constrained entrepreneurs/firms will invest in less durable goods. Thus, differences in depreciation rates may not only say something about technological differences of capital goods used across different individuals, industries, or countries, but also indicate differences in the cost of capital and degree of financial constraints. Among other areas in which an estimate of economic depreciation is important is tax policy, where it is needed as a basis for setting the allowable depreciation for tax purposes (Coen, 1975).

In addition to the direct interest in the question about the rate of depreciation of physical capital, there are also a number of questions in which knowledge (or lack thereof) about depreciation rates enters indirectly. This is because the rate of depreciation is an important parameter in estimating physical capital stocks, which is typically done using the Perpetual Inventory Method. Frequently an estimate of the physical capital stock of an enterprise, specific industrial sector or a whole economy is needed for empirical analyses. However, often all that is available is the net investment that was made over a certain time period. Using the recorded investments and an assumption about the depreciation rate, an estimate of the capital stock can be obtained with the Perpetual Inventory Method (see for example Summers and Heston 1991, Benhabib and Spiegel, 1994, King and Levine, 1994, and Bond et al., 2003; Pritchett, 2000, gives a more general discussion of associated problems). Capital stocks estimated with this method are used in a variety of empirical studies: from firm level studies, e.g. to study productivity changes in response to policy changes, to cross-country analyses, e.g. of the determinants of growth. The estimated capital stock is sensitive to different assumptions about the rate of depreciation. This in turn can cause significant differences in the estimates of interest.[2]

However, depreciation is difficult to measure for individual investment goods and estimates based on actual data are rare. This is particularly true for developing countries for which the necessary detailed data is often missing. In the absence of actual estimates, assumptions on the rates of depreciation have to be made. As pointed out above, cross country studies typically assume constant depreciation across countries.[3] Similarly, the assumptions about depreciation in studies of the manufacturing sector within a developed country typically seem to be guided by estimates of depreciation that are based on data from the U.S. or other developed countries. However, it is not immediately clear that depreciation rates are constant. At the same time, there is no obvious argument in which direction any net

[2]For an illustration, see for example Schündeln (2004), where the returns to capital in Ghanaian manufacturing are estimated under different assumptions about the rate of depreciation of physical capital.

[3]In fact, I am not aware of a single cross-country study, either empirical or theoretical, that considers heterogeneity of depreciation rates across countries.

effect of the differences between depreciation rates in developed and less developed countries would go.

One hypothesis would be that imported, technologically more advanced capital is used that originates and is optimized mainly in other parts of the world and thus is insufficiently suitable for conditions (e.g. with respect to the physical environment) in less developed regions of the world and/or that the resources (for example the skills and parts) do not exist to maintain these "modern" investment goods. This would imply high rates of depreciation. In addition, less durable goods might be favored by investors that are financially constrained (Udry and Anagol 2006), which is arguably more likely for entrepreneurs in developing countries. On the other extreme, one might hypothesize that in less developed countries a lot of used investment goods constitute the capital stock, which might, under certain assumptions about the form of depreciation, lead to depreciation rates that are lower than elsewhere. So arguments for both a larger rate of depreciation and a smaller depreciation in developing countries compared to developed countries can be made. Thus, more empirical work is needed.

If information about individual pieces of equipment is available (for example from market transactions of used capital assets) the form and the rate of depreciation can be estimated as shown in related literature (e.g. Hulten and Wykoff 1981). However, in most firm- or establishment-level data sets, such as the one used in this study, this information is not available. Therefore, it is important to keep in mind that I estimate a measure of aggregate depreciation of the capital stock at the firm-level. Within Asia the case of Indonesia provides a particularly useful case study, as a large panel data set of manufacturing firms that covers a relatively long time series is available. I estimate the depreciation rate to be between 8% and 14%. These numbers are comparable to estimates for the U.S.. This provides some support for the assumption of constant depreciation rates across countries in studies of the industrial sector. By extension, although a country's capital stock consists of more than capital in manufacturing firms, this also supports to some extent the assumption of constant aggregate depreciation rates across countries. Obviously, this study of Indonesia provides just one data point that can be compared to estimates for the U.S., and more empirical work in other developing countries is needed.

I also investigate differences across types of firms, in particular whether depreciation differs across industries, as well as across size, age and ownership groups, and I find evidence for considerable heterogeneity. Finally, I address the hypothesis that financially constrained firms use less durable investment goods.

Below, I first discuss the estimation strategy. I then introduce the data used for the study and present the results. The last section concludes.

2 Estimating the rate of depreciation

The standard model for the evolution of the capital stock, reflected in the Perpetual Inventory Method, assumes that the capital stock evolves as a function of predetermined capital stock, investment and depreciation as follows:

$$K_t = (1 - \delta)K_{t-1} + I_t \tag{1}$$

where δ is the rate of depreciation, K_t is the capital stock in period t and I_t is investment in period t. Thus, it is assumed that the replacement requirement to keep capital constant over time constitutes a constant proportion of the capital stock. This implies a geometric pattern of depreciation, which, as Jorgenson (1974) argues, is a "useful approximation to replacement requirements for a broad class" of depreciation patterns (Jorgenson 1974, 174). I will take this model literally and use it as the basis for the empirical specification, with the parameter of interest being δ.

To arrive at an estimable model, first bring investment to the left hand side of the equation

$$\Leftrightarrow K_t - I_t = (1 - \delta)K_{t-1} \tag{2}$$

and introduce a disturbance term, ϵ_t. Assuming that errors enter multiplicatively, which is the correct specification if for example the source of error is that mismeasured deflators are being used, we get:

$$K_t - I_t = (1 - \delta) \cdot K_{t-1} \cdot e^{\epsilon_t} \tag{3}$$

where ϵ is distributed normally. After taking logs this is equivalent to:

$$\log(K_t - I_t) - \log(K_{t-1}) = \log(1 - \delta) + \epsilon_t \tag{4}$$

This specification can be estimated with a simple OLS regression with a constant. In addition to pooled OLS, I also explore alternative specifications in which I exploit the panel structure of the data

Inflation versus depreciation

The nominal value of the capital stock changes over time because of both depreciation and inflation. A possible concern is that the deflators that are used are measured noisily and inflation drives the results on depreciation. If the measurement error in deflators is pure noise, then this will still lead to unbiased, though less precise estimates. However, if, say, inflation is systematically underestimated, this will lead to a bias, causing an overestimate of depreciation rates. Using variation across sectors and over time will allow me to separately identify time effects from true depreciation as follows:[4]

Again start from equation 1. But now assume that the true K^*_{t-1} is measured with error, and true K^*_{t-1} and observed K_{t-1} are related as follows $K^*_{t-1} = K_{t-1}(1 + \upsilon_t)$, where υ_t measures the error in the deflator that is being used, which importantly is constant across sectors. Then, the true relationship is

$$K_{ist} - I_{ist} = (1 - \delta_s) K^*_{ist-1} \cdot e^{\epsilon_{ist}} \tag{5}$$

where s indexes the industry (sector) in which an enterprise operates, and δ_s is an industry specific depreciation rate. Plugging in $K^*_{t-1} = K_{t-1}(1 + \upsilon_t)$ gives

$$K_{ist} - I_{ist} = (1 - \delta_s) K_{ist-1}(1 + \upsilon_{it}) \cdot e^{\epsilon_{ist}} \tag{6}$$

This demonstrates the danger of mixing depreciation with inflation, if the latter is measured with error. If $\upsilon_{it} \neq 0$ and this is not taken into account, the estimate of depreciation

[4] Similarly, if cross-country data is availalbe, using variation across countries instead of across time separately identify sector and country effects.

will in fact be a function of δ_s and υ_{it}. Taking logs and rearranging the last equation gives:

$$\log(K_{ist} - I_{ist}) = \log(1 - \delta_s) + \log(K_{ist-1}) + \log(1 + \upsilon_{it}) + \epsilon_{ist} \tag{7}$$

$$\Leftrightarrow \log(K_{ist} - I_{ist}) - \log(K_{ist-1}) = \log(1 - \delta_s) + \log(1 + \upsilon_{it}) + \epsilon_{ist} \tag{8}$$

Thus, δ_s can be estimated separately from the time effects υ_{it} by running a regression of $\log(K_{ist} - I_{ist}) - \log(K_{ist-1})$ on a vector of industry and time dummies.

3 Data

I use the *Statistik Industri*, a census of manufacturing establishments that covers all Indonesian manufacturing establishments with more than 20 employees. For this census, questionnaires are distributed and collected by the BPS (Central Bureau of Statistics) and are self-completed by the firms. Firms with 20 employees or more are required by law to fill out the questionnaire. The data set covers up to 20,000 establishments annually. I use data from the years 1988-1995, thus avoiding observations during the years of the financial crisis that hit Indonesia in 1997. Capital stock data is available from 1988 onwards. I do not include 1996 itself to get consistent capital stock data, because there is a slightly different questionnaire format in the year 1996. The capital stock is the estimated value of fixed capital that is reported in the data. To clean the data of extreme outliers, I drop the 1% tails of the distribution of the capital$_t$/capital$_{t-1}$ ratio by industry. However, I have also confirmed that the main results are robust to dropping only the 0.5% tails of the distribution or dropping the 3% tails of the distribution. All data are deflated to 2000 Indonesian Rupiah values (1 US$ is worth approximately Rp 9,600 at the end of 2000).

The sector in which establishments operate (defined by the main product class) is identified by International Standard of Industrial Classification (ISIC, Revision 2) codes that I collapse to the 2-digit level.

4 Results

Baseline results are in table 1. These results indicate that depreciation δ in the full sample ranges between $1 - exp(-0.085) = 0.081$ and $1 - exp(-0.150) = 0.139$, depending on the specifications, i.e. depending on whether year and/or firm fixed effects are included (columns 1-4). The highest estimate of 13.9% is the result of the panel fixed effects specification that includes year effects (column 4). Once I allow depreciation to vary with industry, I find, in column 5, which is based on pooled OLS, that depreciation rates vary between $1 - exp(-0.150 + 0.029) = 0.114$ for firms in SIC2-sector 36 (Non-Metallic Minerals) and $1 - exp(-0.150 - 0.083) = 0.208$ for firms in SIC2-sector 34 (Paper, Printing). Results in column 6, based on a random effects panel model, imply that estimates of depreciation range between 0.042 and 0.153.[5]

[5] Fixed effects models with industry dummies are not estimated because these are poorly identified, since firms rarely change the industry in the data, and if so, this is potentially more due to measurement error in the coding of the sector.

	(1) base, pooled OLS	(2) panel RE	(3) panel FE	(4) panel FE, include year dummies	(5) pooled OLS, include year & industry dummies	(6) panel RE, include year & industry dummies
Constant	-0.085	-0.092	-0.085	-0.150	-0.150	-0.074
	(0.003)***	(0.003)***	(0.002)***	(0.007)***	(0.009)***	(0.008)***
Textile					-0.013	-0.023
					(0.007)*	(0.008)***
Wood, Furniture					-0.049	-0.050
					(0.010)***	(0.011)***
Paper, Printing					-0.083	-0.092
					(0.014)***	(0.015)***
Chemicals, Plastic					-0.060	-0.060
					(0.009)***	(0.010)***
Non-Metallic Mineral					0.029	0.031
					(0.008)***	(0.009)***
Basic Metal					-0.076	-0.089
					(0.030)**	(0.034)***
Machinery and Equipment					-0.048	-0.050
					(0.010)***	(0.011)***
Other Manufacturing					0.019	0.008
					(0.021)	(0.022)
Year Fixed Effects				yes	yes	yes
Observations	81273	81273	81273	81273	81273	81273
R-squared	0.00		0.00	0.00	0.00	

Notes: Omitted industry is “Food, Beverages and Tobacco “. Robust standard errors in parentheses, corrected for pooling at establishment level in pooled and random effects regressions; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 1: Baseline estimates of depreciation rates in Indonesian manufacturing

I now investigate other sources of heterogeneity in depreciation rates. First, I study the role of age and size of the firm. Because size is potentially endogenous, it is important to note that the goal is not to claim causality; I am primarily interested in understanding how firm characteristics correlate with depreciation rates. A corollary of the discussion in the introduction is that the association of depreciation rates with size and age is theoretically ambiguous. One potential hypothesis is that younger firms have newer or more modern equipment on average, which may depreciate faster. Alternatively, it may be that younger firms are more financially constraint and therefore are more likely to invest in capital goods that depreciate faster (Udry and Anagol 2006). A similar argument regarding financial constraints would suggest that smaller firms have higher depreciation rates if size is correlated with financial constraints. On the other hand, it may be that small firms focus on relatively standard manufacturing tasks, which require less modern equipment that may depreciate less quickly, while larger firms are more likely to invest in modern investment goods that depreciate faster on average. Thus, the question how size and age are correlated with depreciation rates is ultimately an empirical one.

Table 2 shows the results. I have created indicator variables for the quartile of the lagged employment distribution. The omitted category is "firms in the first quartile of the lagged employment distribution".[6] I find a significant role of these size variables: firm size is positively correlated with depreciation rates. Using the results of column 2, which uses year and firm fixed effects, the estimate for depreciation in the smallest quartile is 0.064, and depreciation rates increase monotonically with size, with the largest firms having an

[6] The cutoffs for the quartiles are 27 employees, 46 employees and 129 employees.

estimated depreciation rate of $1 - exp(-0.212 - 0.067) = 0.243$. The size quartile indicators remain significant even after I allow for differences across industries (columns 3 to 6).

In this table I also report results from an investigation of age effects. I do find that older firms have smaller depreciation rates (column 4). Columns 5 and 6 indicate that the effect is large in particular for the youngest firms, i.e. those with an age between 0 and 5 years. This is true even after controlling for size, so age does not simply proxy for size.

	(1) panel FE	(2) panel FE, include year dummies	(3) pooled OLS, include year & industry dummies	(4) panel RE, include year & industry dummies	(5) panel RE, include year & industry dummies	(6) panel RE, include year & industry dummies
Constant	-0.005	-0.067	-0.114	-0.156	-0.141	-0.102
	(0.011)	(0.013)***	(0.009)***	(0.010)***	(0.009)***	(0.010)***
Textile			0.012	-0.021	-0.020	0.006
			(0.007)*	(0.008)***	(0.008)***	(0.008)
Wood, Furniture			-0.023	-0.047	-0.045	-0.019
			(0.010)**	(0.011)***	(0.011)***	(0.011)*
Paper, Printing			-0.067	-0.092	-0.093	-0.075
			(0.014)***	(0.015)***	(0.015)***	(0.015)***
Chemicals, Plastic			-0.029	-0.059	-0.059	-0.027
			(0.009)***	(0.010)***	(0.010)***	(0.010)***
Non-Metallic Mineral			0.024	0.032	0.031	0.025
			(0.008)***	(0.009)***	(0.009)***	(0.009)***
Basic Metal			-0.012	-0.087	-0.086	-0.025
			(0.030)	(0.034)**	(0.034)**	(0.034)
Machinery and Equipment			-0.020	-0.048	-0.048	-0.018
			(0.010)**	(0.011)***	(0.011)***	(0.011)*
Other Manufacturing			0.037	0.011	0.013	0.034
			(0.021)*	(0.022)	(0.022)	(0.022)
Size Quartile 2	-0.035	-0.040	-0.022			-0.024
	(0.012)***	(0.012)***	(0.006)***			(0.007)***
Size Quartile 3	-0.101	-0.114	-0.061			-0.069
	(0.016)***	(0.017)***	(0.007)***			(0.008)***
Size Quartile 4	-0.185	-0.212	-0.151			-0.161
	(0.022)***	(0.023)***	(0.008)***			(0.009)***
age				0.001		
				(0.000)**		
Age 0-5					-0.024	-0.024
					(0.007)***	(0.007)***
Age 6-10					-0.002	-0.005
					(0.006)	(0.006)
Year Fixed Effects		yes	yes	yes	yes	yes
Observations	81273	81273	81273	81273	81273	81273
R-squared	0.00	0.00	0.01			

Notes: Omitted industry is "Food, Beverages and Tobacco ". Robust standard errors in parentheses, corrected for pooling at establishment level in pooled and random effects regressions; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2: Is there heterogeneity of depreciation rates across size and age groups?

Table 3 explores the role of type of ownership. Again, theoretical predictions are ambiguous: Focussing on the role of financing as a determinant of depreciation rates, one may hypothesize that foreign owned firms have better access to financing and thus may be able to finance investments that require larger up-front payments but therefore are lasting longer. On the other hand, it may be that foreign firms use more technologically advanced equipment, or equipment that is not suitable or not developed for use in a developing country setting and therefore depreciates faster.

I define ownership based on majority ownership, i.e. a firm is considered foreign owned if more than 50% is owned by foreigners (using one-year lagged values of the ownership information). Similarly, a firm is coded as government owned, when the sum of central government and local government ownership is more than 50% (again using lagged values). The omitted ownership category is privately owned firms that are owned by Indonesian nationals. The findings suggest that foreign owned firms have higher depreciation rates. Using the estimates of column 2, locally owned private firms have deprecation rates of 13.6%, while those that are foreign owned have an estimated depreciation rate of 23.6%. Government owned firms, on the other hand, do not appear to have significantly different depreciation rates once size effects are taken into account. The foreign ownership dummy remains statistically and economically significant, even after controlling for industry and size effects.

	(1) panel FE	(2) panel FE, include year dummies	(3) pooled OLS, include year & industry dummies	(4) panel FE, include year dummies	(5) panel RE, include year & industry dummies	(6) panel FE, include year dummies
Constant	-0.081 (0.003)***	-0.146 (0.008)***	-0.146 (0.009)***	-0.064 (0.013)***	-0.114 (0.009)***	-0.064 (0.013)***
Textile			-0.012 (0.007)*		0.012 (0.007)*	
Wood, Furniture			-0.050 (0.010)***		-0.024 (0.010)**	
Paper, Printing			-0.082 (0.014)***		-0.068 (0.014)***	
Chemicals, Plastic			-0.053 (0.009)***		-0.026 (0.009)***	
Non-Metallic Mineral			0.028 (0.008)***		0.023 (0.008)***	
Basic Metal			-0.064 (0.031)**		-0.008 (0.031)	
Machinery and Equipment			-0.041 (0.010)***		-0.017 (0.010)	
Other Manufacturing			0.027 (0.021)		0.041 (0.021)**	
Foreign owned	-0.127 (0.041)***	-0.124 (0.041)***	-0.147 (0.022)***	-0.118 (0.041)***	-0.091 (0.023)***	-0.118 (0.041)***
Government owned	-0.017 (0.029)	0.008 (0.029)	-0.075 (0.020)***	0.011 (0.029)	-0.025 (0.020)	0.011 (0.029)
Size Quartile 2				-0.040 (0.012)***	-0.021 (0.006)***	-0.040 (0.012)***
Size Quartile 3				-0.114 (0.017)***	-0.059 (0.007)***	-0.114 (0.017)***
Size Quartile 4				-0.211 (0.023)***	-0.143 (0.008)***	-0.211 (0.023)***
Year Fixed Effects		yes	yes	yes	yes	yes
Observations	81273	81273	81273	81273	81273	81273
R-squared	0.00	0.00	0.01	0.00	0.01	0.00

Notes: Omitted industry is “Food, Beverages and Tobacco “. Robust standard errors in parentheses, corrected for pooling at establishment level in pooled and random effects regressions; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3: Heterogeneity of depreciation across types of ownership?

Finally, I investigate the association of financial constraints and depreciation. As pointed out before, Udry and Anagol (2006) show theoretically that financially constrained entrepreneurs invest in less durable goods. We can use the survey data from Indonesia to shed some additional light on this hypothesis. In particular, in one year, namely 1996, a somewhat different survey questionnaire was used (which is why in the present study capital and investment data is only used for years up to 1995), which included a section on business constraints. This section had a question about the existence of a "major constraint that could not be overcome up to the end of 1996". If the respondent answered affirmatively, the questionnaire then asked about the type of constraint. I code a firm as "potentially constrained", if the firm's answer was "capital" in the question about the type of the constraint. While one needs to be careful about overinterpreting the responses to direct, qualitative questions as this one, there is some evidence that suggests that direct questions about financing as a problem indeed are correlated with actual financial constraints. Some evidence comes from a study of small retail businesses in Mexico: Cull et al. (2007) find that their experimentally estimated returns to capital are large for firms that say that financing is a key problem for their business, while the returns are not significantly different from zero for the other firms. Similarly, in Schündeln (2007), using data for a large number of developing countries, I demonstrate that the investment of firms in which the entrepreneur mentions credit as the firm's main problem is sensitive to cash flow, while I cannot reject the null hypothesis that the investment-cash flow sensitivity of firms in the other group is zero. These findings suggest that the entrepreneur's own subjective assessment about financing constraints is correlated with actual financial constraints.

Table 4 presents the results. I find some evidence that suggests that firms that mention credit as a business constraint in 1996 have larger depreciation rates. According to the point estimates, depreciation rates of those firms are approximately two percentage points higher. However, the results are not statistically significant at standard levels (the p-value is 0.16 in columns 1 and 2). Once I exclude more extreme outliers, by dropping the 3% tails of the distribution of $\text{capital}_t/\text{capital}_{t-1}$ by industry, the coefficient on the potentially constrained indicator becomes significant at a 10% significance level (the p-value is 0.052 in column 3 and 0.06 in column 6). Overall, the findings are consistent with the hypothesis that financially constrained firms invest in less durable goods.

	(1) pooled OLS	(2) pooled OLS	(3) pooled OLS, drop 3% outlier	(4) panel RE	(5) panel RE	(6) panel RE, drop 3% outlier
constant	-0.121	-0.117	-0.108	-0.122	-0.118	-0.111
	(0.012)***	(0.012)***	(0.011)***	(0.012)***	(0.012)***	(0.011)***
potentially constrained	-0.021	-0.021	-0.027	-0.022	-0.022	-0.027
	(0.015)	(0.015)	(0.014)*	(0.016)	(0.016)	(0.015)*
Textile	-0.002	-0.001	-0.003	-0.004	-0.002	-0.007
	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
Wood, Furniture	-0.034	-0.035	-0.027	-0.032	-0.032	-0.019
	(0.012)***	(0.012)***	(0.011)**	(0.012)***	(0.012)***	(0.011)*
Paper, Printing	-0.062	-0.060	-0.058	-0.060	-0.059	-0.060
	(0.016)***	(0.016)***	(0.015)***	(0.016)***	(0.016)***	(0.015)***
Chemicals, Plastic	-0.054	-0.048	-0.041	-0.052	-0.046	-0.036
	(0.011)***	(0.011)***	(0.010)***	(0.011)***	(0.011)***	(0.010)***
Non-Metallic Mineral	0.031	0.030	0.036	0.031	0.030	0.038
	(0.009)***	(0.009)***	(0.008)***	(0.009)***	(0.009)***	(0.009)***
Basic Metal	-0.049	-0.040	-0.033	-0.053	-0.044	-0.037
	(0.032)	(0.033)	(0.028)	(0.033)	(0.034)	(0.029)
Machinery and Equipment	-0.045	-0.038	-0.040	-0.044	-0.037	-0.039
	(0.011)***	(0.011)***	(0.010)***	(0.012)***	(0.012)***	(0.011)***
Other Manufacturing	0.054	0.059	0.046	0.049	0.056	0.039
	(0.020)***	(0.020)***	(0.018)**	(0.021)**	(0.021)***	(0.020)*
Foreign owned		-0.126	-0.110		-0.127	-0.098
		(0.025)***	(0.022)***		(0.024)***	(0.021)***
Government owned		-0.081	-0.063		-0.074	-0.050
		(0.023)***	(0.021)***		(0.025)***	(0.025)**
Year Fixed Effects	yes	yes	yes	yes	yes	yes
Observations	50251	50251	48440	50251	50251	48440
R-squared	0.00	0.00	0.01			

Notes: Omitted industry is “Food, Beverages and Tobacco “. Robust standard errors in parentheses, corrected for pooling at establishment level; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Financial constraints and depreciation

5 Conclusion

Depreciation rates are commonly assumed to be constant across firms, industries, and countries. As pointed out in the introduction, this assumption is not insignificant. Nevertheless, depreciation rates receive almost no attention and evidence on depreciation rates is scarce.

In this note I suggest a straightforward econometric approach to estimate depreciation rates from firm-level data and apply it to manufacturing firms' data from Indonesia. In contrast, the methods suggested in the literature require data on individual pieces of equipment, which are usually not available. One objection to the approach may be that individual depreciation rates follow different processes than the estimated average, i.e. establishment-level depreciation rates. However, while depreciation of individual pieces may indeed follow different processes, the aggregate depreciation rates that are needed, e.g., for macro calibrations assume average depreciation rates anyway (e.g. Mankiw et al. 1992).

From firm-level capital data I estimate the depreciation rate in Indonesian manufacturing firms to be between 8% and 14% in the full sample. Comparing these results with the assumptions which are being made in the absence of actual estimates in related literature on manufacturing in developing countries it appears that the assumptions that are made are at the lower end of the estimates. For example, for Ghanaian manufacturing firms Bigsten et al. (2002), assume a depreciation rate of 6%. On the other hand, the estimates are in line with standard depreciation figures used in the literature for the United States, e.g. Kydland and Prescott (1982), who set the depreciation rate equal to 10% and the Bureau of Economic Analysis (Fraumeni 1997, 18), which uses depreciation rates between 10.3% (special industrial machinery) and 12.3% (metalworking machines). Bond et al. (2003) assume 8% depreciation to impute capital in their samples of manufacturing firms from Belgium, France, Germany and the UK. At the macro level, typically lower aggregate depreciation rates are used (e.g. of 5% in Barro and Sala-i-Martin, 1995, and Hauk and Wacziarg, 2004).

In additional empirical results I find significant heterogeneity of depreciation rates across different types of firms. The result that larger and foreign owned firms have higher depreciation rates than small or locally owned firms is consistent with a story in which large and foreign owned firms use more advanced technologies and more "modern" equipment that, on average, depreciates faster. The findings regarding financial constraints are consistent with the hypothesis that financing constraints lead to the acquisition of less durable equipment.

References

[1] Barro, Robert and Xavier Sala-i-Martin (1995), Economic Growth. New York: McGraw Hill.

[2] Benhabib, Jess, and Mark Spiegel. (1994): The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data. *Journal of Monetary Economics* 34, 143–173.

[3] Bigsten A., P. Collier, S. Dercon, M. Fafchamps, B. Gauthier, J. Gunning, A. Oduro, R. Oostendorp, C. Pattilo, M. Söderbom, F. Teal, and A. Zeufack (2002): Adjustment Costs and Irreversibility as Determinants of Investment: Evidence from African Manufacturing. Manuscript.

[4] Bond, Stephen, Julie Elston, Jacques Mairesse, and Benoît Mulkay (2003): Financial Factors and Investment in Belgium, France, Germany and the United Kingdom. A Comparison using Company Panel Data. *Review of Economics and Statistics*, 85 (1), 153-165.

[5] Coen, Robert (1975): Investment Behavior, the Measurement of Depreciation, and Tax Policy. *American Economic Review*, 65 (1) 59-74.

[6] de Mel, Suresh, David McKenzie and Christopher Woodruff (2006): Returns To Capital In Microenterprises: Evidence From A Field Experiment. Manuscript, UCSD.

[7] Fraumeni, Barbara (1997): The Measurement of Depreciation in the U.S. National Income and Product Accounts. *Survey of Current Business*, July 1997, 7-23.

[8] Hauk, William and Romain Wacziarg (2004): A Monte Carlo Study of Growth Regressions. NBER Technical Working Paper 296.

[9] Hulten, Charles and Frank Wykoff (1981): The Estimation of Economic Depreciation Using Vintage Asset Prices. *Journal of Econometrics* 15, 367-396.

[10] Islam, Nazrul (1998): Growth Empirics: A Panel Data Approach – A Reply. *Quarterly Journal of Economics*, 113 (1) 325-329.

[11] Jorgenson, Dale (1974): The Economic Theory of Replacement and Depreciation. In: W. Sellekaerts (ed.): Econometrics and Economic Theory. Essays in Honor of Jan Tinbergen. White Plains, NY.

[12] King, Robert and Ross Levine (1994): Capital Fundamentalism, Economic Development, and Economic Growth. Carnegie-Rochester Conference on Public Policy 40, 259-292.

[13] Kydland, Finn and Edward C. Prescott (1982): Time to Build and Aggregate Fluctuations. Econometrica, 50 (6), 1345-1370.

[14] Mankiw, Gregory, David Romer, and David Weil (1992): A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics* 107(2) 407-437.

[15] Pritchett, Lant (2000): The Tyranny of Concepts: CUDIE (Cumulated, Depreciated, Investment Effort) is Not Capital. Journal of Economic Growth 5 (4), 361-384.

[16] Schündeln, Matthias (2004): Firm Dynamics in the Presence of Financing Constraints: Ghanaian Manufacturing. Unpublished Ph.D. Thesis. Yale University.

[17] Schündeln, Matthias (2007): Financing Constraints: A New Test and an Application to Developing Countries. Manuscript.

[18] Summers, Robert and Heston, Alan (1991): The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950–1988. *Quarterly Journal of Economics* 106(2) 327–68.

[19] Udry, Christopher and Anagol Santosh (2006): The Return to Capital in Ghana. *American Economic Review Papers and Proceedings*, 96 (2) 388-393..