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Appreciating depreciation: physical capital depreciation in a developing country

Matthias Schündeln

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Abstract Little is known about the nature of physical capital in the less-developed countries. This article addresses the lack of empirical study related to depreciation rates, which are a neglected but important ingredient of both micro and macro models and empirical analyses. Based on rich establishment-level survey data, and using a straightforward econometric approach, I estimate depreciation rates of physical capital invested in manufacturing enterprises in Indonesia. I estimate the depreciation rate to be between 8 and 14 %. These numbers compare roughly to published estimates for the U.S. I then investigate hypotheses related to heterogeneity of depreciation rates across different types of firms. Finally, I test the hypothesis that financially constrained firms use less durable investment goods.

Keywords Depreciation rate · Capital stock · Investment · Manufacturing · Indonesia

JEL Classification O14 · D92 · E22 · L6

1 Introduction

Does physical capital depreciate, i.e. decline in efficiency, 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 article seeks to address the lack of empirical study in this area and approaches the question about the existence of differences in depreciation rates

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M. Schündeln (✉)
Goethe University Frankfurt, Grüneburgplatz 1, 60323 Frankfurt am Main, Germany
e-mail: schuendeln@wiwi.uni-frankfurt.de

across countries in the context of one particular part of a country's physical capital stock, namely the capital stock of manufacturing enterprises. In the context of this article, the depreciation rate is defined as the rate at which the efficiency of the capital stock declines (as opposed to the rate at which the book value declines). Thus, to estimate depreciation rates, data on current replacement or resale value of the capital stock is needed, as opposed to accounting data on book values. I therefore exploit a rich establishment-level dataset to provide estimates for depreciation rates of physical capital in the Indonesian manufacturing sector.

From a macro perspective, the importance of depreciation is illustrated by a consideration of depreciation rates in the growth literature: 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 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 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. 2008). 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. Tax policy is another area in which an estimate of economic depreciation is important, because 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, e.g. Summers and Heston 1991; Benhabib and Spiegel 1994; King and Levine 1994; and Bond et al. (2003); for a more general discussion of associated problems see Pritchett (2000). Capital stocks estimated using 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.

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 are often missing. In the absence of actual estimates, assumptions about the rates of depreciation have to be made. As pointed out above, cross-country studies typically assume constant depreciation across countries.[1] 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 whether depreciation rates are constant. At the same time, there is no obvious argument in which direction any net effect of the differences between depreciation rates in the developed and the less-developed countries would go.

One hypothesis would be that imported, technologically more advanced capital is used, which 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 the 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 the 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 study is needed.

Most existing articles that estimate depreciation empirically use information about individual pieces of equipment, usually from sales or rental prices of used capital assets. This information can be used to estimate the form and the rate of depreciation (e.g. Hulten and Wykoff 1981). However, this kind of information is rarely available for developing countries. On the other hand, by now firm- or establishment-level datasets exist for a relatively large number of developing countries. This article illustrates how this kind of information at the firm- or establishment-level can be used to provide much-needed estimates of depreciation rates for developing countries. [2] Within Asia, the case of Indonesia provides a particularly useful case study, as a large panel dataset 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.: The Bureau of Economic Analysis uses depreciation rates between 10.3 %, for special industrial machinery, and 12.3 %, for metalworking machines (Fraumeni 1997, p. 18) in the U.S.. For developing countries, the picture looks somewhat different, though: Based on India’s National Accounts

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

[2] It is important to keep in mind that because of the use of firm-level data, I estimate a measure of aggregate depreciation of the capital stock at the firm-level.

Statistics, Raychaudhuri (1996) reports depreciation rates of roughly 7 % for Indian industries. Similarly, Kumar and Managi (2010) assume a depreciation rate of 7 %, citing India's Central Statistical Organisation. These estimates are at the lower end of the estimates for Indonesia. Low estimates come also from the National Accounts for China, which assume 4 % depreciation for fixed assets (OECD 2000). Wang and Yao (2003) work with 5 % as their baseline, but also consider depreciation rates of 10 % and 15 %, referring to the Statistical Yearbook of China. Also for China, Bai et al. (2006) assume depreciation rates of between 8 % (for structures) and 24 % (for machinery). For China and India, Hsieh and Klenow (2009) assume a depreciation rate of 5 %. Taken together, these numbers provide further evidence for the large range of existing estimates and assumed values and the need for more study on depreciation rates to be able to defend the often-made assumption of constant aggregate depreciation rates across countries.

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, p. 174).

For estimation, I will take this model literally and use it as the basis for the empirical specification, with the parameter of interest being δ. First, rearrange Eq. 1 to collect all variables measured at time t, to get $K_t - I_t = (1 - \delta)K_{t-1}$. After taking logs and further rearranging, we get $\log(K_t - I_t) - \log(K_{t-1}) = \log(1 - \delta)$. This identity might not hold for a number of possible reasons. For example, the omission of other variables that explain changes in the capital stock, which are outside the above simple model of investment behavior. This could, for example, be loss of equipment that is due to theft—another reason as to why the identity might not hold is mismeasurement of the variables to be explained. Finally, depreciation is not the fully deterministic process that the simple model assumes. Therefore, to arrive at an estimable model, we introduce a disturbance term, ϵ_t, as follows:

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

This specification can be estimated with a simple OLS regression with a constant. In addition to the pooled OLS, I also explore alternative specifications in which I exploit the panel structure of the data. This empirical set-up will only produce meaningful estimates for δ if the data for K_t is not simply based on book values, which are the result of an accounting exercise (if K_t were book values, the estimates for δ should simply reflect the depreciation rate that is assumed for accounting). Therefore, it is imperative to use survey data that independently values the capital stock each year.

Besides depreciation and investment, another important reason for changes in the nominal value of the capital stock over time is inflation. A possible concern is that the deflators that are used are measured noisily and cannot fully capture the effect of inflation, so that inflation also influences the results regarding 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, then 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[3]:

Again let us start from Eq. 1. However, we 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

$$K_{ist} - I_{ist} = (1 - \delta_s)K^*_{ist-1} \cdot e^{\epsilon_{ist}} \tag{3}$$

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

$$K_{ist} - I_{ist} = (1 - \delta_s)K_{ist-1}(1 + \upsilon_t) \cdot e^{\epsilon_{ist}} \tag{4}$$

This demonstrates the danger of mixing depreciation with inflation, if the latter is measured with error. If $\upsilon_t \neq 0$ and this is not taken into account, then the estimate of depreciation will in fact be a function of δ_s and υ_t. Taking logs and rearranging the last equation gives the following:

$$\log(K_{ist} - I_{ist}) - \log(K_{ist-1}) = \log(1 - \delta_s) + \log(1 + \upsilon_t) + \epsilon_{ist} \tag{5}$$

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

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[3] Similarly, if cross-country data are available, using variation across countries instead of across time, we can separately identify sector and country effects.

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 dataset covers up to 20,000 establishments annually. I use data from 1988 to 1995, thus avoiding observations during the years of the financial crisis that hit Indonesia in 1997. The data used in the empirical analysis to measure the capital stock are the value of fixed capital, as it is estimated for the survey by the respondent. This number is different from the book value, which is listed separately in the survey. Thus, the necessary condition pointed out above is fulfilled, namely that actual valuations of the use value of capital are available, and not only book values, which would reflect accounting assumptions about depreciation rather than true depreciation in the sense of deterioration of the capital stock's efficiency. Capital stock data are available from 1988 onwards. I do not include 1996 data to get consistent capital stock data, because there is a slightly different questionnaire format in the year 1996. To clean the data of extreme outliers, I drop the 1 % tails of the distribution of the $\text{capital}_t/\text{capital}_{t-1}$ 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.

Given that the capital stock is self-reported, one might be worried whether it is measured with error. First, we note that, since firms are required by law to fill out the questionnaire, purposeful misreporting is likely to be lower than in many other survey datasets. In addition, book values are relevant for tax purposes, not the (self-reported) values of the capital stock, and therefore, this specific possible motivation for misreporting is unlikely in the case of the capital stock variable that is used here. We further note that if capital stock and investment values are consistently overestimated by a (possibly firm-specific) factor x, then this factor drops out of equation (1), and this type of mismeasurement will not be a problem. If there are individual firm-year observations in which the value is misreported by significant amounts, then this will have been taken into account, because extreme outliers of the $\text{capital}_t/\text{capital}_{t-1}$ ratio have been dropped.

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 and 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 specification. More specifically, column (1), which shows the simplest possible specification of Eq. 2, estimates the constant to be -0.085 and therefore $\delta = 0.081$.[4] While

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[4] The constant is estimated to be -0.085, thus $\log(1 - \delta) = -0.085$, which implies an estimated depreciation rate of $\delta = 1 - \exp(-0.085) = 0.081$.

Table 1 Baseline estimates of depreciation rates in Indonesian manufacturing

	(1) Base, pooled OLS	(2) Panel RE	(3) Panel FE	(4) Panel FE, include year dummies	(5) Pooled OLS, include year and industry dummies	(6) Panel RE, include year and 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	81,273	81,273	81,273	81,273	81,273	81,273
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 %

column (1) is a simple pooled OLS regression, columns (2) and (3) take into account the panel structure of the data, with random effects and fixed effects specifications, respectively. Column (4) also adds time fixed effects. Finally, columns (5) and (6) also include industry fixed effects, thus estimating Eq. 5, to take into account time-specific errors in the deflator used and sector-specific depreciation rates.

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 column (5), I find 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] Further, the coefficients are fairly precisely estimated. For the baseline results reported in column (1), for example, the 95 % confidence interval around the point estimates implies depreciation rates between 7.7 and 8.6 %.

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 under more financial constraint and therefore are more likely to invest in capital goods that depreciate faster (Udry and Anagol 2006). A similar argument regarding financial constraint would suggest that smaller firms have higher depreciation rates if size is correlated with financial constraint. 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 as regards 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] 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 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 3–6).

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 that age does not simply proxy for size.

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

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[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.

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

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

	(1) Panel FE	(2) Panel FE, include year dummies	(3) Pooled OLS, include year and industry dummies	(4) Panel RE, include year and industry dummies	(5) Panel RE, include year and industry dummies	(6) Panel RE, include year and 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	81,273	81,273	81,273	81,273	81,273	81,273
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 3 Heterogeneity of depreciation across types of ownership?

	(1) Panel FE	(2) Panel FE, include year dummies	(3) Pooled OLS, include year and industry dummies	(4) Panel FE, include year dummies	(5) Panel RE, include year and industry dummies	(6) Panel FE, include year dummies
Constant	−0.081	−0.146	−0.146	−0.064	−0.114	−0.064
	(0.003)***	(0.008)***	(0.009)***	(0.013)***	(0.009)***	(0.013)***
Textile			−0.012		0.012	
			(0.007)*		(0.007)*	
Wood, furniture			−0.050		−0.024	
			(0.010)***		(0.010)**	
Paper, printing			−0.082		−0.068	
			(0.014)***		(0.014)***	
Chemicals, plastic			−0.053		−0.026	
			(0.009)***		(0.009)***	
Non-metallic mineral			0.028		0.023	
			(0.008)***		(0.008)***	
Basic metal			−0.064		−0.008	
			(0.031)**		(0.031)	
Machinery and equipment			−0.041		−0.017	
			(0.010)***		(0.010)	
Other manufacturing			0.027		0.041	
			(0.021)		(0.021)**	
Foreign owned	−0.127	−0.124	−0.147	−0.118	−0.091	−0.118
	(0.041)***	(0.041)***	(0.022)***	(0.041)***	(0.023)***	(0.041)***
Government owned	−0.017	0.008	−0.075	0.011	−0.025	0.011
	(0.029)	(0.029)	(0.020)***	(0.029)	(0.020)	(0.029)
Size quartile 2				−0.040	−0.021	−0.040
				(0.012)***	(0.006)***	(0.012)***
Size quartile 3				−0.114	−0.059	−0.114
				(0.017)***	(0.007)***	(0.017)***
Size quartile 4				−0.211	−0.143	−0.211
				(0.023)***	(0.008)***	(0.023)***
Year fixed effects		Yes	Yes	Yes	Yes	Yes
Observations	81,273	81,273	81,273	81,273	81,273	81,273
R squared	0.00	0.00	0.01	0.00	0.01	0.00

Notes Omitted industry is ‘Food, Beverages and Tobacco’. Omitted ownership category is ‘privately owned firms’. 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 %

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). In the regressions, 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.

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 are 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: McKenzie and Woodruff (2008) 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. 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 capital 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.

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.

Table 4 Financial constraints and depreciation

	(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	50,251	50,251	48,440	50,251	50,251	48,440
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 %

Nevertheless, depreciation rates receive almost no attention and evidence on depreciation rates is scarce.

In this article, 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 assumptions about depreciation used in the literature for the U.S., e.g. Kydland and Prescott (1982), who set the depreciation rate equal to 10 % and the Bureau of Economic Analysis (Fraumeni 1997, p. 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.

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