Accrual Accounting and Resource Allocation: A General Equilibrium Analysis

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Abstract

I evaluate the role of accrual accounting in improving firms' production decisions and resource allocation across firms. I introduce both cash flow and accounting earnings as imperfect measures of performance into a general equilibrium model with heterogeneous firms under imperfect information. The model demonstrates firms' more informed decisions with an improved measure of performance lead to more resources being allocated to potentially high-productivity firms through the product and input markets. The estimated parameter values are consistent with accrual accounting improving managers' information about future productivity by providing a better measure of performance. The quantitative analysis suggests having accrual accounting information in addition to cash accounting information leads to a 0.7% increase in aggregate productivity and a 1.0% increase in aggregate output through resource allocation in the United States. The estimates are larger in China and India as benchmarks for developing countries: a 1.2%-2.5% increase in aggregate productivity and a 1.7%-3.8% increase in aggregate output. Overall, I demonstrate accrual accounting plays an important role in determining aggregate productivity through resource allocation.

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1 Introduction

What is the role of accrual accounting in allocating resources to better uses, and how much (if at all) does accrual accounting improve aggregate productivity by facilitating resource allocation? This question is fundamental to accounting, but addressing it is challenging for several reasons (Kanodia and Sapra, 2016; Leuz and Wysocki, 2016). First, the analysis needs to take into account that firms' production decisions are inherently interrelated because firms compete for the same set of limited resources, and the equilibrium prices in the product and input markets play a role in allocating resources across the firms (Baumol, 1977, p.497). Second, the analysis must incorporate how accrual accounting affects resource allocation in this setting. The absence of a counterfactual is another challenge. I address this question through a general equilibrium analysis in three steps, because it naturally deals with these challenges: (1) analyzing how accrual accounting influences individual firms' decisions and thus resource allocation across firms in a general equilibrium model with accounting systems, (2) estimating the parameter values in the model that represent the role of accrual accounting in shaping firms' decisions, and (3) evaluating the impact of accrual accounting information on resource allocation and aggregate productivity through counterfactual analyses in the context of the model.

I build on the general equilibrium model in David et al. (2016) to introduce and analyze the role of accrual accounting in facilitating firms' internal decision making and hence in improving resource allocation and aggregate productivity. In their model, resources are allocated to multiple firms through the product and input markets under imperfect information. Firms compete in the product market by making differentiated products, and their production functions with capital and labor vary in productivity. Considering the product and input markets, a firm makes production decisions by forming an expectation of its future productivity while maximizing its profits. The key friction is a manager's imperfect information about future productivity. I introduce accrual accounting systems into the general equilibrium model by adapting Nikolaev's (2016) accrual accounting model.

In the model, accruals can help measure firm performance more accurately and hence be helpful in improving managerial production decisions (e.g., Kaplan, 1984; Hopper et al., 1992; Hemmer and Labro, 2008; Feng et al., 2009; Dichev et al., 2013; Goodman et al., 2014; Hemmer and Labro, 2015; Shroff, 2016). As a result, accrual accounting information can have a direct effect on resource allocation and aggregate productivity by reducing informational frictions. One key distinction between my paper and David et al. (2016) is that I relax David et al.'s (2016) assumption that firms have a perfect measure of current productivity. This assumption implies no measurement systems, including accrual accounting systems, play a role in resource allocation, because any improvement in the measurement of current productivity has no effect on managers' expectations of future productivity due to a perfect measure of current productivity. By contrast, assuming imperfect measures of current productivity allows measurement systems to influence firms' production decisions by improving managers' information about future productivity. My paper focuses on the internal usage of accounting rather than the external usage of accounting. In practice, perfectly measuring firm performance and productivity is difficult even for managers because the costs and benefits of business transactions may occur in different periods.

The complexity of business transactions naturally limits cash flow and accounting earnings to imperfect measures of firm performance and productivity (e.g., Dechow, 1994; Dechow and Dichev, 2002; Dechow et al., 2010; Nikolaev, 2016). Cash accounting systems imperfectly measure firm performance, because cash collections and cash payments are likely to be misaligned with the timing of business transactions. Accrual accounting systems aim to measure firm performance better than cash accounting systems by using accruals. By adjusting cash flow using accruals, accrual accounting systems match the costs and benefits of business transactions with each other into the same period. However, this adjustment frequently requires firms to estimate potential costs and benefits related to current business transactions. This estimation is a source of imperfection in measures of firm performance, even for accounting earnings. In this sense, cash flow and accounting earnings both measure

firm performance with noise: cash flow has a timing error, accruals have a timing and an estimation error, and accounting earnings have an estimation error. The relative magnitudes of timing errors and estimation errors determine whether accrual accounting systems provide managers with a better measure of fundamentals than cash accounting systems.

The model in my paper implies accrual accounting systems are able to improve resource allocation and aggregate productivity by improving managers' information about future productivity. If accrual accounting systems provide an improved measure of fundamentals, managers rely more on accounting earnings than on cash flow to make more informed capital and labor investments. Even though each firm makes its own input choices, capital and labor markets play a role in allocating resources from potentially low-productivity firms to potentially high-productivity firms through prices in the input markets, because firms expecting higher productivity are willing to purchase more resources than firms expecting lower productivity at the same price of resources. This mechanism is stronger when the differentiated products are more substitutable, because potentially high-productivity firms are going to take more market share from potentially low-productivity firms. The aggregation of firms' output demonstrates aggregate productivity increases with the quality of accrual accounting systems, in the sense that an economy produces more aggregate output with the same resources due to having more efficient (ex-post) resource allocation across firms.

I estimate the parameter values in the model that represent the role of accrual accounting in shaping informational frictions, which determine firms' production decisions. I use the simulated method of moments (SMM) based on financial data in the United States, China, and India for comparison with prior studies (e.g., Hansen, 1982; McFadden, 1989; Hsieh and Klenow, 2009; David et al., 2016). In the model, managers have three information sources with which to predict future productivity: cash flow, accounting earnings, and all other information. Their quality determines the quality of managers' overall information. The size of errors in a measure of productivity determines the quality of the measure of productivity.

The estimated parameter values support the argument that accrual accounting systems

improve managers' information about future productivity by providing a better measure of performance. For all three countries, the model-fit test does not reject the null hypothesis that the moment conditions derived by the model's assumptions are consistent with the data-generating process. The standard deviation of the estimation errors in accounting earnings is less than half the standard deviation of the timing errors in cash flow in all three countries. This result confirms the same finding in the United States (Nikolaev, 2016) is also applicable to China and India. The standard deviation of estimation errors in the United States is 5%-6% smaller than in China and India, implying the United States has better accrual accounting systems than China and India, consistent with prior papers' findings (e.g., Leuz et al., 2003). In addition, these estimates are consistent with the firms' investment decisions that I use for the moment conditions. The higher correlation between investment and accounting earnings compared to that between investment and cash flow implies managers rely more on accounting earnings than on cash flow when making investment decisions.

I find the estimated improvement in aggregate productivity due to accrual accounting systems is economically significant. To gauge the magnitude of the effect, I calculate the quality of managers' information sets in a hypothetical situation, and examine their impact on aggregate productivity in the context of the model. In the United States, accrual accounting systems provide a 0.7% increase in aggregate productivity and a 1.0% increase in aggregate output through improved resource allocation, relative to cash accounting systems. The estimates are larger in China and India as benchmarks for developing countries because the quality of the other information sources is lower in China and India than in the United States: a 1.2%-2.5% increase in aggregate productivity and a 1.7%-3.8% increase in aggregate output. Furthermore, I quantify the potential gains for China and India if these countries had "US-quality" accounting information. The quantitative exercise shows having "US-quality" accounting information would increase aggregate productivity by 0.6%-0.7% and aggregate output by 0.8%-1.0% in China and India. These estimates are the quantitative implications of the model (Kydland and Prescott, 1996). However, these counterfactual

exercises do not consider any forces outside the model, such as information-spillover effects of accounting and distinguishable legal institutions in different countries.

The main implication of my paper is not sensitive to different model assumptions, but the estimated impact of accrual accounting on aggregate productivity changes depending on the different model assumptions. To evaluate the estimated impact of accrual accounting on aggregate productivity, I relax the major assumptions that help identify the process of fundamentals and the quality of information sources, conduct a sensitivity test, and validate the estimation method for timing and estimation errors. Following Nikolaev (2016), I identify the process of productivity separately from the process of timing and estimation errors in cash flow and accounting earnings by imposing independence assumptions on the correlation structure of productivity, timing errors, and estimation errors. Relaxing the accounting-property assumptions increases the estimated impact of accrual accounting on aggregate productivity by 0.1%-4.1%. I identify the quality of all other information by assuming firms maximize the firms' profits without frictions other than informational frictions. Allowing firms to face other frictions, such as financial frictions, suggests the estimated impact of accrual accounting on aggregate productivity might be underestimated because of overestimating the quality of all other information. The different values of the parameter characterizing the competition in the product market make the estimated impact of accrual accounting on aggregate productivity vary from 0.4% to 3.5%. Finally, an industry analysis validates the estimation method in my paper by showing the sizes of both timing and estimation errors are positively related to the length of the operating cycle, consistent with prior papers' findings (e.g., Dechow, 1994; Dechow and Dichev, 2002).

This paper is related to recent papers in two different areas: accounting and macroeconomics. Recent accounting papers shed light on the real effect of accounting.[1] However, prior studies pay more attention to the effect of accounting on individual firms' investment

[1]For example, see Kanodia (1980), Kanodia and Lee (1998), Kanodia et al. (2004), McNichols and Stubben (2008), Biddle et al. (2009), Francis et al. (2009), Bushman et al. (2011), Badertscher et al. (2013), Jung et al. (2014), Dutta and Nezlobin (2015), Hann et al. (2015), and Breuer (2016).

decisions than to the effect of accounting on aggregate variables, such as aggregate productivity and the gross domestic product (GDP). My contribution is to quantify the impact of accrual accounting systems on resource allocation and aggregate productivity by building a general equilibrium model with accounting systems.[2]

A growing body of work in macroeconomics studies the role of resource misallocation in hampering aggregate productivity.[3] Hsieh and Klenow (2009) argue aggregate productivity can be hampered when resources are inefficiently allocated across firms. David et al. (2016) further argue one factor that drives such resource misallocation is informational frictions. Resources might be allocated inefficiently across firms ex-post because firms might not perfectly foresee their future productivity. My contribution is to explore how accrual accounting systems are able to shape informational frictions and influence resource allocation.[4]

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 explains the data and estimation. Section 4 lays out the results of the quantitative analysis. Section 5 details robustness tests. Finally, section 6 concludes.

[2]Accounting research has not often used structural estimation (exceptions include Zakolyukina, 2014; Gerakos and Syverson, 2015; Terry, 2015; Bertomeu et al., 2016; Beyer et al., 2016; Gow et al., 2016).

[3]Recent papers in economics pay close attention to the importance of micro-level resource misallocation in aggregate productivity (e.g., Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Bartelsman et al., 2013). An understanding of cross-country GDP differences is an important research topic in economics. The largest part of the GDP differences is attributable to the residual total factor productivity (TFP) or simply aggregate productivity (Hsieh and Klenow, 2010). Prior papers have studied cross-country differences in TFP by analyzing a representative firm's behaviors. However, Restuccia and Rogerson (2008) argue heterogeneous firms in the economy play an important role in determining aggregate productivity. Bartelsman et al. (2013) find the magnitude of resource misallocation across heterogeneous firms in a country is closely related to the economic growth in that country. They measure the efficiency of resource allocation as the covariance between productivity and firm size in the economy–a measure initially proposed by Olley and Pakes (1996).

[4]The method for estimating informational frictions in my paper is applicable to both public and private firms because it only requires financial data. David et al. (2016) estimate the effect of informational frictions on aggregate productivity for public firms, because they study the role of stock markets in aggregating dispersed information, and their estimation method uses both stock return data and financial data. In addition, my paper explicitly considers measurement errors in the data. This issue is a challenge for prior studies in macroeconomics, because differences in measurement errors–rather than differences in optimal decisions–might drive differences in the correlation between investment and productivity across countries (e.g., Hopenhayn, 2014).

2 General Equilibrium Model with Accounting Systems

I build a general equilibrium model with accounting systems by adapting David et al.'s (2016) general equilibrium model and Nikolaev's (2016) accrual accounting model. Figure 1 illustrates the economy in my model. In the model, I explain how each agent, including a representative household and heterogeneous firms, participates in the resource-allocation process, how accounting systems affect firms' production decisions, and how a steady-state equilibrium in the economy characterizes the relation between accrual accounting and resource allocation.

[Figure 1 about here.]

2.1 Representative Household

A representative household determines how much to consume and how much to invest at the aggregate level by maximizing the utility function:

$$\sum_{t=0}^{\infty} \beta^t u(C_t), \tag{1}$$

where C_t is consumption at date t and $0 < \beta < 1$ is the discount factor.[5] The budget constraint is

$$C_t + K_{t+1} \leq (1 + R_t - \delta)K_t + W_t L_t + \Pi_t, \forall t \geq 0, \tag{2}$$

where K_t is the aggregate capital stock at date t, L_t is labor at date t, R_t and W_t are the capital rental and wage rate at date t, δ is the depreciation rate, and Π_t is the total profit from the operations of all the firms.[6] Capital is owned by a representative household and rented to firms. Labor is inelastically supplied to the labor market because a representative household does not value leisure: $L_t = L$.

[5] The utility function, $u(C_t)$, is strictly increasing, strictly concave, and continuously differentiable.

[6] I assume $0 \leq K_{t+1} \leq \overline{K}$ to ensure the payoff function is bounded.

2.2 Monopolistic Competition with Heterogeneous Firms

Heterogeneous firms decide how much to produce using two inputs–capital and labor–under imperfect information about future productivity considering the market structure.

2.2.1 Technology

A continuum of intermediate-good producers exists with a fixed measure of 1. Each intermediate-good producer is indexed by i in a Cobb-Douglas production function:

$$Y_{it} = K_{it}^{\alpha_1} L_{it}^{\alpha_2},\ \alpha_1 + \alpha_2 = 1, \tag{3}$$

where Y_{it} is an intermediate good of intermediate-good producer i at date t, K_{it} is the capital stock of intermediate-good producer i at date t, L_{it} is the labor of intermediate-good producer i at date t, and α_j is the output elasticity of the inputs. Intermediate-good producers have a value-added production function.[7] In other words, their production functions consist of only two inputs–capital and labor–and not an intermediate input.

2.2.2 Market Structure and Revenue

I model the market structure in the economy as monopolistic competition with heterogeneous firms by using a standard constant elasticity substitution (CES) aggregator for a final good:

$$Y_t = \left(\int A_{it} Y_{it}^{\frac{\theta-1}{\theta}} di\right)^{\frac{\theta}{\theta-1}},\ \theta \in (1, \infty), \tag{4}$$

where Y_t is a final good at date t, A_{it} is the productivity of intermediate-good producer i at date t, and θ is the elasticity of substitution (e.g., Dixit and Stiglitz, 1977; Melitz, 2003; Hsieh and Klenow, 2009).[8] I use "a firm" and "an intermediate-good producer" interchangeably. A

[7] I assume the same production function for all intermediate-good producers. Value-added production functions are frequently used because a Leontief gross production function in an intermediate input justifies a value-added production function (e.g., Ackerberg et al., 2015). Another justification of this assumption is that the GDP can be calculated by adding up the value-added part of each agent in the economy.

[8] Appendix A.1 explains a CES aggregator.

final good is viewed as the composite good for a representative household's consumption (e.g., Melitz, 2003). Therefore, I describe a final-good producer's decision from a representative household's perspective. A log form of productivity, a_{it}, follows an AR(1) model:

$$a_{it} = (1-\rho)\overline{a} + \rho a_{it-1} + \epsilon_{it},\ \epsilon_{it} \sim N(0, \sigma^2),\ \sigma_a^2 \equiv \frac{1}{1-\rho^2}\sigma^2,$$

where ρ is a persistence parameter and ϵ_{it} is the i.i.d. innovation of firm i's productivity at date t. A lower-case letter indicates a log form of an upper-case letter in the model if not explicitly stated otherwise: for example, a_{it} is $logA_{it}$.

Under the market structure, the product market competition is summarized as each firm facing a downward-sloping demand function because each firm makes a differentiated product:

$$P_{it} = A_{it}(\frac{Y_{it}}{Y_t})^{-\frac{1}{\theta}}. \tag{5}$$

The slope of a demand function reflects the degree of competition in the product market. For example, the higher elasticity of substitution, θ, means a representative household is more sensitive to changes in prices of differentiated products. In this sense, the revenue of a firm is expressed as follows[9]:

$$P_{it}Y_{it} = Y_t^{\frac{1}{\theta}} A_{it} K_{it}^{\hat{\alpha_1}} L_{it}^{\hat{\alpha_2}},\ \hat{\alpha_j} \equiv (1-\frac{1}{\theta})\alpha_j,\ \hat{\alpha} \equiv \hat{\alpha_1} + \hat{\alpha_2}. \tag{6}$$

Productivity in the model is closely related to accounting numbers, such as revenues and profits. Equation (5) indicates productivity, as a demand shifter, represents how much a representative household is willing to pay for an intermediate good. Therefore, productivity affects a firm's revenues directly in equation (6). Alternatively defining productivity as physical productivity, $Y_{it} = A_{it}K_{it}^{\alpha_1}L_{it}^{\alpha_2}$, will not change the implications of the model because A_{it} will be the only variation across firms, which determines their revenues and

[9] I define $\hat{\alpha_j}$, instead of α_j, for simplicity in subsequent sections.

profits, in both specifications. Defining A_{it} as the only variation across firms hinders me from investigating the sources of productivity, such as consumers' preferences and physical productivity.[10] However, as long as a firm makes production decisions while maximizing its profits regardless of the sources of productivity, an understanding of accounting numbers is important for production decisions.

2.2.3 Input Choices with Imperfect Information

Considering the market structure, a firm makes input choices under imperfect information about future productivity, suggesting the conditional expectation of future productivity, $E_{it-1}[A_{it}]$, affects firms' capital and labor investment decisions. Through $E_{it-1}[A_{it}]$, accrual accounting systems are linked to firms' production decisions. I assume a firm's manager makes production decisions while maximizing the firm's profits. Unless the distinction between a firm and a manager is important, I use "a firm". A firm's problem is expressed by

$$\begin{aligned} & \max_{K_{it},L_{it}} E_{it-1}[P_{it}Y_{it} - W_tL_{it} - R_tK_{it}] \\ = \quad & \max_{K_{it},L_{it}} Y_t^{\frac{1}{\theta}} E_{it-1}[A_{it}]K_{it}^{\hat{\alpha_1}}L_{it}^{\hat{\alpha_2}} - W_tL_{it} - R_tK_{it}, \end{aligned} \tag{7}$$

where $E_{it}[\cdot]$ is the expectation conditional on all of the information available to the manager of firm i at the beginning of date t. The main friction is a manager's imperfect information about future productivity: the other variables are choice variables or aggregate variables that are deterministic in a steady-state equilibrium. The profit-maximization assumption only with informational frictions allows me to focus on the informational role of accrual accounting in firms' production decisions. However, section 5.2 discusses how the relaxation of this assumption affects the implications of my paper. The timeline is summarized in

[10] Foster et al. (2008) discuss the difference between revenue and physical productivity in detail.

Figure 2.

[Figure 2 about here.]

A firm's optimal capital investment decision is expressed by

$$K_{it} = \frac{E_{it-1}[A_{it}]^{\theta}}{\int E_{it-1}[A_{it}]^{\theta} di} \int K_{it} di. \tag{8}$$

In equation (8), a firm considers average capital, $\int K_{it} di$, and average expected productivity, $\int E_{it-1}[A_{it}]^{\theta} di$, to determine the level of its capital investment.[11] The optimal capital investment decision implies a firm expecting higher productivity invests more in capital than a firm expecting lower productivity, because given the same input choices, potentially high-productivity firms perceive higher marginal benefits with respect to capital. The first-order conditions for a firm's profit maximization with respect to capital and labor imply the marginal benefit of capital and labor should be the same as the input prices, R_t and W_t:

$$\hat{\alpha_1} K_{it}^{\hat{\alpha_1}-1} Y_t^{\frac{1}{\theta}} E_{it-1}[A_{it}] L_{it}^{\hat{\alpha_2}} = R_t, \; \hat{\alpha_2} L_{it}^{\hat{\alpha_2}-1} Y_t^{\frac{1}{\theta}} E_{it-1}[A_{it}] K_{it}^{\hat{\alpha_1}} = W_t. \tag{9}$$

This relation between expected productivity and investment becomes stronger as the elasticity of substitution, θ, becomes larger. I focus on a firm's optimal capital investment decision because I use investment as a key variable for estimation.[12]

2.3 Information Structure

Accounting systems affect firms' production decisions by shaping managers' information about future productivity. Accounting systems influence managers' information, because informational frictions for managers arise not only because of uncertainty about a change in

[11] Average capital is the same as aggregate capital because I assume a continuum of firms with a fixed measure of 1.

[12] Appendix A.2 and David et al. (2016) explain how to derive a firm's optimal-investment decision. I solve an optimal-decision problem with respect to labor in Appendix A.5.

future productivity ($A_{it} - A_{it-1}$), but also because of uncertainty about current productivity (A_{it-1}). The conditional expectation of future productivity can be expressed by

$$E_{it-1}[A_{it}] = E_{it-1}[A_{it} - A_{it-1}] + E_{it-1}[A_{it-1}].$$

Accrual accounting systems help managers improve the conditional expectation of future productivity through $E_{it-1}[A_{it-1}]$. This information structure is the key distinction between my paper and David et al. (2016), who focus exclusively on uncertainty about a change in future productivity, assuming $E_{t-1}[A_{it-1}] = A_{it-1}$. Prior studies suggest how accrual accounting systems influence a manager's information sets and, in turn, firms' investment decisions. Dichev et al. (2013) show 80% of surveyed CFOs answer that managers use externally reported accounting earnings to make internal decisions partly because internal accounting systems are closely linked to external accounting systems. Hemmer and Labro (2015) demonstrate theoretically that the properties of accounting earnings are consistent with the argument that managers use financial reports for internal decision making. Shroff (2016) provides suggestive evidence that if changes in GAAP require managers to collect and process additional information, the changes in GAAP affect corporate investment by influencing managers' information sets.

2.3.1 Accounting Systems

Accrual accounting systems aim to capture current firm performance better than cash accounting systems, but they are not perfect. Prior accounting studies demonstrate accruals are informative for understanding businesses, but accrual accounting systems still have errors.[13] Dechow (1994) finds an accrual accounting system provides accounting earnings that are more correlated with stock returns than cash flow is. Dechow and Dichev (2002) demonstrate an accrual accounting system might provide an imperfect measure of firm performance

[13]For example, see Dechow et al. (1998), Richardson et al. (2005), Barth et al. (2016), and Bushman et al. (2016).

because accruals might contain estimation errors due to future consequences of current transactions. However, Dechow and Dichev (2002) do not explicitly model true earnings as well as cash flow and accounting earnings, because they focus on the role of accruals in recognizing cash flow in different periods without explicitly considering the linkage between cash flow and true earnings.

I build on Nikolaev's (2016) accrual accounting model because the author models an accrual accounting system that improves an imperfect measure of firm performance by explicitly introducing true earnings into accrual accounting systems. In addition, Nikolaev (2016) proposes an estimation method for evaluating the quality of accounting earnings to overcome a fundamental identification issue in accounting: separating the process of fundamentals from the quality of different information sources. I extend this concept of an accrual accounting system by specifying the true earnings as an outcome of firms' investment decisions, based on a Cobb-Douglas production function. This linkage allows me to study the relation between accrual accounting systems and firms' input choices.

Cash flow and accounting earnings are both defined as imperfect measures of performance and productivity. Π_{it} is true earnings, which are determined by true productivity but are not observable by managers:

$$\Pi_{it} = \underbrace{Y_t^{\frac{1}{\theta}} A_{it} K_{it}^{\hat{\alpha_1}} L_{it}^{\hat{\alpha_2}}}_{Revenue} - (\underbrace{W_t L_{it} + R_t K_{it}}_{Cost}). \tag{10}$$

Cash flow, CF_{it}, is measured based on cash payments and cash collections, but cash flow does not reflect the true fundamentals, because current transactions frequently involve future consequences, suggesting current cash payments and cash collections might not be related to current transactions:

$$
\begin{aligned}
CF_{it} &= \Pi_{it} + \epsilon^{c}_{it} \\
&= \Pi_{it} + \underbrace{(A^{ac}_{it} - 1) Y_t^{\frac{1}{\theta}} A_{it} K_{it}^{\hat{\alpha_1}} L_{it}^{\hat{\alpha_2}}}_{\epsilon^{c}_{it}} \\
&= Y_t^{\frac{1}{\theta}} \underbrace{A_{it} A^{ac}_{it}}_{A^{c}_{it}} K_{it}^{\hat{\alpha_1}} L_{it}^{\hat{\alpha_2}} - W_t L_{it} - R_t K_{it}, \qquad (11)
\end{aligned}
$$

where ϵ^{c}_{it} is a timing error in cash flow, A^{ac}_{it} is a timing error in cash-flow-based productivity, and A^{c}_{it} is cash-flow-based productivity. By defining a timing error as a deviation from true revenues, cash accounting systems provide both an imperfect measure of firm performance, CF_{it}, and an imperfect measure of productivity, A^{c}_{it}. I assume a^{ac}_{it} is an i.i.d. random variable and follows $N(-\frac{\sigma^2_{ac}}{2}, \sigma^2_{ac})$ so that all measures of productivity adhere to a log-normal distribution, and $E[A_{it} A^{ac}_{it} | A_{it}] = A_{it}$. Accrual accounting systems estimate future consequences and record accruals to better measure firm performance, but this estimation is not perfect, implying accounting earnings contain estimation errors:

$$
\begin{aligned}
AE_{it} &= CF_{it} + AC_{it} \\
&= \Pi_{it} + \epsilon^{e}_{it} \\
&= \Pi_{it} + \underbrace{(A^{ae}_{it} - 1) Y_t^{\frac{1}{\theta}} A_{it} K_{it}^{\hat{\alpha_1}} L_{it}^{\hat{\alpha_2}}}_{\epsilon^{e}_{it}} \\
&= Y_t^{\frac{1}{\theta}} \underbrace{A_{it} A^{ae}_{it}}_{A^{e}_{it}} K_{it}^{\hat{\alpha_1}} L_{it}^{\hat{\alpha_2}} - W_t L_{it} - R_t K_{it}, \qquad (12)
\end{aligned}
$$

where AE_{it} is the accounting earnings of firm i at date t, AC_{it} is the accruals of firm i at date t, ϵ^{e}_{it} is an estimation error in accounting earnings, A^{ae}_{it} is an estimation error in accounting-earnings-based productivity, and A^{e}_{it} is accounting-earnings-based productivity. I assume a^{ae}_{it} is an i.i.d. random variable and follows $N(-\frac{\sigma^2_{ae}}{2}, \sigma^2_{ae})$. Estimation errors exist

because accrual accounting systems require making assumptions, estimates, and judgments, which might not be perfect.

I express cash flow and accounting earnings differently to point out the key features of accrual accounting systems in the model:

$$AC_{it} \quad = \quad \epsilon^{e}_{it} - \epsilon^{c}_{it}.$$

First, an accrual contains both a timing error in cash flow and an estimation error in accounting earnings. Therefore, as the size of the timing errors, σ^2_{ac}, becomes larger relative to the size of the estimation errors, σ^2_{ae}, accrual accounting systems do more to improve the measurement of fundamentals. Second, accrual accounting systems aim to fix a timing error in cash flow with a minimal estimation error in accounting earnings by using accruals. If accrual accounting systems achieve this goal effectively, estimation errors are unlikely to be systematically correlated with timing errors and fundamentals. However, the imperfection of accrual accounting systems, managers' income-smoothing incentives, and conservatism lead to this assumption being violated. Thus, section 5.1 discusses how the relaxation of this assumption affects the implications of my paper. Finally, the expected value of the cash flow and accounting earnings is the same as the true earnings, because the expected value of noise is zero:[14]

$$E[\epsilon^{c}_{it}] = E[\epsilon^{e}_{it}] = 0,\ E[CF_{it}|A_{it}] = E[AE_{it}|A_{it}] = \Pi_{it}.$$

[14]A deeper understanding of this statistical characterization of accrual accounting systems is useful for interpreting the counterfactual analyses in section 3.4. My paper focuses on the role of accrual accounting systems as a benchmark for cash accounting systems. Even though accruals are used to match the benefits and costs of business transactions, accruals are also measured using additional information regarding cash collections and payments. The additional details are transaction- and event-related information, such as product delivery, contractual features, and credit worthiness (e.g., Ijiri, 1975; Leuz, 1998; Gao, 2013). In contrast to cash accounting systems, the distinction and value of accrual accounting systems in my model potentially comes from facilitating and incorporating this transaction- and event-related information. In this sense, the counterfactual analyses in section 3.4 incorporate this supporting information into the accrual accounting information, and I use "accrual accounting information" and "accrual accounting systems" interchangeably in this paper.

2.3.2 Managers' Information

Managers have three sources of information from which to form an expectation regarding future productivity: cash flow, accounting earnings, and all other information.

$$a_{it}|\mathbb{I}_{it-1} \sim N(E_{it-1}[a_{it}], V_{it-1}[a_{it}]), \tag{13}$$

where $\mathbb{I}_{it-1} = \{a^c_{it-1}, \cdots, a^c_{i0}, a^e_{it-1}, \cdots, a^e_{i0}, s_{it-1}, \cdots, s_{i0}\}$ is a manager's information set. The conditional variance of future productivity, $V_{it-1}[a_{it}]$, defines informational frictions for managers. A large conditional variance of future productivity means a manager is highly uncertain about the firm's future productivity. The stationary expectation process implies $V_{it-1}[a_{it}] = \overline{V}$. The quality of information is defined as the inverse of variance of noise: for example, $\frac{1}{\sigma^2_{ae}}$. Appendix A.3 explains how managers form $E_{it-1}[a_{it}]$ with only imperfect measures of fundamentals by using a Kalman filter.

Considering all other information is important to study the incremental impact of accrual accounting on informational frictions. All other information, s_{it}, is another signal containing information about future productivity shocks:

$$s_{it} = a_{it+1} + a^s_{it},$$

where a^s_{it} is noise and follows an i.i.d. normal distribution as the mean of zero and variance of σ^2_s.[15] In the model, I acknowledge managers use information other than accounting information for decision making.

Accrual accounting systems can reduce the conditional variance of future productivity, $\overline{V}$, by improving an imperfect measure of current productivity. The relation between accrual accounting information and $\overline{V}$ is defined by

[15] All other information can contain information in stock prices.

$$\overline{V} = \rho^2(\frac{\sigma_s^2}{\sigma^2+\sigma_s^2})^2 \frac{\overline{V}\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2)}{\overline{V}(\sigma_{ae}^2+\sigma_{ac}^2)(\sigma^2+\sigma_s^2)+\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2+\rho^2\overline{V})} + \frac{\sigma^2\sigma_s^2}{\sigma^2+\sigma_s^2}. \quad (14)$$

Using the implicit function theorem, I verify $\frac{d\overline{V}}{d\sigma_{ae}^2} \geq 0$. The quality of accounting earnings decreases the conditional variance of future productivity, because managers understand their current businesses better with accounting earnings than without accounting earnings. The quality of the other information sources reduces the importance of accrual accounting systems, because managers rely on different information sources for input choices depending on their relative quality. Appendix A.3 explains this relation.

2.4 Equilibrium

Through a general equilibrium analysis, I illustrate how the reduction in informational frictions, $\overline{V}$, due to accrual accounting systems affects aggregate productivity and output. A steady-state equilibrium in this economy consists of a wage rate (W), a capital rental rate (R), an intermediate-good price and quantity ($\{P_{it}, Y_{it}\}_{i\in I}$), optimal input choices ($\{K_{it}, L_{it}\}_{i\in I}$), and aggregate levels of output (Y), capital (K), labor (L), and consumption (C) such that:

1. A representative household's optimization implies $R = \frac{1}{\beta} - 1 + \delta$, where β is the discount factor and δ is the depreciation rate;

2. Given R and W, an intermediate-good producer maximizes its profits by choosing $\{P_{it}, Y_{it}\}$, K_{it}, and L_{it};

3. All markets are cleared: $C + \delta K = Y = \int P_{it}Y_{it}di$, $\int K_{it}di = K$, and $\int L_{it}di = L$.

2.4.1 Aggregate Productivity

The product-market-clearing condition characterizes aggregate productivity and implies:

$$Y = \int P_{it} Y_{it} di = K^{\hat{\alpha_1}} L^{\hat{\alpha_2}} Y^{\frac{1}{\theta}} \frac{\int A_{it} (E_{it-1}[A_{it}])^{\frac{\hat{\alpha}}{1-\hat{\alpha}}} di}{(\int E_{it-1}[A_{it}]^{\frac{1}{1-\hat{\alpha}}} di)^{\hat{\alpha}}}.$$

Aggregate output, Y, is expressed in a log form by

$$y = \frac{1}{\theta} y + \hat{\alpha_1} k + \hat{\alpha_2} l + log \int A_{it} (E_{it-1}[A_{it}])^{\frac{\hat{\alpha}}{1-\hat{\alpha}}} di - \hat{\alpha} log \int (E_{it-1}[A_{it}])^{\frac{1}{1-\hat{\alpha}}} di.$$

The last two terms on the right-hand side of the above equation can be simplified as follows[16]:

$$\begin{pmatrix} a_{it} \\ E_{it-1}[a_{it}] \end{pmatrix} \sim N \left(\begin{bmatrix} \overline{a} \\ \overline{a} \end{bmatrix}, \begin{bmatrix} \sigma_a^2 & \sigma_a^2 - \overline{V} \\ \sigma_a^2 - \overline{V} & \sigma_a^2 - \overline{V} \end{bmatrix} \right),$$

$$y = \alpha_1 k + \alpha_2 l + \underbrace{\frac{\theta}{\theta - 1} \overline{a} + \frac{1}{2} (\frac{\theta}{\theta - 1}) \frac{\sigma_a^2}{1 - \hat{\alpha}} - \frac{1}{2} \theta \overline{V}}_{a}. \tag{15}$$

In equation (15), aggregate productivity, a, is negatively related to the conditional variance of future productivity, $\overline{V}$. Most importantly, this firm-level uncertainty measure, $\overline{V}$, is a summary measure of informational frictions in an economy. In other words, if firms have imprecise information with regard to their productivity, their (ex-post) inefficient investment decisions will induce resource misallocation and, in turn, reduce aggregate productivity. This relation is stronger when the product market is more competitive. In equation (15), aggregate output is not determined yet, because the aggregate capital is interrelated with the aggregate output.

[16] Appendix A.4 briefly explains equation (15). Online Appendix I.A and I.B of David et al. (2016) explain equation (15) in detail.

2.4.2 Rental Rate of Capital and Wage Rate

To fully characterize aggregate output and capital, I first characterize the rental rate of capital and wage rate. In a steady state, the Euler equation for a representative household implies:[17]

$$1 = \beta(1 - \delta + R). \tag{16}$$

A representative household distributes its income to aggregate consumption and aggregate investment while considering the capital rental rate, R, the discount factor, β, and the depreciation rate, δ. In a steady state, the functional form of the utility function does not affect the rental rate for capital, R, because the marginal utility of consumption today is the same as the marginal utility of consumption tomorrow, due to constant consumption.

The wage rate can be expressed as a function of aggregate output given parameter values in a steady-state equilibrium:

$$w = \frac{1}{1-\hat{\alpha_1}} log\hat{\alpha_2}(\frac{\hat{\alpha_1}}{\hat{\alpha_2}R})^{\hat{\alpha_1}} L^{\hat{\alpha}-1} + \frac{1}{1-\hat{\alpha_1}}(\overline{a} + \frac{1}{2}\frac{\sigma_a^2 - \overline{V}}{1-\hat{\alpha}} + \frac{1}{2}\overline{V} + \frac{1}{\theta}y). \tag{17}$$

In equation (17), a steady-state equilibrium wage, w, is positively related to aggregate output because the demand for labor determines an equilibrium wage, given the aggregate labor is inelastically supplied.[18]

2.4.3 Aggregate Capital and Output

To characterize aggregate capital, the relation between capital and labor is expressed at the aggregate level by

[17] A steady-state equilibrium means the aggregate variables are stable, suggesting the left-hand side of equation (16) is that $\frac{u'(C)}{u'(C)} = 1$. The Euler equation and transversality condition are the necessary and sufficient conditions for a representative household's optimal decisions (Acemoglu, 2009, p.212). In a steady state, the transversality condition is readily satisfied: $\lim_{t\to\infty} \beta^t(1 - \delta + R)u'(C)K = 0$.

[18] Appendix A.5 briefly describes how to derive equation (17). Online Appendix I.A and I.B of David et al. (2016) explain equation (17) in detail.

$$K = \frac{\hat{\alpha_1} L}{\hat{\alpha_2} R} W. \tag{18}$$

Then, a log change in capital is the same as a log change in wages with respect to informational frictions:

$$\frac{dk}{d\overline{\overline{V}}} = \frac{dw}{d\overline{\overline{V}}}. \tag{19}$$

Equation (19) helps characterize the relation between aggregate output and informational frictions:

$$\begin{aligned} \frac{dy}{d\overline{\overline{V}}} &= \alpha_1 (\frac{dk}{d\overline{\overline{V}}}) - \frac{1}{2}\theta \\ &= -\frac{1}{2}\theta \frac{1}{1-\alpha_1}. \end{aligned} \tag{20}$$

The above equation indicates informational frictions reduce aggregate output. Capital share, α_1, strengthens the negative relation between informational frictions and aggregate output, because this economy accumulates less aggregate capital if aggregate productivity is lower. Equations (15) and (20) are the same as equations (10) and (13) in David et al. (2016).

2.5 Equilibrium Analysis

The model demonstrates the quality of accrual accounting systems improves firms' input choices and, in turn, facilitates resource allocation across firms through the input and product markets. This effect results in increased aggregate productivity and output, as in equations (15) and (20). In the general equilibrium model, the product and input markets are cleared while multiple agents, including heterogeneous firms and a representative household, maximize their profits and utility under budget constraints. Each individual firm makes more informed investment decisions if accrual accounting systems improve managers' infor-

mation about future productivity by providing a better measure of fundamentals than cash accounting systems, as in equation (14).

Individual firms' input decisions add up to aggregate effects as follows. First, firms access the same capital and labor market to purchase inputs, generally implying one firm's more efficient input choice could generate better resource allocation across firms. If one firm is willing to purchase more resources at the same price of resources than another firm due to its high expected productivity, resources are allocated from the potentially low-productivity firm to the potentially high-productivity firm through prices in the input markets. This resource-allocation process becomes more efficient as the manager's expectation becomes more precise. Second, the product market competition determines how strongly firms' input choices respond to their understanding of future productivity. Potentially high-productivity firms are going to take more market share from potentially low-productivity firms as a representative household substitutes high-productivity goods for low-productivity goods more aggressively. Finally, a representative household provides aggregate capital depending on aggregate productivity, which is determined by both the distribution of productivity and resource allocation across firms in equation (20). Therefore, this economy accumulates more aggregate capital as the aggregate productivity becomes higher.

3 Data and Identification

I analyze the United States, China, and India, using Compustat and Compustat Global for financial data. I identify the parameter values in the model that govern informational frictions by using two accounting-property assumptions and one investment-optimality assumption. I estimate the parameter values in the model by using the SMM. I conduct counterfactual analyses about aggregate productivity and output as a function of informational frictions, $\overline{V}$, with estimated parameter values.

3.1 Data

I use Compustat and Compustat Global to obtain financial data for public firms in three different countries in 2012.[19] I choose the United States, China, and India for comparison with prior studies (Hsieh and Klenow, 2009; David et al., 2016). In addition, China and India could be good benchmarks for developing countries, as compared to the United States. The sample firms are public firms listed on major exchanges. In particular, I exclude firms in the United States listed in over-the-counter (OTC) markets, because firms in such markets might face a different information environment than listed firms on major exchanges, such as the NYSE, AMEX, or NASDAQ, face (Bushee and Leuz, 2005; Ang et al., 2013).[20] I demean variables to control for a year fixed effect and, then, exclude the top and bottom 1% observations for variables.

Productivity, A_{it}, and investment, I_{it}, are two key variables in this paper. To measure productivity based on cash flow and accounting earnings, I have to measure accruals first. To consistently measure accruals across countries, I use a balance-sheet approach following Leuz et al. (2003):

$$AC_{it} = (\Delta CA_{it} - \Delta Cash_{it}) - (\Delta CL_{it} - \Delta STD_{it} - \Delta TP_{it}) - Dep_{it},$$

where ΔCA_{it}= change in total current assets, $\Delta Cash_{it}$=change in cash/cash equivalents, ΔCL_{it}= change in total current liabilities, ΔSTD_{it}= change in short-term debt included in current liabilities, ΔTP_{it}= change in income taxes payable, and Dep_{it}= depreciation and amortization expense for firm i in year t. However, this methodology could suffer from

[19] This paper uses financial data from 2010 to 2013 to construct variables for the cross-sectional analysis in 2012. Private firms might be considered potential sample firms even though their financial data are not readily available (e.g., Minnis, 2011). One concern is that private firms and public firms face different information environments, suggesting assuming the same parameter values for two different groups of firms might be problematic. Furthermore, when examining the cross-country variation in the information environment, the endogenous choice of being public in different countries might matter.

[20] All of the Indian firms in the sample are listed in either the Bombay Stock Exchange or the National Stock Exchange of India, and the Chinese firms are mostly listed in the Hong Kong, Shanghai, or Shenzhen Stock Exchanges.

a measurement problem because large corporate events, such as mergers and acquisitions, generate large accruals that are less related to the difference between a cash accounting system and an accrual accounting system (Hribar and Collins, 2002). To mitigate this concern, I verify the empirical moments in this paper using a balance-sheet approach are similar to the empirical moments using a cash-flow-statement approach in the United States.

Cash flow and accounting earnings are transformed into imperfect measures of productivity using equations (11) and (12). Revenues in equations (11) and (12) are value added, and not traditional accounting revenues, because the model considers only capital and labor as inputs. The value added for accounting earnings is calculated as 50% of sales to exclude costs of intermediate inputs from sales.[21] The value added for cash flow is measured by the following:

$$VA^c_{it} = VA^e_{it} - AC_{it},$$

where VA^c_{it} and VA^e_{it} are the value added for cash flow and accounting earnings, respectively. I subtract the total accruals from the value added for accounting earnings to calculate the value added for cash flow, because unearned revenues, accounts receivables, and inventories directly affect the value added. However, this specification prevents me from investigating the uncertainty about revenues and costs separately. Imperfect measures of productivity are calculated by using the following equation[22]:

$$a^c_{it} + Constant = va^c_{it} - \hat{\alpha} k_{it},\ a^e_{it} + Constant = va^e_{it} - \hat{\alpha} k_{it}. \tag{21}$$

I use gross property, plant and equipment (PP&E) to measure capital stock, K_{it} (e.g., Peters and Taylor, 2016).[23] Thus, (net) investment is calculated as a difference in capital stock,

[21] The national income and product accounts (NIPA) indicates, for an average firm, value added accounts for 50%-55% of sales. Considering a difference in the ratio of value added to sales across industries does not widely change the empirical moments in the United States.

[22] See equation (25).

[23] Capital stock could be measured as net PP&E (e.g., Whited, 1992). Then, investment could be measured by capital expenditure (e.g., Richardson, 2006). These different measures do not widely change the empirical

$i_{it} = k_{it} - k_{it-1}$.

3.2 Identification

This paper faces two identification challenges. Only having noisy measures of productivity makes separately identifying the process of productivity and the variance of noise in cash flow and accounting earnings difficult. Identifying the quality of all other information managers hold is another challenge because all other information is unobservable. I identify the parameter values that govern the process of firms' productivity and the quality of different information sources by using accounting-properties and investment-optimality assumptions: $\Psi = \{\rho, \sigma^2, \sigma^2_{ac}, \sigma^2_{ae}, \sigma^2_s\}$.

Accounting properties provide identification assumptions for the volatility of firms' productivity, σ^2_a, and the quality of cash flow, σ^2_{ac}, and accounting earnings, σ^2_{ae}, according to Nikolaev (2016). The volatility of firms' productivity, σ^2_a, is a function of the persistence of firms' productivity, ρ, and the volatility of innovation in firms' productivity, σ^2. I assume timing errors in cash flow and estimation errors in accounting earnings are uncorrelated with firms' productivity. For stable firms, timing errors in cash flow are unlikely to be systematically positive or negative when firms' productivity increases, because the mismatches of cash collections and payments with the timing of business transactions might not always move in the same direction as firms' productivity moves. Estimation errors in accounting earnings are unlikely to be systematically related to firms' productivity, because accrual accounting systems aim to measure the consequences of current business transactions efficiently.[24] In addition, I assume noise in cash flow and accounting earnings are uncorrelated with each other, because accrual accounting systems aim to provide a less noisy measure of firms' productivity by removing an expected part of noise in cash flow from accounting earnings as in equation (12). These accounting-property assumptions provide three moment conditions to

moments in this paper.

[24]However, growth firms, managers' income-smoothing incentives, and conservatism lead to the violation of these identification assumptions. I evaluate the estimated impact of accrual accounting on aggregate productivity while relaxing these assumptions in section 5.1.

identify σ_a^2, σ_{ac}^2, and σ_{ae}^2:

$$cov(a_{it}^c, a_{it}^e) = cov(a_{it} + a_{it}^{ac}, a_{it} + a_{it}^{ae}) = var(a_{it}) = \sigma_a^2,$$

$$var(a_{it}^c) = var(a_{it} + a_{it}^{ac}) = var(a_{it}) + var(a_{it}^{ac}) = \sigma_a^2 + \sigma_{ac}^2,$$

$$var(a_{it}^e) = var(a_{it} + a_{it}^{ae}) = var(a_{it}) + var(a_{it}^{ae}) = \sigma_a^2 + \sigma_{ae}^2.$$

An investment-optimality condition provides identification assumptions for the quality of unobservable information, σ_s^2, which is all other information managers hold, s_{it}. If firms efficiently use information to make input choices, the variance of capital stock reveals the quality of all other information managers hold given the quality of cash flow and accounting earnings is already identified:

$$var(k_{it}) = var(\frac{1}{1-\hat{\alpha}} E_{it}[a_{it}]) = (\frac{1}{1-\hat{\alpha}})^2 (\sigma_a^2 - \overline{V}). \tag{22}$$

In other words, firms make more volatile investment decisions as the quality of all other information they have about future productivity improves, given that the quality of cash flow and accounting earnings is fixed. For example, the volatility of investment is zero if firms have no information about future productivity. To consider the existence of other frictions correlated with productivity, I choose the correlation between capital stock and productivity–instead of the variance of capital stock–as a key moment condition following David et al. (2016).

$$corr(k_{it}, a_{it-1}^c) = \frac{\rho \sigma_a^2}{\sqrt{\sigma_a^2 - \overline{V}} \sqrt{\sigma_a^2 + \sigma_{ac}^2}},$$

$$corr(k_{it}, a^e_{it-1}) \quad = \quad \frac{\rho\sigma_a^2}{\sqrt{\sigma_a^2 - \overline{V}}\sqrt{\sigma_a^2 + \sigma_{ae}^2}}.$$

For example, if a firm overreacts to productivity due to other frictions holding all else constant, the variance of capital stock increases. However, the correlation between capital stock and productivity does not increase because the covariance between capital stock and productivity also increases. Section 5.2 explains this moment condition in detail.

Table 1 summarizes which moments help identify specific parameter values. The moment conditions derived by the model's assumptions are an identification strategy in my paper.

[Table 1 about here.]

I use a difference specification to deal with the firm fixed effects due to firms' different production functions and firm-specific investment policies. In particular, I use investment growth because investment is sticky (e.g., Morck et al., 1990). I simulate the relation between moments and parameter values in Figure 3 to show moments are informative to identify parameters, because I do not derive an exact expression for moments, due to their complexity. Figure 3 indicates moments have monotonic relations with parameter values.

[Figure 3 about here.]

3.3 Simulated Method of Moments

I use the simulated method of moments (SMM) to estimate the parameter values for evaluating the role of accrual accounting information in shaping informational frictions (McFadden, 1989). The intuition is that I search for the parameter values that statistically satisfy the moment conditions derived from the model's assumptions (Strebulaev and Whited, 2012). I estimate parameter values $\Psi = \{\rho, \sigma^2, \sigma_{ac}^2, \sigma_{ae}^2, \sigma_s^2\}$ by assuming $\theta = 6$ and $\alpha_1 = 0.33$. In the literature, the elasticity of substitution, θ, ranges from 3 to 10 (Broda and Weinstein, 2006;

Hsieh and Klenow, 2009). I assume the output elasticity of capital, α_1, is 0.33 in all three countries, because Gollin (2002) argues α_1 does not widely vary, ranging from 0.2 to 0.35 across countries. Appendix B.1 explains this estimation method in detail.

3.4 Counterfactual Analysis

I conduct two counterfactual analyses with the estimated parameters. First, I estimate the impact of accrual accounting systems on aggregate productivity by comparing them with a hypothetical economy without accrual accounting systems. This exercise is a thought experiment that asks what firms' input choices would be and what resource allocation across firms would be if accrual accounting systems did not exist. A manager's information sets would have only cash flow and all other information with which to make input choices: a_{it}^c and s_{it}. This counterfactual experiment is viewed as changing various features in an economy at once to alter the quality of accounting earnings, which affects resource allocation and aggregate productivity.

Second, I estimate the potential gains for China and India if these countries had the same quality of accrual accounting systems as the United States. The counterfactual value of the quality of accounting earnings for China and India is the estimated value of the quality of accounting earnings in the United States, $\sigma^2_{ae,US}$. Keeping the process of productivity in China and India intact, this counterfactual analysis examines how changing the quality of accrual accounting information would affect firms' input choices and, eventually, resource allocation across firms in these countries. This hypothetical exercise is delicate because even if Chinese and Indian firms had the same quality of accrual accounting information as U.S. firms, Chinese and Indian firms might not disclose the information. Therefore, the estimated gains from this exercise have to be adjusted downward if the assumption that all other information a manager holds does not contain additional information about its current productivity with regard to cash flow and accounting earnings in China and India is violated.

One benefit of these exercises, which are different from other research settings, is that

these counterfactual analyses evaluate the role of overall accrual accounting systems that are determined by the interaction of various factors, including managerial skills, internal information systems, accounting rules, and internal and external auditors. These counterfactual exercises focus on aggregate resource allocation as the mechanism through which accrual accounting systems influence aggregate productivity and output in the context of the model. However, these quantitative exercises need to be carefully interpreted because of three reasons. First, if a change in regulations affects not only accrual accounting systems but also other systems, the estimated result in my paper is only partly informative for the change in regulations. Second, a change in regulations is likely to have different effects on accrual accounting systems and, eventually, on resource allocation in different countries due to the complementarity among countries' institutions (e.g., Leuz, 2010). Finally, if accrual accounting systems influence aggregate productivity through various channels, including informational externalities, the counterfactual analysis in my paper is not informative for the mechanisms other than the direct impact of accrual accounting systems on firms' production decisions.

The counterfactual analysis proceeds in two steps. First, I calculate a hypothetical conditional variance of future productivity, $\tilde{V}$, using equation (14) based on a counterfactual value of the quality of accounting earnings and the estimated values of the other parameters. Second, I exploit equations (15) and (20) to estimate the impact of accrual accounting systems on aggregate productivity and output by using the difference between $\overline{V}$ and $\tilde{V}$.

4 Quantitative Analysis

4.1 Descriptive Statistics

Table 2 shows the descriptive statistics.[25] The United States has the largest average firm size. The average accruals are negative in all three countries. The volatility of cash flow, accounting earnings, and investment activities is higher in China and India than in the United States. However, differences in the volatility of timing and estimation errors, rather than differences in the volatility of productivity, might be driving part of this difference.

[Table 2 about here.]

4.2 Empirical Moments and Parameter Values

Table 3 demonstrates the empirical moments are close to the simulated moments in the United States, China, and India. The model-fit test does not reject the null hypothesis that the moment conditions derived by the model's assumptions are consistent with the data-generating process at a 1% significance level. P-values for US and Indian data are high, but a low p-value of 1.6% for Chinese data indicates the possibility that the model assumptions might not be a good approximation for Chinese data (e.g., Wong, 2016).

[Table 3 about here.]

Table 4 is consistent with accrual accounting systems improving managers' information about future productivity by providing managers with a better measure of fundamentals than cash accounting systems. The standard deviations can be interpreted as percentage deviations, because the underlying variables are in a log form. The standard deviation of timing errors in cash-flow-based productivity, σ_{ac}, is more than twice as large as the standard deviation of estimation errors in accounting-earnings-based productivity, σ_{ae}, in all three

[25] The shares of GDP sample firms accounted for are 31%, 19%, and 23% in the United States, China, and India, respectively. This figure is calculated as the sum of 50% of the sample firms' sales divided by GDP. Approximately, 50% of the sample firms' sales is the value added.

countries, suggesting the quality of accounting earnings is higher than the quality of cash flow (e.g., Nikolaev, 2016). If the moment conditions only used the variance and covariance of cash-flow- and accounting-earnings-based productivity, one concern would be that the lower variance of accounting-earnings-based productivity might mean accounting earnings is less informative than cash flow because of excessive income smoothing (e.g., Dechow and Skinner, 2000). However, the higher correlation of investment with accounting-earnings-based productivity than with cash-flow-based productivity in Table 3 suggests accrual accounting systems in general increase the informativeness of an imperfect measure of fundamentals for firms' investment decisions.

Table 4 finds the standard deviation of noise in all other information, σ_s, ranges from 22% to 38%, meaning the role of all other information in reducing informational frictions, $\overline{V}$, is important. This finding is consistent with the argument that a firm has various information sources besides accrual accounting systems to make production decisions. Considering a manager with cash flow information and all other information, I will estimate the incremental impact of accrual accounting information on aggregate productivity in Table 5 and 6.

The conditional variance of future productivity, $\overline{V}$, is 0.02-0.04 in the United States, China, and India. Relative to the initial uncertainty, the informational frictions in all three countries are significantly reduced by 93%-98%. However, the economically significant informational frictions in all three countries emphasize the importance of informational frictions in determining aggregate productivity through resource misallocation and the potential role of accrual accounting systems in improving resource allocation and aggregate productivity by reducing the conditional variance of future productivity.

Table 4 also sheds light on cross-sectional differences in information environments and operational environments. Table 4 points out the magnitude of noise in accounting earnings, σ_{ae}, in the United States is 5%-6% lower than in China and India. The quality of accounting earnings is the highest in the United States, consistent with Leuz et al.'s (2003) findings. The size of timing errors, σ_{ac}, is larger in China and India than in the United States, implying

cash payments and collections are more misaligned with the timing of business transactions in China and India than in the United States. The magnitude of informational frictions, $\overline{V}$, is the smallest in the United States because the high quality of all information sources and the low volatility of productivity contribute to the low conditional variance of future productivity.[26] The estimated magnitude of informational frictions in my paper is less than that of David et al. (2016). One reason is that I use one year instead of three years as the investment horizon. Furthermore, the difference in the magnitude of noise in accounting earnings across countries might influence the results of David et al. (2016), who find the size of informational frictions, comparable to $\overline{V}$ in my paper, is 0.13-0.26 in the United States, China, and India.

[Table 4 about here.]

4.3 Impact of Accrual Accounting Information on Aggregate Productivity

Table 5 shows the impact of accrual accounting information on aggregate productivity, a, is 0.7%-2.5% in the United States, China, and India. This reduction in informational frictions, $\overline{V}$, from accrual accounting information also increases aggregate output, y, by 1.0%-3.8% in the United States, China, and India. As of 2012, a 1% of GDP in the United States, a 1.7% of GDP in China, and a 3.8% of GDP in India were \$161 billion, \$124 billion, and \$70 billion, respectively. By comparison, Midrigan and Xu (2014) demonstrate a financial friction would generate a 5%-10% loss in aggregate productivity through resource misallocation in Korea. The impact of accrual accounting information on aggregate productivity is smallest in the

[26]The low quality of financial information in China and India might partly explain the low correlation between investment and productivity in these two countries, which also serves as evidence of significant resource misallocation in these two countries in prior papers (e.g., Hopenhayn, 2014). However, my paper also echoes the large differences in resource misallocation in the United States, China, and India cannot be solely explained by the differences in measurement errors outlined in Table 4 (e.g., Hsieh and Klenow, 2009). The low correlation between investment and productivity in China and India might reflect other frictions, such as political connections. I discuss this issue in section 5.2 in detail.

United States because the volatility of its firms' productivity is smallest and the quality of its other information sources is the highest. Compared to the magnitude of informational frictions, the reduction in informational frictions, $\overline{V}$, from accounting earnings accounts for 15%-20% of the magnitude of informational frictions.[27]

This estimate in Table 5 might capture both the internal and external usage of accounting information, because the high correlation between investment and accounting earnings, which is a key moment in this paper, might indicate accounting earnings help encourage managers to make input choices aligned with investors' interests and future productivity (e.g., Bushman and Smith, 2001). Accounting earnings could be used both internally and externally to improve firm-level investment efficiency. The external usage of accounting earnings affects firm-level capital and labor investment efficiency through corporate governance and capital markets (e.g., Bushman and Smith, 2001; Kanodia and Sapra, 2016).[28] Even though the external usage of accounting earnings is not modelled explicitly, my quantitative analysis admits the possibility that this channel contributes to the estimated effect of accounting information on resource allocation and aggregate productivity through an increase in the correlation between investment and accounting earnings.

[Table 5 about here.]

Table 6 shows if China and India had "US-quality" accounting information, the estimated gains for these countries would be a 0.6%-0.7% increase in aggregate productivity and a 0.8%-1.0% increase in aggregate output. These estimates would require Chinese and Indian firms to not have all other information about their current performance. The estimates in Table 5 and 6 are the quantitative implications of the model. The impact of improved

[27] I conduct another counterfactual analysis on perfect accrual accounting information. What if managers have a perfect measure of fundamentals through accrual accounting systems? The quantitative analysis suggests the impact of perfect accrual accounting information on aggregate productivity, a, and aggregate output, y, is 0.3%-1.2% and 0.5%-1.7% in the United States, China, and India.

[28] Kanodia and Lee (1998) demonstrate disclosure incentivizes managers to invest efficiently because interim reports partially reveal managers' private information to investors ex-post. Biddle et al. (2009) show the quality of accounting earnings reduces both over- and under-investment problems due to adverse selection and agency problems. Jung et al. (2014) demonstrate the quality of accounting earnings improves labor investment efficiency through similar channels to Biddle et al.'s (2009).

accrual accounting systems on aggregate productivity through efficient resource allocation is comparable to 1%-2% of the overall effect of improved resource allocation on aggregate productivity in China and India, as estimated by Hsieh and Klenow (2009). They find 30%-60% of the aggregate productivity differences among the United States, China, and India could be explained by different degrees of resource misallocation in each country, because high-productivity firms might not always get more resources than low-productivity firms in China and India. However, Asker et al. (2014) argue if a firm's investment decision is dynamic, the estimated effect of resource misallocation on aggregate productivity in Hsieh and Klenow (2009) using a static distribution of productivity can partly capture different volatilities of fundamentals in different countries instead of different magnitudes of distortions in different countries.

[Table 6 about here.]

5 Robustness Tests

5.1 Accounting Properties

As a robustness test, I estimate the impact of accrual accounting on resource allocation and aggregate productivity while relaxing the accounting-property assumptions. Even though the accounting-property assumptions provide a natural starting point, firm characteristics and accounting practices are likely to affect these assumptions and, in turn, influence the estimation results. Nikolaev (2016) explains these possibilities and how to generalize his model to incorporate these possibilities. For growing firms, an increase in productivity might be related to negative timing errors, because growing firms are likely to invest more in working capital as well as in capital and labor (McNichols, 2000). As accruals, these positive working capital investments could generate the negative relation between productivity shocks and timing errors, because an increase in cash flow might not be as large as an increase in productivity.

Estimation errors might also be correlated with productivity shocks and timing errors (e.g., Healy, 1985; Basu, 1997; Gerakos and Kovrijnykh, 2013). Simply, accrual accounting systems might not remove all of the timing errors, resulting in the relation between productivity shocks and estimation errors being in the same direction as the relation between productivity shocks and timing errors. Furthermore, managers' income-smoothing incentives could lead to a negative relation between productivity shocks and estimation errors (e.g., Gerakos and Kovrijnykh, 2013). Accrual accounting systems could underreact to current productivity shocks if managers are willing to smooth accounting earnings over time. Another reason might be conservatism (e.g., Basu, 1997; Watts, 2003a,b). For contracting purposes, accrual accounting systems defer the recognition of positive news, such as positive revaluations of assets, resulting in a positive relation between timing errors and estimation errors.

To evaluate the influence of these cases on the estimation results, I use two different specifications of accounting systems. First, I explore the effects of the correlation between productivity shocks and errors on the estimation results. The alternative specification of accounting systems is as follows:

$$a^c_{it} = a_{it} + \xi^c \epsilon_{it} + a^{ac}_{it}, a^e_{it} = a_{it} + \xi^e \epsilon_{it} + a^{ae}_{it},$$

where ξ^c and ξ^e reflect the relation of productivity shocks with cash flow and accounting earnings and ϵ_{it} is the innovation in productivity. Table 7 Panel A demonstrates both timing errors and estimation errors are negatively related to productivity shocks.[29] However, the negative relation is smaller for accounting earnings than for cash flow in all three countries. The large negative relation between productivity shocks and timing errors in China and India implies the role of accrual accounting information is more important in these countries

[29]In Table 7, I use two additional moments, $corr(a^c_{it}, a^c_{it-2})$ and $corr(a^e_{it}, a^e_{it-2})$. In Table 7 Panel A, I estimate parameters searching for limited sets of parameter values, because a larger number of parameters would make the optimization process less stable. If I search for a full set of parameter values to estimate parameters, I sometimes reach an uninteresting parameter value of ξ^c close to -1, meaning cash flow has no information about current productivity shocks.

relative to the benchmark case in equations (11) and (12).

Second, I investigate how the correlation between timing errors and estimation errors changes the estimation results. The alternative specification of accounting systems is as follows:

$$a_{it}^{c} = a_{it} + a_{it}^{ce} + a_{it}^{ac}, a_{it}^{e} = a_{it} + a_{it}^{ce} + a_{it}^{ae},$$

where a_{it}^{ce} reflects common errors in cash flow and accounting earnings that are unrelated to productivity shocks. Table 7 Panel B indicates the magnitude of common errors in cash flow and accounting earnings is small. The estimation results are robust to this alternative specification.

[Table 7 about here.]

5.2 Other Frictions

The existence of other frictions changes a firm's problem and weakens the argument that the variance in equation (22) reveals the quality of all other information managers hold. A firm's new objective function can be expressed by

$$\underset{K_{it},L_{it}}{max} E_{it-1}[Y_t^{\frac{1}{\theta}}(1-\tau_{Y_{it}})A_{it}K_{it}^{\hat{\alpha_1}}L_{it}^{\hat{\alpha_2}} - W_tL_{it} - (1+\tau_{K_{it}})R_tK_{it}],$$

where $\tau_{Y_{it}}$ is a distortion of production and $\tau_{K_{it}}$ is a distortion of input choices (Hsieh and Klenow, 2009; David et al., 2016). This expression potentially incorporates other frictions, such as taxes, political connections, government policies, and managers' private benefits. Hopenhayn and Rogerson (1993) demonstrate an increase in firing costs reduces not only long-term employment rates but also labor productivity, because this policy hinders firms from hiring or firing their employees in response to positive or negative shocks. Midrigan and Xu (2014) demonstrate financial frictions decrease aggregate productivity by distorting

firms' entry and technology adoption decisions as well as by driving resource misallocation.[30] With the existence of other frictions, an optimal capital investment rule is derived:

$$\begin{aligned} k_{it} &= \frac{E_{it-1}[a_{it}+\tau_{it}]}{1-\hat{\alpha}} + Constant \\ &= \frac{(1+\gamma)E_{it-1}[a_{it}]+\epsilon^{\tau}_{it}}{1-\hat{\alpha}} + Constant, \end{aligned} \tag{23}$$

where γ reflects a distortion correlated with productivity and ϵ^{τ}_{it} is a distortion uncorrelated with productivity.[31] Equation (23) implies the relation between the variance and the quality of all other information managers hold is distorted as follows:

$$var(k_{it}) = var(\frac{1+\gamma}{1-\hat{\alpha}}E_{it-1}[a_{it}] + \frac{1}{1-\hat{\alpha}}\epsilon^{\tau}_{it}) = (\frac{1+\gamma}{1-\hat{\alpha}})^2(\sigma_a^2 - \overline{V}) + (\frac{1}{1-\hat{\alpha}})^2 var(\epsilon^{\tau}_{it}).$$

Therefore, this paper focuses on the correlation between the capital stock and (observable) measures of productivity, rather than the variance of the capital stock, to overcome this problem following David et al. (2016). Suppose $\gamma \neq 0$ but $\sigma^2_{\epsilon^{\tau}} = 0$, where $\sigma^2_{\epsilon^{\tau}}$ is the variance of a distortion uncorrelated with productivity. The correlations $corr(k_{it}, a^c_{it-1})$ and $corr(k_{it}, a^e_{it-1})$ are a robust moment to γ to estimate σ^2_s, because the effects of distortions correlated with productivity in the denominator and the numerator offset each other[32]:

$$corr(k_{it}, a^c_{it-1}) = \frac{(\frac{1+\gamma}{1-\hat{\alpha}})cov(E_{it-1}[a_{it}], a^c_{it-1})}{\sqrt{(\frac{1+\gamma}{1-\hat{\alpha}})^2 var(E_{it-1}[a_{it}])}\sqrt{var(a^c_{it-1})}} = \frac{cov(E_{it-1}[a_{it}], a^c_{it-1})}{\sqrt{var(E_{it-1}[a_{it}])}\sqrt{var(a^c_{it-1})}}.$$

[30] Prior studies analyze the quantitative impact of financial frictions on aggregate productivity and output (e.g. Buera et al., 2011; Moll, 2014).

[31] I assume $log(1-\tau_{Y_{it}})$ and $log(1+\tau_{K_{it}})$ follow a specific log-normal distribution. τ_{it} is the combination of $log(1-\tau_{Y_{it}})$ and $log(1+\tau_{K_{it}})$. $\tau_{it} = \gamma a_{it} + \epsilon^{\tau}_{it}$, where ϵ^{τ}_{it} follows an i.i.d. log-normal distribution as the mean of zero and variance of $\sigma^2_{\epsilon^{\tau}}$. I assume managers observe ϵ^{τ}_{it} before making investment decisions.

[32] I assume γ is greater than -1.

Suppose $\gamma = 0$ but $\sigma^2_{\epsilon^\tau} \neq 0$. $corr(k_{it}, a^c_{it-1})$ and $corr(k_{it}, a^e_{it-1})$ underestimate σ^2_s because the lower correlation suggests higher variance of the capital stock and, in turn, higher quality of all other information:

$$corr(k_{it}, a^c_{it-1}) = \frac{cov(E_{it-1}[a_{it}], a^c_{it-1})}{\sqrt{(var(E_{it-1}[a_{it}]) + var(\epsilon^\tau_{it}))}\sqrt{var(a^c_{it-1})}}.$$

The existence of other distortions underestimates the impact of accrual accounting systems on resource allocation and aggregate productivity, suggesting the estimate in this paper is likely to provide a lower bound, at least if I focus on the correlation rather than the variance.

5.3 Elasticity of Substitution

I evaluate the sensitivity of the estimation results to the elasticity of substitution, θ. I use this parameter both to calculate productivity and to conduct counterfactual analyses, with common values of this parameter ranging from 3 to 10 in the literature. Table 8 indicates the estimated parameter values in my paper are robust to the different values of θ in all three countries. However, the estimated effect of accrual accounting information on aggregate productivity and output increases as the elasticity of substitution increases because of the competition effect. This result is closely related to equations (15) and (20), the equilibrium results in the model. The impact of accrual accounting information on aggregate productivity ranges from 0.4%-3.5% in the United States, China, and India.

[Table 8 about here.]

5.4 Industry Analysis

I conduct an industry analysis to validate my estimation method and explore how large the role of accrual accounting information is in shaping informational frictions in different industries. Prior studies demonstrate cash flow and accounting earnings both have more difficulty in measuring firm performance when the operating cycle is longer (e.g., Dechow,

1994; Dechow and Dichev, 2002). A long operating cycle implies cash collections and payments are more likely to be misaligned with the timing of business transactions. In addition, a long operating cycle might make matching the benefit and cost of business transactions difficult for accrual accounting systems. My estimates for the size of timing errors and estimation errors in Figure 4 Panels A and B are consistent with prior papers' findings. Related to these phenomena, one interesting question is whether, in the context of the model, the importance of accrual accounting information is increasing or decreasing with the operating cycle, because both timing and estimation errors increase in the operating cycle. Figure 4 Panel C demonstrates accrual accounting systems reduce informational frictions, $\overline{V}$, more in an industry with a longer operating cycle, meaning large timing errors in cash flow elevate the role of accounting earnings even though accounting earnings also have large estimation errors.

[Figure 4 about here.]

6 Conclusion

I show accrual accounting systems improve resource allocation and aggregate productivity by helping managers make better input choices with a less noisy measure of performance. An understanding of how (and how much) accrual accounting influences aggregate productivity is important in accounting. The general equilibrium model with accounting systems demonstrates firms' more informed decisions with an improved measure of performance lead to more resources being allocated to potentially high-productivity firms through the product and input markets. The quantitative analysis demonstrates the estimated impact of accrual accounting on aggregate productivity is economically significant.

However, the quantitative analysis should be interpreted only in the context of the model. For example, the monopolistic competition of heterogeneous firms is a standard assumption in the literature, but it does not consider strategic interaction among firms. Explicitly

modeling adjustment costs and accrual reversals might be helpful for a deeper understanding of the interaction between adjustment costs and informational frictions and the impact of different accounting properties on resource allocation. Furthermore, the quantitative analysis does not consider any forces outside the model, such as distinguishable legal institutions in different countries.

Whereas I focus on the direct effect of accrual accounting on firms' decisions and, in turn, aggregate productivity in a general equilibrium model with heterogeneous firms under imperfect information, a general equilibrium analysis could be useful for understanding other economy-wide effects of accounting. For example, prior papers emphasize the role of accrual accounting systems in mitigating agency problems in firms and therefore influencing firms' decisions (e.g., Bushman and Smith, 2001; Armstrong, Guay, and Weber, 2010). Information spillover might be another channel through which accounting information influences aggregate productivity (e.g., Badertscher et al., 2013; Leuz and Wysocki, 2016). A general equilibrium analysis could be a useful tool for investigating quantitative implications about aggregate effects and externalities of accounting.

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A Model

A.1 Constant Elasticity Substitution Aggregator

A CES aggregator means the degree to which a representative household substitutes one good for another good when responding to a change in a relative price between these goods

is constant. The final good is produced by a competitive firm with perfect information. The first-order condition of a final-good producer's problem provides a downward-sloping demand function for an intermediate-good producer:

$$\begin{aligned} P_{it} &= \frac{\theta}{\theta-1}(\int A_{it}Y_{it}^{\frac{\theta-1}{\theta}}di)^{\frac{1}{\theta-1}}\frac{\theta-1}{\theta}A_{it}Y_{it}^{-\frac{1}{\theta}} \\ &= A_{it}(\frac{Y_{it}}{Y_t})^{-\frac{1}{\theta}}, \end{aligned}$$

where P_{it} is a relative price of intermediate good i with respect to a final good, Y_t. I verify the constant elasticity of substitution, θ, using this demand function. The ratios of price and quantity of two different intermediate goods satisfy the equation:

$$\frac{P_{jt}}{P_{it}} = \frac{A_{jt}}{A_{it}}(\frac{Y_{it}}{Y_{jt}})^{\frac{1}{\theta}}.$$

I transform this equation into a log form:

$$log\frac{P_{jt}}{P_{it}} - log\frac{A_{jt}}{A_{it}} - \frac{1}{\theta}log\frac{Y_{it}}{Y_{jt}} = 0.$$

The implicit function theorem suggests the elasticity of substitution, θ, is constant:

$$-\frac{\partial(Y_{it}/Y_{jt})/(Y_{it}/Y_{jt})}{\partial(P_{it}/P_{jt})/(P_{it}/P_{jt})} = -\frac{\partial log(Y_{it}/Y_{jt})}{\partial log(P_{it}/P_{jt})} = \frac{1}{\frac{1}{\theta}} = \theta.$$

A.2 Optimal Capital Investment Decisions

Equation (9) implies:

$$\frac{L_{it}}{K_{it}} = \frac{\hat{\alpha_2}R_t}{\hat{\alpha_1}W_t}. \tag{24}$$

Using equation (24), a firm's maximization problem is reduced to an optimal decision of capital:

$$\underset{K_{it}}{max} Y_t^{\frac{1}{\theta}} E_{it-1}[A_{it}] K_{it}^{\hat{\alpha}} (\frac{\hat{\alpha_2} R_t}{\hat{\alpha_1} W_t})^{\hat{\alpha_2}} - (1 + \frac{\hat{\alpha_2}}{\hat{\alpha_1}}) R_t K_{it}. \tag{25}$$

The first-order condition for an optimal decision problem with respect to capital is as follows:

$$\hat{\alpha} Y_t^{\frac{1}{\theta}} E_{it-1}[A_{it}] K_{it}^{\hat{\alpha}-1} (\frac{\hat{\alpha_2} R_t}{\hat{\alpha_1} W_t})^{\hat{\alpha_2}} = (1 + \frac{\hat{\alpha_2}}{\hat{\alpha_1}}) R_t.$$

$$K_{it} = E_{it-1}[A_{it}]^{\frac{1}{1-\hat{\alpha}}} (\hat{\alpha} Y_t^{\frac{1}{\theta}} (\frac{\hat{\alpha_2} R_t}{\hat{\alpha_1} W_t})^{\hat{\alpha_2}} ((1 + \frac{\hat{\alpha_2}}{\hat{\alpha_1}}) R_t)^{-1})^{\frac{1}{1-\hat{\alpha}}}.$$

The sum of the capital stock of all firms is the same as the aggregate capital stock, K_t:

$$\begin{aligned} \int K_{it} di &= (\hat{\alpha} Y_t^{\frac{1}{\theta}} (\frac{\hat{\alpha_2} R_t}{\hat{\alpha_1} W_t})^{\hat{\alpha_2}} ((1 + \frac{\hat{\alpha_2}}{\hat{\alpha_1}}) R_t)^{-1})^{\frac{1}{1-\hat{\alpha}}} \int E_{it-1}[A_{it}]^{\frac{1}{1-\hat{\alpha}}} di. \\ \frac{K_t}{\int E_{it-1}[A_{it}]^{\frac{1}{1-\hat{\alpha}}} di} &= (\hat{\alpha} Y_t^{\frac{1}{\theta}} (\frac{\hat{\alpha_2} R_t}{\hat{\alpha_1} W_t})^{\hat{\alpha_2}} ((1 + \frac{\hat{\alpha_2}}{\hat{\alpha_1}}) R_t)^{-1})^{\frac{1}{1-\hat{\alpha}}}. \end{aligned} \tag{26}$$

A.3 Kalman Filter

I express a manager's expectation process by using a state-space representation of a manager's information structure as an aspect of productivity. The state and observation equations are expressed as follows:

$$a_{it} = (1 - \rho)\overline{a} + \rho a_{it-1} + \epsilon_{it},$$

$$X_{it-1} = H a_{it-1} + U + \eta_{it-1},$$

$$X_{it} = \begin{bmatrix} a_{it}^c \\ a_{it}^e \\ s_{it} \end{bmatrix}, H = \begin{bmatrix} 1 \\ 1 \\ \rho \end{bmatrix}, U = \begin{bmatrix} -\frac{\sigma_{ac}^2}{2} \\ -\frac{\sigma_{ae}^2}{2} \\ (1-\rho)\overline{a} \end{bmatrix}, \eta_{it} = \begin{bmatrix} a_{it}^{ac\prime} \\ a_{it}^{ae\prime} \\ \epsilon_{it+1} + a_{it}^s \end{bmatrix},$$

$$\begin{bmatrix} \epsilon_{it} \\ \eta_{it-1} \end{bmatrix} \sim N(\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \Omega = \begin{bmatrix} \sigma^2 & \underset{1\times3}{S} \\ \underset{3\times1}{S'} & \underset{3\times3}{R} \end{bmatrix} = \begin{bmatrix} \sigma^2 & 0 & 0 & \sigma^2 \\ 0 & \sigma^2_{ac} & 0 & 0 \\ 0 & 0 & \sigma^2_{ae} & 0 \\ \sigma^2 & 0 & 0 & \sigma^2 + \sigma^2_s \end{bmatrix}), \tag{27}$$

where $a^{ac'}_{it} = a^{ac}_{it} + \frac{\sigma^2_{ac}}{2}$ and $a^{ae'}_{it} = a^{ae}_{it} + \frac{\sigma^2_{ae}}{2}$. In equation (27), a manager forms an expectation of future productivity, a_{it}, by observing a vector of signals, X_{it-1}. This paper assumes the error terms in η_{it} are uncorrelated with each other.

A manager forms a best estimate of future productivity by using the Kalman filter, because it is an optimal process for predicting future productivity when the data-generating process is linear and normal (e.g., Kalman, 1960; Gourieroux and Monfort, 1997, pp.575-585). A key mechanism is Bayes' theorem, which is used to derive the conditional distribution of future productivity. The Kalman filter follows three stages to update information and forecast future states. First, managers form their expectations about signals, X_{it-1}, based on their expectation of current productivity.

$$a_{it-1}|\mathbb{I}_{it-2} \sim N(E_{it-2}[a_{it-1}], V_{it-2}[a_{it-1}]),$$

$$X_{it-1}|\mathbb{I}_{it-2} \sim N(HE_{it-2}[a_{it-1}] + U, V_{it-2}[a_{it-1}]HH' + R).$$

Second, the unexpected part of signals updates managers' expectations of current productivity, $E_{it-1}[a_{it-1}]$:

$$a_{it-1}|\mathbb{I}_{it-1} \sim N(E_{it-1}[a_{it-1}], V_{it-1}[a_{it-1}]),$$

$$E_{it-1}[a_{it-1}] = E_{it-2}[a_{it-1}] + G_{it-1}(X_{it-1} - HE_{it-2}[a_{it-1}] - U),$$

$$G_{it-1} = V_{it-2}[a_{it-1}]H'(V_{it-2}[a_{it-1}]HH' + R)^{-1},$$

$$V_{it-1}[a_{it-1}] = (1 - G_{it-1}H)V_{it-2}[a_{it-1}].$$

Finally, managers form their expectations of future productivity, a_{it}, using updated information:

$$a_{it}|\mathbb{I}_{it-1} \sim N(E_{it-1}[a_{it}], V_{it-1}[a_{it}]),$$

$$E_{it-1}[a_{it}] = (1-\rho)\overline{a} + (\rho - SR^{-1}H)E_{it-1}[a_{it-1}] + SR^{-1}(X_{it-1} - U),$$

$$V_{it-1}[a_{it}] = (\rho - SR^{-1}H)^2 V_{it-1}[a_{it-1}] + \sigma^2 - SR^{-1}S'.$$

The stationary covariance matrix satisfies the following:

$$\overline{V} = (\rho - SR^{-1}H)^2(\overline{V} - \overline{V}H'(\overline{V}HH' + R)^{-1}H\overline{V}) + \sigma^2 - SR^{-1}S', \tag{28}$$

$$\overline{G} = \overline{V}H'(\overline{V}HH' + R)^{-1}.$$

I have to initiate this filtering by setting up $E_{i0}[a_{i1}]$ and $V_{i0}[a_{i1}]$. I simulate a_{i1} such that a_{i1} follows the unconditional distribution of productivity. $E_{i0}[a_{i1}]$ is given to satisfy $V_{i0}[a_{i1}] = \overline{V}$. In this way, $V_{it-1}[a_{it}]$ and G_{it-1} are constant as $V_{it-1}[a_{it}] = \overline{V}$ and $G_{it-1} = \overline{G}$.

Equation (28) defines the relation between the quality of information and the conditional variance of future productivity. The equation is rearranged as follows.

$$\overline{V} = \rho^2(\frac{\sigma_s^2}{\sigma^2 + \sigma_s^2})^2 \frac{\overline{V}\sigma_{ae}^2\sigma_{ac}^2(\sigma^2 + \sigma_s^2)}{det(B)} + \frac{\sigma^2\sigma_s^2}{\sigma^2 + \sigma_s^2},$$

$$B \equiv \overline{V} H H' + R,$$

$$det(B) = \overline{V}(\sigma_{ae}^2 + \sigma_{ac}^2)(\sigma^2 + \sigma_s^2) + \sigma_{ae}^2 \sigma_{ac}^2 (\sigma^2 + \sigma_s^2 + \rho^2 \overline{V}) \geq \sigma_{ae}^2 \sigma_{ac}^2 (\sigma^2 + \sigma_s^2).$$

Then, the implicit function theorem implies

$$\begin{aligned} \frac{d\overline{V}}{d\sigma_{ae}^2} &= \frac{\overline{V}^2 \sigma_{ac}^4 (\sigma^2 + \sigma_s^2)^2}{M} \\ &\geq 0, \end{aligned}$$

$$M \equiv (\frac{\sigma^2 + \sigma_s^2}{\rho \sigma_s^2})^2 det(B)^2 - \sigma_{ae}^4 \sigma_{ac}^4 (\sigma^2 + \sigma_s^2)^2.$$

In addition,

$$\frac{d^2\overline{V}}{d\sigma_{ac}^2 d\sigma_{ae}^2} = \frac{\partial \frac{d\overline{V}}{d\sigma_{ae}^2}}{\partial \sigma_{ac}^2} + \frac{\partial \frac{d\overline{V}}{d\sigma_{ae}^2}}{\partial \overline{V}} \frac{d\overline{V}}{d\sigma_{ac}^2} \geq 0,$$

$$\frac{\partial \frac{d\overline{V}}{d\sigma_{ae}^2}}{\partial \sigma_{ac}^2} = \frac{\overline{V}^2 2\sigma_{ac}^2 (\sigma^2 + \sigma_s^2)^2}{M^2} det(B) (\frac{\sigma^2 + \sigma_s^2}{\rho \sigma_s^2})^2 \overline{V} \sigma_{ae}^2 (\sigma^2 + \sigma_s^2) \geq 0,$$

$$\frac{\partial \frac{d\overline{V}}{d\sigma_{ae}^2}}{\partial \overline{V}} = \frac{\overline{V} 2\sigma_{ac}^4 (\sigma^2 + \sigma_s^2)^2}{M^2} (\sigma_{ae}^2 \sigma_{ac}^2 (\sigma^2 + \sigma_s^2) (\frac{\sigma^2 + \sigma_s^2}{\rho \sigma_s^2})^2 det(B) - \sigma_{ae}^4 \sigma_{ac}^4 (\sigma^2 + \sigma_s^2)^2) \geq 0,$$

$$\begin{aligned} \frac{d\overline{V}}{d\sigma_{ac}^2} &= \frac{\overline{V}^2 \sigma_{ae}^4 (\sigma^2 + \sigma_s^2)^2}{M} \geq 0. \end{aligned}$$

A.4 Aggregate Productivity

Two integrals are simplified as follows:

$$\begin{aligned} log\int A_{it}(E_{it-1}[A_{it}])^{\frac{\hat{\alpha}}{1-\hat{\alpha}}}di &= log\int exp(a_{it}+\frac{\hat{\alpha}}{1-\hat{\alpha}}logE_{it-1}[A_{it}])di \\ &= log\int exp(a_{it}+\frac{\hat{\alpha}}{1-\hat{\alpha}}E_{it-1}[a_{it}]+\frac{1}{2}\frac{\hat{\alpha}}{1-\hat{\alpha}}\overline{V})di \\ &= \frac{1}{1-\hat{\alpha}}\overline{a}+\frac{1}{2}\sigma_a^2+\frac{1}{2}(\frac{\hat{\alpha}}{1-\hat{\alpha}})^2(\sigma_a^2-\overline{V}) \\ &\quad +\frac{\hat{\alpha}}{1-\hat{\alpha}}(\sigma_a^2-\overline{V})+\frac{1}{2}\frac{\hat{\alpha}}{1-\hat{\alpha}}\overline{V}. \end{aligned}$$

$$\begin{aligned} log\int (E_{it-1}[A_{it}])^{\frac{1}{1-\hat{\alpha}}}di &= log\int exp(\frac{1}{1-\hat{\alpha}}logE_{it-1}[A_{it}])di \\ &= log\int exp(\frac{1}{1-\hat{\alpha}}E_{it-1}[a_{it}]+\frac{1}{2}\frac{1}{1-\hat{\alpha}}\overline{V})di \\ &= \frac{1}{1-\hat{\alpha}}\overline{a}+\frac{1}{2}(\frac{1}{1-\hat{\alpha}})^2(\sigma_a^2-\overline{V})+\frac{1}{2}\frac{1}{1-\hat{\alpha}}\overline{V}. \end{aligned}$$

A.5 Wage Rate

First, I derive an optimal decision problem of labor:

$$\underset{L_{it}}{max}Y^{\frac{1}{\theta}}E_{it-1}[A_{it}](\frac{\hat{\alpha_1}W}{\hat{\alpha_2}R})^{\hat{\alpha_1}}L_{it}^{\hat{\alpha}}-(1+\frac{\hat{\alpha_1}}{\hat{\alpha_2}})WL_{it}.$$

The first-order condition of the maximization problem above is as follows:

$$\hat{\alpha}Y^{\frac{1}{\theta}}E_{it-1}[A_{it}](\frac{\hat{\alpha_1}W}{\hat{\alpha_2}R})^{\hat{\alpha_1}}L_{it}^{\hat{\alpha}-1}=(1+\frac{\hat{\alpha_1}}{\hat{\alpha_2}})W,$$

$$L_{it}=(\hat{\alpha_2}Y^{\frac{1}{\theta}}E_{it-1}[A_{it}](\frac{\hat{\alpha_1}}{\hat{\alpha_2}R})^{\hat{\alpha_1}}W^{\hat{\alpha_1}-1})^{\frac{1}{1-\hat{\alpha}}}. \tag{29}$$

Equation (29) characterizes an optimal labor decision of a firm. Second, the labor-market-clearing condition implies the following:

$$L = (\hat{\alpha_2} Y^{\frac{1}{\theta}} (\frac{\hat{\alpha_1}}{\hat{\alpha_2} R})^{\hat{\alpha_1}} W^{\hat{\alpha_1}-1})^{\frac{1}{1-\hat{\alpha}}} \int E_{it-1}[A_{it}]^{\frac{1}{1-\hat{\alpha}}} di,$$

$$\begin{aligned} W &= (\hat{\alpha_2}(\frac{\hat{\alpha_1}}{\hat{\alpha_2} R})^{\hat{\alpha_1}} L^{\hat{\alpha}-1})^{\frac{1}{1-\hat{\alpha_1}}} (\int E_{it-1}[A_{it}]^{\frac{1}{1-\hat{\alpha}}} di)^{\frac{1-\hat{\alpha}}{1-\hat{\alpha_1}}} Y^{\frac{1}{\theta}\frac{1}{1-\hat{\alpha_1}}} \\ &= (\hat{\alpha_2}(\frac{\hat{\alpha_1}}{\hat{\alpha_2} R})^{\hat{\alpha_1}} L^{\hat{\alpha}-1})^{\frac{1}{1-\hat{\alpha_1}}} ((\int exp(\frac{1}{1-\hat{\alpha}} E_{it-1}[a_{it}] + \frac{1}{1-\hat{\alpha}} \frac{1}{2} \overline{V}) di)^{1-\hat{\alpha}} Y^{\frac{1}{\theta}})^{\frac{1}{1-\hat{\alpha_1}}} \\ &= (\hat{\alpha_2}(\frac{\hat{\alpha_1}}{\hat{\alpha_2} R})^{\hat{\alpha_1}} L^{\hat{\alpha}-1})^{\frac{1}{1-\hat{\alpha_1}}} (exp(\overline{a} + \frac{1}{2} \frac{\sigma_a^2 - \overline{V}}{1-\hat{\alpha}} + \frac{1}{2} \overline{V}) Y^{\frac{1}{\theta}})^{\frac{1}{1-\hat{\alpha_1}}}. \end{aligned}$$

B Estimation

B.1 Simulated Method of Moments

The intuition behind the method of moments is to find a value of Ψ that minimizes the difference between empirical moments and analytical (or simulated) moments (Hansen, 1982). The estimation procedure consists of multiple steps. Strebulaev and Whited (2012) explain the methodology in detail. First, I calculate the empirical moments, $m(D)$, using data from Compustat and Compustat Global data. Second, I simulate data based on parameter values, and calculate simulated moments. Specifically, I simulate $a_{it}, a_{it}^c, a_{it}^e$, and s_{it} for N firms over 100 periods, given that $\Psi = \{\rho, \sigma^2, \sigma_{ac}^2, \sigma_{ae}^2, \sigma_s^2\}$, S times. I calculate optimal investment decisions using Kalman filtering with a steady-state-limit filter. The important thing is to determine how to simulate k_{it} based on this information. According to available information sets for managers, including a_{it}^c, a_{it}^e, and s_{it}, managers form expectations optimally as in Appendix A.3. The mean squared errors of these expectations are the same as $\overline{V}$. To keep $V_{it}[a_{it}] = \overline{V}$ over the whole period, I use a stationary covariance matrix for every period and every firm by setting initial expectations with $V_{i1}[a_{i1}] = \overline{V}$. I use the last three periods to

calculate one cross-sectional observation of $Z_i|\Psi$. I use this observation to calculate simulated moments, $m(Z_i|\Psi)$. I do not specify $\bar{\alpha}$ or aggregate variables to simulate productivity and investment, because I use a difference specification. In other words, Δa_{it}^c, Δa_{it}^e, and Δi_{it} only depend on Ψ, θ, α_1, and α_2. Third, I choose parameter values to minimize the weighted difference between empirical moments and simulated moments:

$$\hat{\Psi} = \underset{\Psi}{argmin}\Gamma(\Psi) = \underset{\Psi}{argming}(D,\Psi)' \times [\Sigma(1+\frac{N}{NS})]^{-1} \times g(D,\Psi), \tag{30}$$

$$g(D,\Psi) = m(D) - \frac{1}{S}\sum_{i=1}^{S} m(Z_i|\Psi),$$

where Σ is the covariance matrix of $m(D)$. Each component of $m(D)$ is used to estimate Σ. To satisfy equation (30), the SMM assumes Ψ exists.

The asymptotic distribution of $\hat{\Psi}$ follows a normal distribution:

$$\sqrt{N}(\hat{\Psi} - \Psi_0) \to N(0, \mathbb{W}),$$

$$\mathbb{W} = (1+\frac{N}{NS})(Q\Sigma^{-1}Q')^{-1},$$

$$Q' = \frac{\partial g(D,\Psi)}{\partial \Psi'}.$$

Q is numerically calculated using $\hat{\Psi}$. To examine the model fit, I conduct a general test of the over-identifying restrictions of the model because I have five parameters to estimate and seven moment conditions:

$$J = \sqrt{N}g(D,\hat{\Psi})' \times [\hat{\Sigma}(1+\frac{N}{NS})]^{-1} \times \sqrt{N}g(D,\hat{\Psi}) \to \chi^2(2).$$

This J statistic tests the null hypothesis that parameter values exist that satisfy the moment

conditions.

Figure 1: Economy

This figure illustrates the economy in my model.

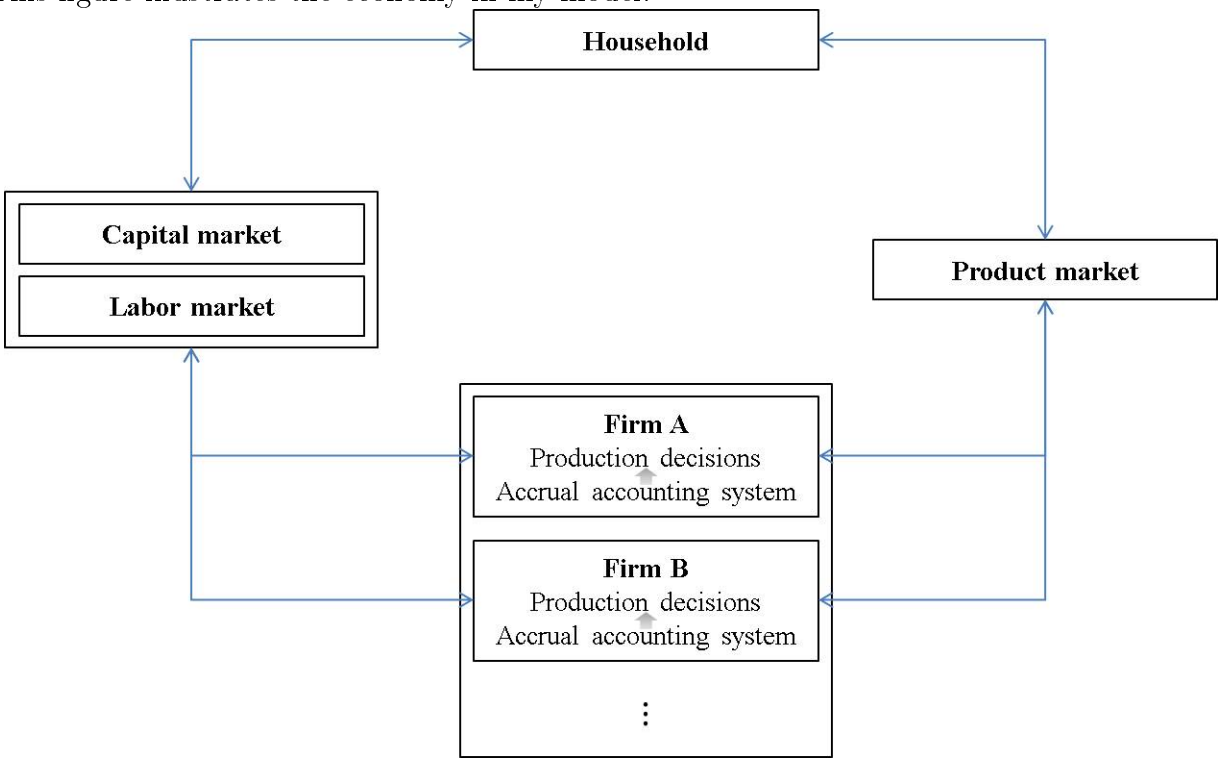

Figure 2: Timeline

This figure explains the timeline in the model. a_{it} is the productivity of firm i at date t. a^c_{it} and a^e_{it} are, respectively, the cash-flow- and accounting-earnings-based productivity of firm i at date t. s_{it} is all other information the manager of firm i holds at date t.

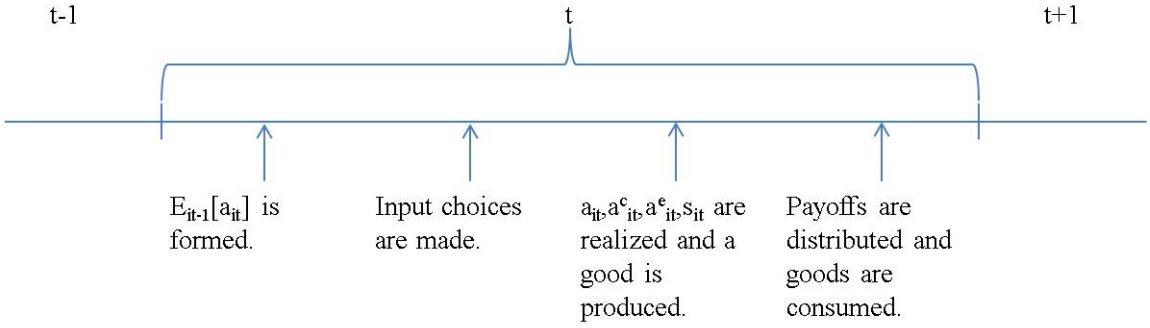

Figure 3: Simulation

This figure shows the relation between moments and parameters. a^c_{it} and a^e_{it} are cash-flow- and accounting-earnings-based productivity: $a^c_{it} = a_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + a^{ae}_{it}$. Productivity, a_{it}, follows an AR(1) model: $a_{it} = (1-\rho)\overline{a} + \rho a_{it-1} + \epsilon_{it}$. s_{it} is all other information about productivity: $s_{it} = a_{it+1} + a^s_{it}$. i is investment measured as the first difference of capital stock.

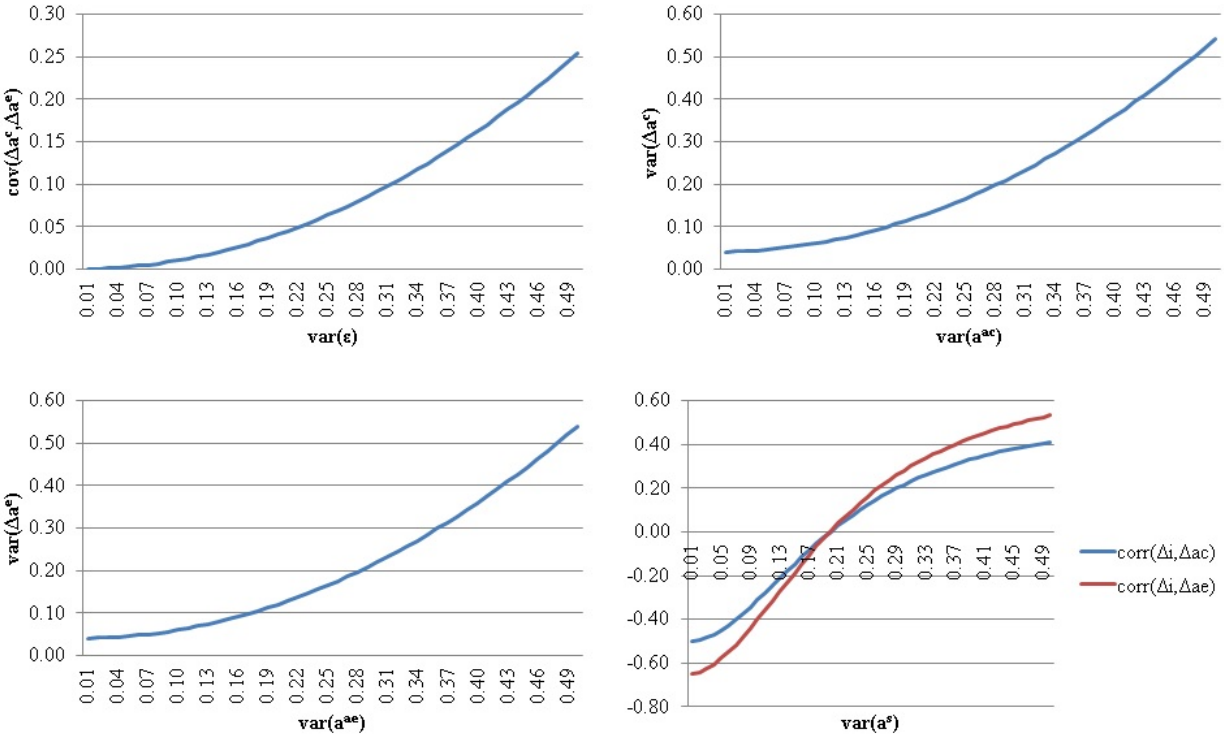

Figure 4: Accrual Accounting and Operating Cycle

This figure illustrates the relation between the role of accrual accounting and the length of the operating cycle. Panel A illustrates the relation between the standard deviation of timing errors, σ_{ac}, and the length of the operating cycle in industries. Panel B illustrates the relation between the standard deviation of estimation errors, σ_{ae}, and the length of the operating cycle in industries. Panel C illustrates the relation between the impact of accrual accounting in reducing informational frictions, $\overline{V}$, and the length of the operating cycle in industries. a^c_{it} and a^e_{it} are cash-flow- and accounting-earnings-based productivity: $a^c_{it} = a_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + a^{ae}_{it}$. Productivity, a_{it}, follows an AR(1) model: $a_{it} = (1-\rho)\overline{a} + \rho a_{it-1} + \epsilon_{it}$. ρ is the persistence of productivity. σ^2 is the volatility of innovation in productivity. s_{it} is all other information about productivity: $s_{it} = a_{it+1} + a^s_{it}$. σ^2_{ac}, σ^2_{ae}, and σ^2_s are the variance of noise in cash flow, accounting earnings, and all other information, respectively. $\overline{V}$ is a summary measure of informational frictions (or the conditional variance of future productivity). To estimate the impact of accrual accounting systems on informational frictions, I first calculate a hypothetical conditional variance of future productivity, $\tilde{V}$, based on a counterfactual value of the quality of accounting earnings and the estimated values of the other parameters using the following equation: $\tilde{V} = \rho^2(\frac{\sigma^2_s}{\sigma^2+\sigma^2_s})^2 \frac{\tilde{V}\sigma^2_{ae}\sigma^2_{ac}(\sigma^2+\sigma^2_s)}{\tilde{V}(\sigma^2_{ae}+\sigma^2_{ac})(\sigma^2+\sigma^2_s)+\sigma^2_{ae}\sigma^2_{ac}(\sigma^2+\sigma^2_s+\rho^2\tilde{V})} + \frac{\sigma^2\sigma^2_s}{\sigma^2+\sigma^2_s}$. Second, I calculate the difference between $\overline{V}$ and $\tilde{V}$. $Operating\,cycle_{it} = \frac{(AR_{it}+AR_{it})/2}{Sales_{it}/360} + \frac{(Inv_{it}+Inv_{it-1})/2}{COGS_{it}/360}$, where AR_{it} is accounts receivable and Inv_{it} is inventory. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables. I use Fama-French 48 industry classification.

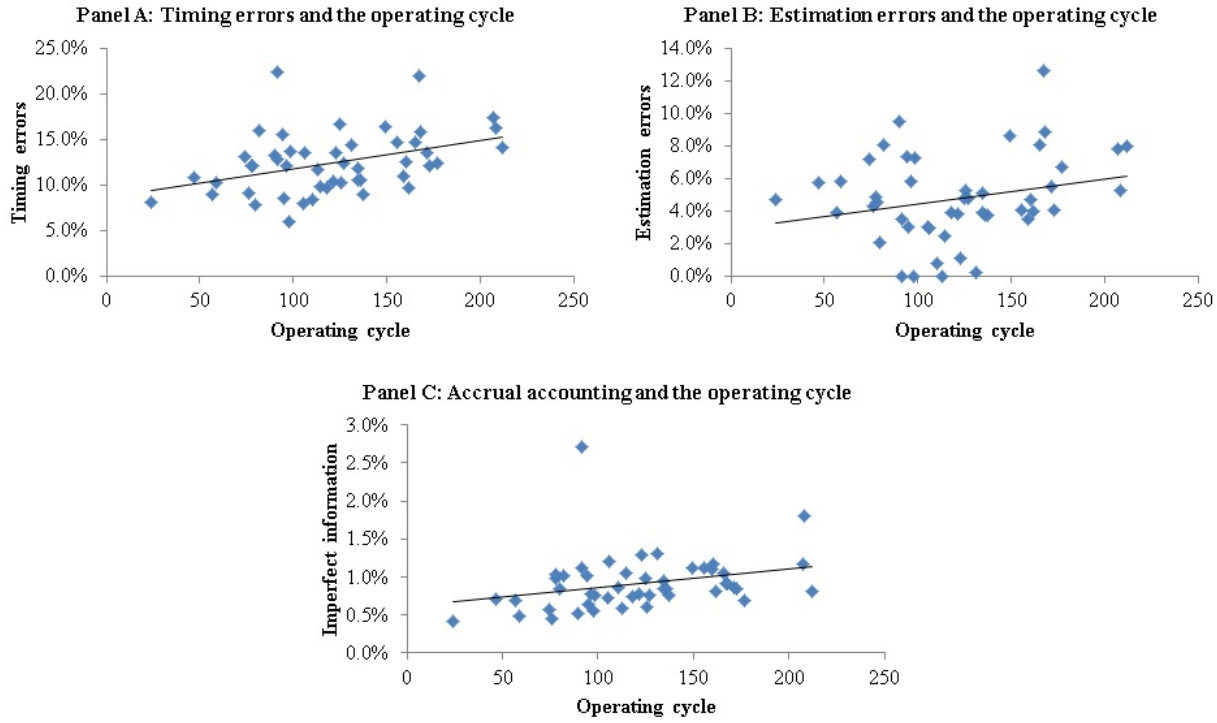

Table 1: Moments

This table summarizes which specific moments help identify specific parameter values. a^c_{it} and a^e_{it} are cash-flow- and accounting-earnings-based productivity: $a^c_{it} = a_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + a^{ae}_{it}$. Productivity, a_{it}, follows an AR(1) model: $a_{it} = (1-\rho)\overline{a} + \rho a_{it-1} + \epsilon_{it}$. ρ is the persistence of productivity. σ^2 is the volatility of innovation in productivity. i is investment measured as the first difference of capital stock. s_{it} is all other information about productivity: $s_{it} = a_{it+1} + a^s_{it}$. σ^2_{ac}, σ^2_{ae}, and σ^2_s are the variance of noise in cash flow, accounting earnings, and all other information, respectively.

Moment	Parameter
$corr(a^c_{it}, a^c_{it-1})$ $corr(a^e_{it}, a^e_{it-1})$ }	ρ
$cov(\Delta a^c_{it}, \Delta a^e_{it})$ $var(\Delta a^c_{it})$ $var(\Delta a^e_{it})$ }	σ^2_{ac}, σ^2_{ae}, and σ^2
$corr(\Delta i_{it+1}, \Delta a^c_{it})$ $corr(\Delta i_{it+1}, \Delta a^e_{it})$ }	σ^2_s

Table 2: Descriptive Statistics

This table shows the descriptive statistics. Sales, capital (or gross PP&E), profit, and accruals are expressed in millions of dollars. a^c_{it} and a^e_{it} are cash-flow- and accounting-earnings-based productivity: $a^c_{it} = a_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + a^{ae}_{it}$. Cash flow and accounting earnings are transformed into imperfect measures of productivity: $a^c_{it} + Constant = va^c_{it} - \hat{\alpha}k_{it}, a^e_{it} + Constant = va^e_{it} - \hat{\alpha}k_{it}$. The value added for accounting earnings is calculated as 50% of sales to exclude costs of intermediate inputs from sales. The value added for cash flow is measured by the following: $VA^c_{it} = VA^e_{it} - AC_{it}$, where VA^c_{it} and VA^e_{it} are the value added for cash flow and accounting earnings, respectively. i is investment measured as the first difference of capital stock. I use gross property, plant and equipment (PP&E) to measure capital stock. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables.

US	N	Mean	Std Dev	Q1	Median	Q3
Sales	2,388	4,262.41	17,446.83	172.00	711.10	2,636.13
Capital	2,388	3,276.53	14,847.31	59.26	315.84	1,563.09
Profit	2,388	303.18	1,789.38	0.06	27.61	149.16
Accruals	2,388	(197.32)	877.04	(107.69)	(20.67)	(1.53)
Δa^c	2,388	0.41%	23.49%	-9.19%	0.55%	10.49%
Δa^e	2,388	0.41%	17.68%	-6.80%	0.75%	8.28%
Δi	2,388	0.45%	17.90%	-4.90%	0.97%	6.08%
China	N	Mean	Std Dev	Q1	Median	Q3
Sales	1,993	1,619.57	13,302.77	109.51	251.90	679.81
Capital	1,993	1,348.32	11,972.51	67.14	162.63	470.12
Profit	1,993	74.97	609.97	4.12	13.80	39.70
Accruals	1,993	(62.65)	718.35	(31.24)	(4.88)	9.06
Δa^c	1,993	-0.64%	44.93%	-22.69%	-2.95%	19.24%
Δa^e	1,993	-0.60%	25.24%	-14.51%	0.98%	12.72%
Δi	1,993	1.13%	25.88%	-7.59%	3.67%	10.71%
India	N	Mean	Std Dev	Q1	Median	Q3
Sales	1,742	478.78	3,093.27	15.21	53.10	188.14
Capital	1,742	369.92	2,159.97	8.38	30.18	101.22
Profit	1,742	29.63	212.57	0.08	1.27	8.12
Accruals	1,742	(7.42)	183.80	(5.77)	(0.64)	1.01
Δa^c	1,742	-0.72%	43.61%	-22.90%	-3.51%	17.48%
Δa^e	1,742	1.82%	28.99%	-10.04%	3.02%	15.31%
Δi	1,742	-0.57%	23.73%	-6.59%	0.12%	5.96%

Table 3: Moment Conditions

This table provides information about the comparison between empirical and simulated moments and model fit. a^c_{it} and a^e_{it} are cash-flow- and accounting-earnings-based productivity: $a^c_{it} = a_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + a^{ae}_{it}$. Cash flow and accounting earnings are transformed into imperfect measures of productivity: $a^c_{it} + Constant = va^c_{it} - \hat{\alpha} k_{it}$, $a^e_{it} + Constant = va^e_{it} - \hat{\alpha} k_{it}$. The value added for accounting earnings is calculated as 50% of sales to exclude costs of intermediate inputs from sales. The value added for cash flow is measured by the following: $VA^c_{it} = VA^e_{it} - AC_{it}$, where VA^c_{it} and VA^e_{it} are the value added for cash flow and accounting earnings, respectively. i is investment measured as the first difference of capital stock. I use gross property, plant and equipment (PP&E) to measure capital stock. s_{it} is all other information about productivity: $s_{it} = a_{it+1} + a^s_{it}$. σ^2_{ac}, σ^2_{ae}, and σ^2_s are the variance of noise in cash flow, accounting earnings, and all other information, respectively. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables. The standard errors are reported in parentheses except in the last row in which the p-values are reported in parentheses.

Moment	US		China		India	
	Empirical	Simulated	Empirical	Simulated	Empirical	Simulated
$corr(a^c_{it}, a^c_{it-1})$	0.9660	0.9616	0.8598	0.8557	0.8681	0.8574
	(0.0295)		(0.0324)		(0.0340)	
$corr(a^e_{it}, a^e_{it-1})$	0.9833	0.9778	0.9558	0.9514	0.9491	0.9327
	(0.0314)		(0.0337)		(0.0372)	
$cov(\Delta a^c_{it}, \Delta a^e_{it})$	0.0238	0.0238	0.0311	0.0320	0.0584	0.0586
	(0.0018)		(0.0036)		(0.0052)	
$var(\Delta a^c_{it})$	0.0551	0.0552	0.2017	0.2045	0.1901	0.1909
	(0.0032)		(0.0104)		(0.0106)	
$var(\Delta a^e_{it})$	0.0313	0.0312	0.0637	0.0618	0.0840	0.0829
	(0.0018)		(0.0031)		(0.0057)	
$corr(\Delta i_{it+1}, \Delta a^c_{it})$	0.2120	0.2136	0.0838	0.1448	0.2248	0.2317
	(0.0348)		(0.0301)		(0.0376)	
$corr(\Delta i_{it+1}, \Delta a^e_{it})$	0.2889	0.2880	0.3115	0.2716	0.3637	0.3595
	(0.0385)		(0.0380)		(0.0482)	
J statistic	0.0433		8.2609		0.4248	
	(0.9786)		(0.0161)		(0.8086)	

Table 4: Parameter Values

This table contains the estimated parameter values. The estimation uses data from three countries. The parameters are estimated using SMM. a^c_{it} and a^e_{it} are cash-flow- and accounting-earnings-based productivity: $a^c_{it} = a_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + a^{ae}_{it}$. Productivity, a_{it}, follows an AR(1) model: $a_{it} = (1-\rho)\overline{a} + \rho a_{it-1} + \epsilon_{it}$. ρ is the persistence of productivity. σ^2 is the volatility of innovation in productivity. σ^2_a is the volatility of productivity. s_{it} is all other information about productivity: $s_{it} = a_{it+1} + a^s_{it}$. σ^2_{ac}, σ^2_{ae}, and σ^2_s are the variance of noise in cash flow, accounting earnings, and all other information, respectively. $\overline{V}$ is a summary measure of informational frictions (or the conditional variance of future productivity): $\overline{V} = \rho^2(\frac{\sigma^2_s}{\sigma^2+\sigma^2_s})^2 \frac{\overline{V}\sigma^2_{ae}\sigma^2_{ac}(\sigma^2+\sigma^2_s)}{\overline{V}(\sigma^2_{ae}+\sigma^2_{ac})(\sigma^2+\sigma^2_s)+\sigma^2_{ae}\sigma^2_{ac}(\sigma^2+\sigma^2_s+\rho^2\overline{V})} + \frac{\sigma^2\sigma^2_s}{\sigma^2+\sigma^2_s}$. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables. The standard errors are reported in parentheses.

Country	ρ	σ	σ_{a_c}	σ_{a_e}	σ_s	$\overline{V}$	$\sqrt{\overline{V}}$	$\frac{\overline{V}}{\sigma^2_a}$
US	0.9837	0.1522	0.1249	0.0617	0.2206	0.0168	0.1296	2.35%
	(0.0075)	(0.0015)	(0.0007)	(0.0018)	(0.0080)	(0.0016)	(0.0061)	
China	0.9749	0.1764	0.2925	0.1236	0.2439	0.0236	0.1536	3.76%
	(0.0052)	(0.0052)	(0.0017)	(0.0034)	(0.0103)	(0.0028)	(0.0092)	
India	0.9530	0.2367	0.2559	0.1116	0.3826	0.0444	0.2107	7.27%
	(0.0105)	(0.0044)	(0.0019)	(0.0048)	(0.0320)	(0.0050)	(0.0120)	

Table 5: The Impact of Accrual Accounting Information on Aggregate Productivity and Output

This table shows the impact of accrual accounting information on aggregate productivity and output. $\overline{V}$ is a summary measure of informational frictions (or the conditional variance of future productivity). To estimate the impact of accrual accounting systems on aggregate productivity and output, I first calculate a hypothetical conditional variance of future productivity, $\tilde{V}$, based on a counterfactual value of the quality of accounting earnings and the estimated values of the other parameters using the following equation: $\tilde{V} = \rho^2(\frac{\sigma_s^2}{\sigma^2+\sigma_s^2})^2 \frac{\tilde{V}\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2)}{\tilde{V}(\sigma_{ae}^2+\sigma_{ac}^2)(\sigma^2+\sigma_s^2)+\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2+\rho^2\tilde{V})} + \frac{\sigma^2\sigma_s^2}{\sigma^2+\sigma_s^2}$. Second, I use the difference between $\overline{V}$ and $\tilde{V}$ to exploit the following equations: $\frac{da}{d\overline{V}} = -\frac{1}{2}\theta$ and $\frac{dy}{d\overline{V}} = -\frac{1}{2}\theta\frac{1}{1-\alpha_1}$. a is the aggregate productivity. y is the aggregate output. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables.

Country	$\Delta\overline{V}$	Δa	Δy
US	-0.0023	0.69%	1.03%
China	-0.0038	1.15%	1.72%
India	-0.0084	2.52%	3.76%

Table 6: The Impact of "US-quality" Accrual Accounting Information on Aggregate Productivity and Output

This table shows the impact of "US-quality" accrual accounting information on aggregate productivity and output. $\overline{V}$ is a summary measure of informational frictions (or the conditional variance of future productivity). To estimate the impact of accrual accounting systems on aggregate productivity and output, I first calculate a hypothetical conditional variance of future productivity, $\tilde{V}$, based on a counterfactual value of the quality of accounting earnings and the estimated values of the other parameters using the following equation: $\tilde{V} = \rho^2(\frac{\sigma_s^2}{\sigma^2+\sigma_s^2})^2 \frac{\tilde{V}\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2)}{\tilde{V}(\sigma_{ae}^2+\sigma_{ac}^2)(\sigma^2+\sigma_s^2)+\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2+\rho^2\tilde{V})} + \frac{\sigma^2\sigma_s^2}{\sigma^2+\sigma_s^2}$. Second, I use the difference between $\overline{V}$ and $\tilde{V}$ to exploit the following equations: $\frac{da}{d\overline{V}} = -\frac{1}{2}\theta$ and $\frac{dy}{d\overline{V}} = -\frac{1}{2}\theta\frac{1}{1-\alpha_1}$. a is the aggregate productivity. y is the aggregate output. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables.

Country	$\Delta\overline{V}$	Δa	Δy
China	-0.0019	0.57%	0.85%
India	-0.0023	0.70%	1.04%

Table 7: Different Specifications of Accounting Properties

This table shows how the estimates for the impact of accrual accounting on aggregate productivity and output change under different specifications of accounting properties. a^c_{it} and a^e_{it} are cash-flow- and accounting-earnings-based productivity: In Panel A, $a^c_{it} = a_{it} + \xi^c \epsilon_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + \xi^e \epsilon_{it} + a^{ae}_{it}$. σ_{ac} and σ_{ae} are the standard deviations of noise in cash flow and accounting earnings. ξ^c and ξ^e reflect the relation of productivity shocks with cash flow and accounting earnings. In Panel B, $a^c_{it} = a_{it} + a^{ce}_{it} + a^{ac}_{it}$ and $a^e_{it} = a_{it} + a^{ce}_{it} + a^{ae}_{it}$. σ_{ac} and σ_{ae} are the standard deviations of noise in cash flow and accounting earnings. a^{ce}_{it} reflects common errors in cash flow and accounting earnings that are unrelated to productivity shocks. Productivity, a_{it}, follows an AR(1) model: $a_{it} = (1-\rho)\overline{a} + \rho a_{it-1} + \epsilon_{it}$. ρ is the persistence of productivity. σ^2 is the volatility of innovation in productivity. s_{it} is all other information about productivity: $s_{it} = a_{it+1} + a^s_{it}$. σ^2_{ac}, σ^2_{ae}, and σ^2_s are the variance of noise in cash flow, accounting earnings, and all other information, respectively. $\overline{V}$ is a summary measure of informational frictions (or the conditional variance of future productivity). To estimate the impact of accrual accounting systems on aggregate productivity and output, I first calculate a hypothetical conditional variance of future productivity, $\tilde{V}$, based on a counterfactual value of the quality of accounting earnings and the estimated values of the other parameters using the following equation: $\tilde{V} = \rho^2(\frac{\sigma^2_s}{\sigma^2+\sigma^2_s})^2 \frac{\tilde{V}\sigma^2_{ae}\sigma^2_{ac}(\sigma^2+\sigma^2_s)}{\tilde{V}(\sigma^2_{ae}+\sigma^2_{ac})(\sigma^2+\sigma^2_s)+\sigma^2_{ae}\sigma^2_{ac}(\sigma^2+\sigma^2_s+\rho^2\tilde{V})} + \frac{\sigma^2\sigma^2_s}{\sigma^2+\sigma^2_s}$. Second, I use the difference between $\overline{V}$ and $\tilde{V}$ to exploit the following equations: $\frac{da}{d\overline{V}} = -\frac{1}{2}\theta$ and $\frac{dy}{d\overline{V}} = -\frac{1}{2}\theta\frac{1}{1-\alpha_1}$. a is the aggregate productivity. y is the aggregate output. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables.

Panel A: $\xi^c \neq 0, \xi^e \neq 0$							
Country	σ_{ac}	σ_{ae}	ξ^c	ξ^e	$\Delta\overline{V}$	Δa	Δy
US	0.1215	0.0566	-0.0346	-0.0194	0.0026	0.78%	1.16%
China	0.2921	0.1050	-0.3089	-0.0628	0.0082	2.46%	3.67%
India	0.2477	0.1055	-0.3185	-0.2983	0.0219	6.57%	9.81%
Panel B: $a^{ce}_{it} \neq 0$							
Country	σ_{ac}	σ_{ae}	σ_{ace}		$\Delta\overline{V}$	Δa	Δy
US	0.1222	0.0570	0.0009		0.0025	0.75%	1.12%
China	0.2886	0.1177	0.0000		0.0042	1.26%	1.88%
India	0.2478	0.1007	0.0000		0.0096	2.88%	4.30%

Table 8: Sensitivity Tests

This table shows the sensitivity tests. θ is the elasticity of substitution. a_{it}^c and a_{it}^e are cash-flow- and accounting-earnings-based productivity: $a_{it}^c = a_{it} + a_{it}^{ac}$ and $a_{it}^e = a_{it} + a_{it}^{ae}$. σ_{ac} and σ_{ae} are the standard deviations of noise in cash flow and accounting earnings. Productivity, a_{it}, follows an AR(1) model: $a_{it} = (1-\rho)\overline{a} + \rho a_{it-1} + \epsilon_{it}$. ρ is the persistence of productivity. σ^2 is the volatility of innovation in productivity. s_{it} is all other information about productivity: $s_{it} = a_{it+1} + a_{it}^s$. σ_{ac}^2, σ_{ae}^2, and σ_s^2 are the variance of noise in cash flow, accounting earnings, and all other information, respectively. $\overline{V}$ is a summary measure of informational frictions (or the conditional variance of future productivity). To estimate the impact of accrual accounting systems on aggregate productivity and output, I first calculate a hypothetical conditional variance of future productivity, $\tilde{V}$, based on a counterfactual value of the quality of accounting earnings and the estimated values of the other parameters using the following equation: $\tilde{V} = \rho^2(\frac{\sigma_s^2}{\sigma^2+\sigma_s^2})^2 \frac{\tilde{V}\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2)}{\tilde{V}(\sigma_{ae}^2+\sigma_{ac}^2)(\sigma^2+\sigma_s^2)+\sigma_{ae}^2\sigma_{ac}^2(\sigma^2+\sigma_s^2+\rho^2\tilde{V})} + \frac{\sigma^2\sigma_s^2}{\sigma^2+\sigma_s^2}$. Second, I use the difference between $\overline{V}$ and $\tilde{V}$ to exploit the following equations: $\frac{da}{d\overline{V}} = -\frac{1}{2}\theta$ and $\frac{dy}{d\overline{V}} = -\frac{1}{2}\theta\frac{1}{1-\alpha_1}$. a is the aggregate productivity. y is the aggregate output. The sample firms are public firms in the United States, China, and India in 2012. I demean variables controlling for a year fixed effect. I exclude the top and bottom 1% extreme observations for variables.

Panel A: $\theta = 4$					
Country	σ_{ac}	σ_{ae}	$\Delta\overline{V}$	Δa	Δy
US	0.1244	0.0613	0.0020	0.40%	0.60%
China	0.2958	0.1208	0.0032	0.64%	0.96%
India	0.2614	0.1137	0.0075	1.50%	2.24%
Panel B: $\theta = 8$					
Country	σ_{ac}	σ_{ae}	$\Delta\overline{V}$	Δa	Δy
US	0.1246	0.0618	0.0025	1.00%	1.49%
China	0.2926	0.1268	0.0039	1.56%	2.33%
India	0.2573	0.1102	0.0087	3.48%	5.19%