Productivity Volatility and the Misallocation of Resources in Developing Economies

Allan Collard-Wexler and John Asker and Jan De Loecker
NYU Stern- Princeton & NBER

April 10, 2012
Poland

kernel = epanechnikov, bandwidth = 0.1915

Tanzania

kernel = epanechnikov, bandwidth = 0.3618
• There exist *large* differences in firm performance within narrow defined industries at any point in time (2 JEL’s: Bartelsman and Doms (2000) and Syverson (2011)).
• Dispersion across firms does vary across countries.
• Performance typically measured in *sales per input* or *TFPR*.
Motivation: Misallocation

• Work of Olley and Pakes (1996) as well as Bartelsmann, Haltiwanger and Scarpetta (2009) show that the allocation of output to firms has a first order role in explaining industry-level productivity growth.

• Hsieh and Klenow (2009) build a model to quantify possible welfare effects of misallocation, differences in the marginal product of capital between plants at the national level.

• Model Stylized Fact 1: The alignment between inputs and productivity has a first-order impact on welfare.
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- **Model Stylized Fact 1**: The alignment between inputs and productivity has a first-order impact on welfare.
Motivation: Volatility

- Collard-Wexler (2011) Plant Entry and Exit in Ready-Mix Concrete based on Productivity: role of productivity variability.
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Motivation: Volatility

- Collard-Wexler (2011) Plant Entry and Exit in Ready-Mix Concrete based on Productivity: role of productivity variability.
- **Could differences in volatility explain differences in the extent of misallocation?**
1. There are differences in the size of productivity shocks in different countries.

2. These volatility differences translate into a cross-sectional difference in the dispersion of productivity.

3. With adjustment costs, productivity volatility gives rise to misallocation, the failure of the $MRP_K$ (measured by the output capital ratio) to equalize across establishments in a country.

4. We find that the combination of adjustment costs and volatility differences can replicate cross-country differences in productivity dispersion and misallocation.
Volatility Channel vs Adjustment Cost Channel

- Reallocation Adverse Policies: in countries with policies that hinder reallocation we will see more misallocation.
- Volatility Channel: countries with the most misallocation also have the largest changes in employment and capital.
Data and Measurement
Data

• Data from the World Bank’s Enterprise Research datasets on 41 countries for 70,000 establishments (2001-2006).

• Three year panel on production variables (these questions are not consistently part of the questionnaire) for 5,010 establishments in 33 countries.

• Additional Manufacturing Census Data for Mexico, Columbia, Chile, India, Slovenia, and Survey Data for 4 Sub-Saharan African countries (Ghana, South Africa, Kenya and Tanzania).
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Productivity Measurement

Output is generated using a Leontief in Materials, Cobb-Douglas in Capital-Labor production function:

\[ Q_{ict} = \min \left( A_{ict} K_{ict}^{\alpha_K} L_{ict}^{\alpha_L}, f(M) \right) \]  

(1)

and thus at the cost minimizing material bundle:

\[ Q_{ict} = A_{ict} K_{ict}^{\alpha_K} L_{ict}^{\alpha_L} \]  

(2)

Demand is given by an isoelastic residual demand curve.

\[ Q_{ict} = B_{ict} P_{ict}^{-\epsilon} \]  

(3)

Revenue function:

\[ S_{ict} = Y_{ict} K_{ict}^{\beta_K} L_{ict}^{\beta_L} \]  

(4)

where \( Y_{ict} = A_{ict}^{1-\frac{1}{\epsilon}} B_{ict}^{\frac{1}{\epsilon}} \), and \( \beta_X = \alpha_X (1 - \frac{1}{\epsilon}) \).
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where \( Y_{ict} = A_{ict}^{1-\frac{1}{\epsilon}} B_{ict}^{\frac{1}{\epsilon}} \), and \( \beta_X = \alpha_X (1 - \frac{1}{\epsilon}) \).
• Static Marginal Revenue Product of Capital is:

\[
\frac{\partial S_{it}}{\partial K} = \beta_K \frac{S_{it}}{K_{it}}
\]

• Obtain \( \beta_L \) and \( \beta_K \) from profit maximization’s implications for the labor costs share, and constant returns to scale.

• Specifically: Profit Max implies that

\[
\beta_L = \frac{w_{ct}L_{ict}}{S_{ict}}
\]

We allow \( \beta_L \) to vary at the level of a sector within a country to allow for flexibility in the production function.
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## Summary Statistics

<table>
<thead>
<tr>
<th>Establishment Level Data</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>N</th>
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<tbody>
<tr>
<td>Log Sales</td>
<td>7.1</td>
<td>3.1</td>
<td>-5.6</td>
<td>22.3</td>
<td>5010</td>
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<tr>
<td>Log Capital</td>
<td>7</td>
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<td>22.5</td>
<td>5010</td>
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<td>Workers</td>
<td>261.3</td>
<td>840.1</td>
<td>1</td>
<td>23385</td>
<td>5010</td>
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<tr>
<td>Productivity</td>
<td>0.7</td>
<td>1.1</td>
<td>-5.8</td>
<td>5.9</td>
<td>5010</td>
</tr>
<tr>
<td>Zero Investment</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>1</td>
<td>5010</td>
</tr>
<tr>
<td>Change in Sales</td>
<td>0.1</td>
<td>0.6</td>
<td>-7.6</td>
<td>7.1</td>
<td>5010</td>
</tr>
<tr>
<td>Change in Capital</td>
<td>0.1</td>
<td>0.5</td>
<td>-4.4</td>
<td>8.7</td>
<td>5010</td>
</tr>
<tr>
<td>Change in Productivity</td>
<td>0</td>
<td>0.6</td>
<td>-7.9</td>
<td>7.2</td>
<td>5010</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country Level Data</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishments per Country</td>
<td>151.8</td>
<td>147</td>
<td>5</td>
<td>734</td>
<td>33</td>
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<tr>
<td>Std. Productivity (Dispersion)</td>
<td>0.9</td>
<td>0.3</td>
<td>0.4</td>
<td>1.5</td>
<td>33</td>
</tr>
<tr>
<td>Std. Change of Productivity (Volatility)</td>
<td>0.6</td>
<td>0.2</td>
<td>0.2</td>
<td>1.1</td>
<td>33</td>
</tr>
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</table>
## Productivity Dispersion and Volatility

<table>
<thead>
<tr>
<th>Specification</th>
<th>I</th>
<th>II (unweighted)</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Var:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\text{Std.}[y_{ict} - y_{ict-1}])</td>
<td>0.57***</td>
<td>0.58***</td>
<td>0.56***</td>
<td>0.58***</td>
</tr>
<tr>
<td></td>
<td>(0.20)</td>
<td>(0.23)</td>
<td>(0.19)</td>
<td>(0.17)</td>
</tr>
<tr>
<td>(\text{Log Assets} (t - 1))</td>
<td></td>
<td></td>
<td></td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.01)</td>
</tr>
<tr>
<td>(\text{Constant})</td>
<td>0.65***</td>
<td>0.63***</td>
<td>0.65***</td>
<td>0.67***</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.13)</td>
<td>(0.11)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>(\text{Industry FE})</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>(\text{Establishments})</td>
<td>5010</td>
<td>5010</td>
<td>5010</td>
<td>5010</td>
</tr>
<tr>
<td>(\text{Countries})</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>(\text{R-Squared})</td>
<td>.26</td>
<td>.24</td>
<td>.31</td>
<td>.32</td>
</tr>
</tbody>
</table>

Note: All columns show regressions on country level aggregates weighted by the number of establishments per country. Sampling error is accounted for using a bootstrap procedure where \(\text{Std.}y_{ict}\) and \(\text{Std.}[y_{ict} - y_{ict-1}]\) are recomputed for each bootstrap replication (200 bootstrap replications are used).
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<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Var:</td>
<td></td>
<td>Standard Deviation of $s_{ict} - k_{ict}$, by country</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std.$[y_{ict} - y_{ict-1}]$</td>
<td>0.65** (0.22)</td>
<td>0.74*** (0.22)</td>
<td>0.63** (0.23)</td>
<td>0.66** (0.22)</td>
</tr>
<tr>
<td>Log Assets ($t - 1$)</td>
<td></td>
<td></td>
<td>-0.01 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.70*** (0.12)</td>
<td>0.65*** (0.13)</td>
<td>0.70*** (0.13)</td>
<td>0.74*** (0.13)</td>
</tr>
<tr>
<td>Industry FE</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Establishments</td>
<td>5010</td>
<td>5010</td>
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</tr>
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<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>R-Squared</td>
<td>.23</td>
<td>.33</td>
<td>.29</td>
<td>.30</td>
</tr>
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<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Var:</strong></td>
<td>Standard Deviation of $y_{ict}$, by industry-country</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std.$[y_{ict} - y_{ict-1}]$</td>
<td>0.41*** (0.08)</td>
<td>0.41*** (0.07)</td>
<td>0.34*** (0.09)</td>
<td>0.34*** (0.09)</td>
</tr>
<tr>
<td>Log Capital</td>
<td>-0.00 (0.00)</td>
<td>0.00 (0.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td>-0.03*** (0.01)</td>
<td>-0.01* (0.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry FE</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country FE</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.69*** (0.05)</td>
<td>0.71*** (0.05)</td>
<td>0.64*** (0.05)</td>
<td>0.65*** (0.05)</td>
</tr>
<tr>
<td>Observations</td>
<td>4983</td>
<td>4983</td>
<td>4983</td>
<td>4983</td>
</tr>
<tr>
<td>Country-Industry</td>
<td>236</td>
<td>236</td>
<td>236</td>
<td>236</td>
</tr>
<tr>
<td>R-Squared</td>
<td>.12</td>
<td>.13</td>
<td>.55</td>
<td>.55</td>
</tr>
</tbody>
</table>
Robustness

- Alternative Productivity Measures: gross-output Cobb-Douglas with material, labor and capital; value added production function.
- Auxiliary Data.
## Country-Industry Results: Auxiliary Data

<table>
<thead>
<tr>
<th>Specification</th>
<th>W-B</th>
<th>Mexico</th>
<th>Chile</th>
<th>India</th>
<th>Slovenia</th>
<th>Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Var:</strong></td>
<td></td>
<td>Standard Deviation of $y_{ict}$, by industry-country</td>
<td></td>
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<td></td>
<td></td>
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<td>0.27***</td>
<td>0.37***</td>
<td>0.36***</td>
<td>0.22*</td>
<td>0.33***</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.05)</td>
<td>(0.15)</td>
<td>(0.01)</td>
<td>(0.10)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Country FE</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry FE</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>4983</td>
<td>16227</td>
<td>22662</td>
<td>24927</td>
<td>21765</td>
<td>2827</td>
</tr>
</tbody>
</table>
Model
• Rely on a dynamic investment model allowing for a study of the link between productivity volatility and dispersion, and revisit the static FOC of capital.

• Take the productivity model and incorporate it in textbook model of investment (Dixit and Pindyck 1994), and in particular Bloom (2009):

• The point is not that this is the most complete model, rather what is the minimal structure we need to focus on role of dynamic inputs of production.

• This structure will allow us to compute out the optimal dispersion we see in an industry, and confront this with the data to learn about the importance of the adjustment cost mechanism.
Introducing Adjustment Costs

- We use Bloom’s 3 components of adjustment costs: 1) Fixed Costs, 2) Irreversible Investment, 3) Convex Adjustment Costs. No labor adjustment costs.

\[
C(I_{it}, K_{it}, \Omega_{it}) = C^F_K 1(I_{it} \neq 0) \pi(\Omega_{it}, K_{it}) \\
+ I_{it}^+ - (1 - C^P_K)I_{it}^- \\
+ C^Q_K K_{it} \left( \frac{I_{it}}{K_{it}} \right)^2
\]

- where capital depreciates in a standard fashion

\[K_{ict+1} = (1 - \delta)K_{ict} + I_{ict}\]
• The producer-level shock $\Omega_{it}$ contains both demand and efficiency shocks.

• Suppose that $\Omega_{it}$ follows an AR(1) process with normally distributed shocks $\nu_{it}$ given by:

$$\ln(\Omega_{it}) = \mu + \rho_c \ln(\Omega_{it-1}) + \sigma_c \nu_{it}$$
Dynamic Programming Problem

\[
V(\Omega_{ict}, K_{ict}) = \max_{I_{ict}} \pi(\Omega_{ict}, K_{ict}) - C(I_{ict}, K_{ict}, \Omega_{ict})
\]

\[
+ \beta \int_{\Omega_{ict+1}} V(\Omega_{ict+1}, \delta K_{ict} + I_{ict}) \phi(\Omega_{ict+1} | \Omega_{ict}, \rho, \mu, \sigma_c) d\Omega_{ict+1}
\]

- which will generate an optimal investment and a cross-sectional dispersion (Ergodic Distribution)

\[
\text{Std.} \omega_{it} = \frac{\sigma}{\sqrt{1 - \rho^2}} \tag{5}
\]

- where \( \omega_{it} = \ln(\Omega_{it}) \)
## Calibration: parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha = \frac{1}{3})</td>
<td></td>
</tr>
<tr>
<td>(\epsilon = -4)</td>
<td></td>
</tr>
<tr>
<td>(\delta = 10%)</td>
<td></td>
</tr>
<tr>
<td>(\beta = \frac{1}{1+6.5%})</td>
<td></td>
</tr>
<tr>
<td>(C_K^P = 42.7%)</td>
<td>Values taken from Bloom (2009).</td>
</tr>
<tr>
<td>(C_K^F = 1.1%)</td>
<td></td>
</tr>
<tr>
<td>(C_K^Q = 0.996)</td>
<td></td>
</tr>
<tr>
<td>(\rho \in {0.754, 0.865, 0.968})</td>
<td></td>
</tr>
<tr>
<td>(\mu = 0.13)</td>
<td>Values taken from specification V in Table 8. Values for (\rho) correspond to values for Moldova, Tanzania, and Nicaragua respectively.</td>
</tr>
<tr>
<td>(\sigma \in [0.1, 1.4])</td>
<td></td>
</tr>
</tbody>
</table>
1. Solve the model (on a grid).
2. Simulate paths of 10,000 firms for 1000 months.
3. We show summary statistics for the last period in the simulation (steady-state).
Panel 1: Dispersion in the static MRPK

- Rho = 0.968
- Rho = 0.865
- Rho = 0.754
Panel 2: Dispersion in productivity

Dispersion Volatility Relationship
Panel 4: Dispersion of the change in capital

\[
\text{Std}(\ln(k_t) - \ln(k_{t-1}))
\]

Sigma
Panel 5: Proportion of establishments with zero investment in a year
How do these predictions from the model do against the data?
Confronting the model’s predictions to data

- How do these predictions from the model do against the data?
- Compute model using two parameters per country \((\rho, \sigma)\), and use common parameters everywhere else.
- To the extent that we can explain differences in dispersion: completely determined by the differences in persistence and volatility in the underlying productivity process.
- We first estimate \((\rho, \sigma)\) for each country.
### AR Process for Productivity

<table>
<thead>
<tr>
<th>Dependent Var: ( \omega_{it} )</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \omega_{it-1} )</td>
<td>0.83***</td>
<td>0.88***</td>
<td>0.87***</td>
<td>0.90***</td>
<td>0.84***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.04)</td>
<td>(0.02)</td>
<td>(0.04)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>( (\omega_{it-1}) \bullet ) (Country Dummy) Var.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \omega_{it-1}^2, \omega_{it-1}^3, \omega_{it-1}^4 ), Constant</td>
<td>0.15***</td>
<td>0.12***</td>
<td>0.13***</td>
<td>0.10***</td>
<td>0.13***</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
</tr>
<tr>
<td><strong>Variance ( \sigma )</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
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<td>0.66***</td>
<td>0.66***</td>
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<tr>
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<td>(0.04)</td>
<td>(0.00)</td>
<td>(0.01)</td>
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<td>Country Specific Variance Var.</td>
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<td>-4468</td>
<td>-4055</td>
<td>-4026</td>
<td>-3985</td>
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</tbody>
</table>
Misallocation Volatility Relationship

Panel 1: Dispersion in the static MRPK
Panel 4: Standard deviation of change in capital
Panel 5: Proportion of establishments with zero investment
Model Fit

- Let $x$ be data, and $\hat{x}$ the corresponding predicted value by our model, then we can measure the extent to which the variation in the data.

- Sum of squared errors explained by the model (note that this number can be negative):

$$S^2 = 1 - \frac{(x - \hat{x})(x - \hat{x})}{x'x}$$

<table>
<thead>
<tr>
<th></th>
<th>Full Model</th>
<th>Zero Adj. Costs</th>
<th>$(\rho, \sigma)$</th>
</tr>
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<tbody>
<tr>
<td>P. 1: Dispersion MRPK</td>
<td>0.610</td>
<td>0.597</td>
<td>0.827</td>
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<td>P. 2: Productivity dispersion</td>
<td>0.686</td>
<td>0.682</td>
<td>0.920</td>
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<td>P. 3: Std. of change MRPK</td>
<td>0.284</td>
<td>0.938</td>
<td>0.107</td>
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<td>P. 4: Std. of change in capital</td>
<td>0.735</td>
<td>-10.715</td>
<td>0.597</td>
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<tr>
<td>P. 5: Zero investment</td>
<td>0.821</td>
<td>0.304</td>
<td>0.746</td>
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Discussion of results

• The dynamic process underlying productivity can generate cross-sectional dispersion of productivity and capital allocation. Our results suggest it’s a first-order determinant of differences in productivity and, hence, income across countries.

• Conclusions regarding welfare and policy depend on the view of this dynamic process, i.e. whether we think it’s policy variant.

• TFP is residual of a sales generating production function and therefore captures physical productivity and demand side factors.

• To the extent that policy can induce a more predictable business environment, that would be welfare improving. Otherwise firms in our sample seem to be behaving in an optimal way.
• As in any producer-level dataset we face issues of measurement. An obvious concern is that variables used to recover productivity contain measurement error, this would lead to a correlation between dispersion and volatility, and even in the MRP of capital.

• The measurement error structure required to generate pattern in the data is very specific, and would need to generate cross-country differences in persistence as well.

\[ \hat{\omega}_{ict} = \mu + \eta_{ict} \]  \hspace{1cm} (6)

\[ \eta_{ict} = \rho_c \eta_{ict-1} + \sigma_c \nu_{ict} \]  \hspace{1cm} (7)
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The measurement error structure required to generate pattern in the data is very specific, and would need to generate cross-country differences in persistence as well.

\[
\hat{\omega}_{ict} = \mu + \eta_{ict} \tag{6}
\]

\[
\eta_{ict} = \rho_c \eta_{ict-1} + \sigma_c \nu_{ict} \tag{7}
\]
Frisch Bracketing

- What about measurement error in inputs such as capital?
- Define inputs as:

\[ \text{inputs} = \log (K^{\alpha_k} L^{\alpha_l} M^{\alpha_m}) \]

- We can run the following regressions of inputs on outputs and vice-versa:

\[
\begin{align*}
    s_{it} &= \alpha_i i_{it} + \epsilon_{it}^s \\
    i_{it} &= \beta s_{it} + \epsilon_{it}^i
\end{align*}
\]  \hspace{1cm} (8)

- Denote the measurement error in \( i \) as \( \sigma_{\nu i} \) and the measurement error in \( s \) as \( \sigma_{\nu s} \). Notice that \( \hat{\alpha} \rightarrow \alpha \frac{\sigma_i^2}{\sigma_i^2 + \sigma_{\nu i}^2} \) and \( \hat{\beta} \rightarrow \frac{1}{\alpha} \frac{\sigma_s^2}{\sigma_s^2 + \sigma_{\nu s}^2} \)
Conclusion
Conclusion 1

- Large Differences in Productivity Volatility.
- With adjustment costs, these differences in volatility translate into differences in $MRP_K$, or misallocation.
- Different Dispersion Levels is no evidence for policies that hinder allocation of resources: it’s what the Social Planner would do.
Conclusion 2

- Silent on where do adjustment costs come from (technology vs policy).
- Silent on what causes these differences and magnitudes of productivity shocks in the first place:
  - Efficiency changes.
  - Demand Shocks.
  - Markup Heterogeneity.
- Open question is what could be done to moderate productivity shocks.
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