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Micro Growth Accounting (MGA)

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1. Introduction

The Gross Solow's Residual (GRS) estimated at the aggregate level did already give a big push to the search of the engines of growth and building of growth models. First, the GSR was positively associated to the GDP growth. Second, the measurement connection of the labor and capital inputs identified quality improvements in both inputs which were connected to different engines of growth. Then, the sectorial GSR estimates offered new insights too. It shows the GSR process varies through sectors and time periods, which suggested that we may need a more complicated analysis, rather than assuming a smooth path of technological change.

The GSR at firm level provides additional information that could help in this endeavor. Some useful results were obtained already. One of them is that we need to understand better what is happening within the firms, rather than between them due to a sectorial behavior. It looks that the sector analysis could have the same shortcut than the aggregate approach.

In this paper we want to analyze the characteristics that present the frequency distribution of the GSR at firms' level for each sector and its behavior through time. We want to analyze characteristics as variance, asymmetry, and kurtosis that gave interesting insights at the start of the analysis of the personal income and firm size distributions. In paying attention to the frequency distribution of firms' GSR for each sector and different periods of time we have at least two alternatives. One is to look at the regular frequency distribution without separating by its ranking in productivity levels, and the other separating the firms according to its position at the productivity frontier, or other characteristics. The last one mainly looks at the convergence behavior. We think that both approaches provide useful insights about the growth process, which could come from inside and outside the firms.

There are already many interesting papers analyzing the TFP (Total Factor Productivity) at firm level for many countries, which will be taken as the basis for the first step of our study. They cover mainly United States, France, Australia, Chile, and Israel. These studies include also an analysis of the levels of the TFP and provide a degree of association of TFP with some variables like firm size, dynamics of the firm entry and exit, labor regulation, intangible capital, innovation, demand complementarity, and foreign trade, which we do not consider in this paper. In the next Sections (2 to 8) we present some of the results of these studies relevant for our approach and it will become more clear our objectives. Other micro indicators, such as input prices at firm level, could complement the GSR information.

2. Learning from previous works: The Griliches-Regev longitudinal panel of Israel manufacturing firms, 1955-1999

In their work (Griliches & Regev, 1995) the 1305 continuing firms for the period 1979-1988 are classified by branch groups, scales, sectors, and establishment years. The biggest TFP growth are observed for the electronic and electric branch group, for the highest scales firms (300 and more workers per firm), for the public sector, and for the 30 years of oldest. The aggregate annual TFP growth was almost 1%. For almost all the classification there are big differences in the TFP growth rates except for establishment years (except for the oldest from 1950).

An evaluation of the degree of dispersion of firms TFP growth rate through time, could be get by comparing the weighted average of TFP growth (0.92) with the unweighted average TFP growth (-0.38). This big difference could imply the existence of a high association between the weights (or sizes) and the TFP growth rates.

The main conclusions of their work are the followings: "Productivity growth in Israel industries was rather slow in the 1980's and only a few industries stood out positively. Among these firms, growth was significantly higher for the R&D and human capital intensive ones. In spite of the large amount of turnover and churning in firms and jobs, most of the productivity growth occurred within firms. Productivity growth in industry as a whole did not come primarily from the exit of failing firms or from faster growth of more productive firms. What happened within firms was decisive and that is also what needs attention if the productivity performance of Israel industries is to improve in the future".

3. Learning from previous works: The experience of France

There are very interesting messages for the micro growth accounting analysis from the work of Garicano, Lelarge and Van Reenen (2016). With firm data they look mainly for the effects of labor regulation on firm sizes, developing an econometric methodology to estimate the threshold produced by the regulation variable according to firm sizes (number of workers by firm). They generate the well-known relationship between TFP and firm size, identifying then the location of the threshold. By affecting the firm size distribution, the labor regulation influences also the firm TFP distribution. They conclude "Productivity appears to rise monotonically with size, although there is more heteroscedasticity for the larger firms as we would expect because there are fewer firms in each ben. The relationship between TFP and size is basically log-linear ... Firms are more likely to stay at size 49 and not grow ..." The existence of heteroscedasticity in the TFP relationship could suggest that firm TFP variability across time could be bigger for the firms with bigger size, which could be important to take into account.

The work by Cette, Corde and Lecat (2017) searches for an explanation of the stagnation of the TFP in France since 2003, after the previous slowdown since 1980, moving from an annual growth rate of 2.1 percent to 1.5 percent. For the period 1991-2012, they present the trend and the dispersion of TFP across firms. We observe a positive trend for the 5 percent most productive firm and a very small positive trend in the 95 percent less productive firms.

They provide estimates of dispersion (inter-quartiles and inter-deciles) of the firms' TFP and labor productivity levels for the period 1991-2013. Both indicators show certain dispersion stability until 2005, then they increase steadily. The inter-quartile dispersion is much bigger for TFP than for labor productivity. This could imply that the covariance between TFP and the capital-labor ratio (K/L) is negative and bigger in absolute value than the dispersion of (K/L). This implication is obtained thinking in the dispersion measured by the variance, which could not be true for inter-quartile measurements (which is an order statistics). The similarity of the inter-decile for TFP and labor productivity could indicate more similar firm behavior for the extreme observation.

Then, convergence indicator shows a decreasing convergence in TFP for almost the whole period, but some constancy in the case of labor productivity, which shows decreasing convergence only for the last 3 years of the period.

4. Learning from previous works: Results for Chile

In the work of Pavcnik (2002) we can find some results for Chile. She studies the evolution of the plant level productivity following trade liberalization. In her work she applies the Olley-Pakes decomposition, where the weighted aggregate productivity is decomposed in the unweighted aggregate productivity and the total covariance between a plant's share of the industry output and its productivity. This decomposition is valid also in terms of productivity growth.

The period analyzed is 1978-1986 for 8 sectors. Even though we observe different trends for the TFP growth across section, the variance across sector shows a declining trend. The covariance component of the Olley-Pakes decomposition is very stable through the period, with difference across sectors, and lower for 1986 compared to 1980.

The correlation between productivity growth and output growth for each sector varies from 0.089 for Wood to 0.226 for Textiles. If we compare the result for the aggregate of the economy this correlation looks very low.

Some of the conclusions are that the trade effect, dynamic of exit and resource reallocations from less to more efficient producers within industries, indicates "... my empirical evidence indicates that channels other than economies of scale yield intra-industry productivity improvements from trade. The incorporation of within industry plant heterogeneity should be a fruitful area for the future theoretical work on welfare gains from trade."

Alvarez and Fuentes (2018) study the effects of economic policies on TFP, putting emphasis on the effects of labor market policies such as the minimum wages. They analyze the period of 1992-2005 covering around 5000 plants. They observed a correlation of 0.67 between TFP and labor productivity at the aggregate level for the period 1993-2005.

The aggregate TFP in Chile increased 35% in the period 1986-1997, and since then stagnated in the period 1997-2005. We observe similar behavior in many countries.

They found that the minimum wage in real terms increased by 22% in the period 1998-2000, reducing the TFP in 5.8%. This negative effect was higher for the firm with more unskilled workers.

5. Learning from previous works: Recent evidences for USA

In the work of Foster, Grim, Haltiwanger and Wolf (2018), they show some of the results that come from a joint effort of the research program at the Center of Economic Studies (CES), combining many sources of microdata information. The analysis of productivity dispersion is connected to productivity growth and innovation, which is very well emphasized. They suggest an improvement in the content of the different surveys, which could be very helpful to microdata research programs. They look at to the different agents that participated in the economic activity. Their message is different to the Griliches-Regev mentioned in the case of Israel. They pointed out that productivity growth engines come not only from within firms. In the final part of their conclusions they express "It is our view that overcoming these conceptual and measurement challenges will involve a multi-dimensional approach. First, is continuing and expanding the integration of both person-level and business-level data. Currently, these include both survey and administrative sources, but they could also include commercial data. Second is continuing efforts to link these data longitudinally and to improve these links. Third, is using a more focused approach to survey content: to use special modules like an Annual Survey of Entrepreneurs (or the forthcoming Annual Business Survey) to ask deeper questions about hard-to-measure concepts such as intent to innovate. Fourth, is using economic relationships between relatively easy-to-measure concepts (such as entry and productivity dispersion) to help to divert our measurement efforts towards areas of the economy where innovation is taking place. The payoff from these efforts could be substantial. It will only be through such efforts that we can understand the complex and noisy process through which innovation leads to productivity and job growth. "... It should also be of interest in this endeavor to analyze the direction of the data gathering by the private sector, which could respond more to market requests.

They highlight the Collaborative Micro Productivity (CMP) project, which seeks to pursue the usefulness of producing higher moments statistics from micro-level data (using productivity as the pilot statistic). They also emphasize the relevance of the improvement of the measures of innovation, needed to relate to the new measurements of productivity behavior. The expansion of the coverage of this data is so big that it could improve the previous efforts on the estimation of rates of return on R&D (see Akcigit, 2019). For the estimate they will combine estimates of TFP's quantity and revenue indicators of output.

As we mentioned before, "understanding high versus low frequency productivity dispersion and productivity of growth dynamics would be another useful area of inquiry." The data coverage is very impressive: 7 million establishments and 6 million firm observations per year of the non-farm business sector for the period 1976-2013. We think that these efforts should also be incorporated in the generation of business cycles indicators.

Looking through some of the results we notice the behavior of Within-Industry Dispersion in Labor Productivity for the period 1997-2013. Young firms present higher dispersion than mature firms, and also a higher positive trend. In mature firms the tech one shows a lower dispersion. Dispersion is measured by the inter-quartile range within industry, labor productivity is measured by log revenue per worker, and the industry is defined at the 4 digit NAICS level. We can also see that the covariance component of the Dynamic Olley-Parks Decomposition of Aggregate Productivity Growth for High Tech industries is declining in the period 1996-2014.

Petrin, White and Reiter (2011), in their work try to identify the shares of plant-level resource reallocation and technical progress on US manufacturing productivity growth. They use the US Census of Manufacturers that includes 200.000 manufacturing establishments, and the Annual Survey of Manufacturers Samples, covering between 50.000 and 70.000 plants, which includes "almost all establishments with more than 250 employees, all plants that are part of very large companies, and all plants in certain industries that are considered important to track. These plants account for approximately half of the sample. The other half includes plants that are sampled from the population with a probability related to the plant's value of shipments within each 5-digit product class ..."

In the period 1977-1996 the average annual growth rates were 2.3 for value added, 2.2 for aggregate productivity, 0.2 for technical efficiency, and 2.1 for resource reallocation. The variability (across time) was higher for value added, compared to aggregate productivity, and also higher for technical efficiency compared to resource reallocation. This variability is for the aggregate and not across firms.

The prevalence of resource reallocation in the aggregate productivity growth for the different economic sectors was almost general, with the exceptions of food and tobacco, paper, and petroleum and coal. The proportion of years with positive reallocation contribution was higher than 70%. They conclude by saying "This finding also suggests that plant-level aggregate productivity growth indices based only on technical efficiency miss a large source of growth, and mischaracterize reallocation growth by looking at only technical efficiency and not considering each input gap individually". In a sense this gives support to paying attention to the Gross Solow's Residual (GSR).

The Bureau of Labor Statistics (BLS) and the US Census Bureau indicated a program to observe how productivity varies by establishment, denominated Dispersion Statistics on Productivity (DISP) that covers all 86 4-digit 2012 NAICS industries for the year 1987 through 2018. The dispersion measures include standard deviations, interquartile ranges, and interdecile ranges of the within-industry distribution of establishment-level productivity-level. All sample data are frequency weighted.

In the period 1987-2018 the Multifactor-Productivity dispersion for the whole industry has a small increase mainly due to the increase of the dispersion of the industries with bigger dispersion.

In our case we want to measure the productivity variability in each firm and analyze the frequency distribution of the observed GSR with firm data in each sector and in different subperiods. No one of the studies that I already mentioned provides this. In part due that are paying attention to convergence and explanations, and also for confidentiality requirements, thus provides information by sector levels (even though they work with firm data).

The "goal of the DISP project is to better understand the relationships between productivity dispersion within an industry and the industry's overall productivity trend". Among the questions they want to answer are: relation between productivity dispersion differences to distribution of wages and income, and which industries have the most/least dispersed productivity distributions. Distribution statistics are a new way of looking productivity in official US economic statistics."

In the period 1987-2017 they found much higher dispersion for the beverages compared to motor vehicles bodies and trailer.

The work of Bull, Chansky and Kim (2018) shows the big Multifactor Productivity slowdown in US manufacturing in subperiod 2004-2016 compared with the subperiod 1992-2004. This happened for 70% of the industrial sectors. In the aggregate the annual productivity growth slowdown was of 2.3%. They conclude saying that "... we have also encountered evidence of systemic trends that may be harmful to productivity growth. While by no means conclusive, this article adds to the growing body of evidence that (manufacturing) industries that shift their production processes may be doing so at the expense of innovation.

Consequently, productivity gains may be dispersed. This trend is worth watching closely".

Syverson (2004) in his work evaluates the importance of product substitutability in the productivity dispersion. He uses the 1977 Census of Manufactures (CM) to compute the productivity distribution moments for 443 four-digit industries using 200.000 plant level data. He uses labor and TFP productivity. He finds that a great amount of productivity variation between plants is observed within. He measures industry productivity dispersion as the interquartile productivity difference divided by the industry's median productivity level. His TFP1 (closer to GSR) shows the greatest dispersion. He concludes that "The evidence presented suggests that product substitutability -a characteristic of industry demand- is systematically related to the shape of the industry's equilibrium plant-level productivity distribution. Measurable factors likely correlated with high substitutability, such as low transport costs and less physical product differentiation, are shown to be negatively related with productivity dispersion and positively wit median productivity in an industry". ... "These results suggest that, although the technological supply-side factors that have been the focus of the related literature doubtlessly play a role in creating productivity dispersion, demand-side influence are also important ... Exploring the specific output market mechanism driving these results may be a fruitful path for further research".

As we see, the demand factors are brought again to explain economic growth. Also this paper is paying attention to the dual of TFP looking at wage dispersion provided in Davis and Haltiwanger (1991).

Cunningham et al (2021) "uses detailed industry-level data on productivity growth, establishment and firm entry rates, and establishment level productivity dispersion from three public-use data service: BLS Industry Productivity Statistics, Business Dynamic Statistics (BDS), and Dispersion Statistics in Productivity (DISP). In addition, we construct additional dispersion measures from the residual data underlying DISP. Throughout the article, we use industry-level measures for all 86 four-digit NAICS industries in the manufacturing sector". They also try to mitigate business cycle influences. "The within-industry IQR dispersion measure describes how much more productive an establishment at the 75th percentile of the productivity distribution is than one at the 25th percentile".

The TFP dispersion in the 1997-2016 period shows a similar variability than the TFP productivity. They present separate estimates for high-tech industries, which presents higher dispersion growth.

They conclude by asserting that "Overall, these results lend support to the hypothesis that rising within-industry dispersion at the least partly reflects innovation and experimentation. Future work using the restricted-use micro-productivity data could explore the reasons we observe a stronger relationship between entry and productivity dispersion in for the upper half of the productivity distribution".

Bartelsman and Doms (2000) explain the usefulness of working with longitudinal micro-level data sets (LMDs), which follow large numbers of establishments or firms over time. They summarize very interesting findings, some of them made in 1960. In their decomposition of TFP growth for U.S. Manufacturing Establishments, for the census period 1977-87 they found the shares of within-plant (48 percent), between plant (-8 percent), cross-plant (34 percent), and Net-entry (26 percent). As factors behind the Patterns they mention: Regulation, Management, Ownership, Technology and Human Capital, and International Exposure. They also suggest that future research should concentrate on: Reasons of heterogeneity, Beyond manufacturing, Another directions to pursue on the data front as to link data on workers to the establishments to which they work, Data quality, Price taking and market interactions, Cross-country comparisons, and Increased micro-macro linkages.

6. Learning from previous works: The Australian efforts

Fox, Cao, and Soriano (2021), explain the efforts that they are doing under the program BLADE (Business Longitudinal Analysis Data Environment) working with firm-level integrated microdata. They are working in "ANZSIC and division code mismatches, asset disposals in gross output and value added; negative value added and the construction of MFP; missing labor data; and capital measurement".

The Research Paper of Nguyen and Hausell (2014), provide estimates of productivity growth in Australia Manufacturing and Business Services. They study the productivity of continuing, entry and exit firms in the period 2002-2011. They found that "Entering and exiting firms in both manufacturing and business services have lower productivity than established firms. Entrants experience their largest increase in productivity in the second year of operation but after five years are still ten percent below established firms... The net impact of entry and exit is modest for manufacturing, but more significant for business services. In aggregate, entering firms lowered productivity growth by 13 percent in manufacturing, and 23 percent in business services. Existing firms raised productivity growth by 12 percent in manufacturing, and 23 percent in business services. However, at firm levels of industry classification, the results vary considerably and reinforce the notion that firm productivity is disperse even in narrowly-defined industries".

Campbell, Nguyen, Sibelle, and Soriano (2019) provide estimates of labor productivity dispersion in selected Australian industries. They measure the labor productivity dispersion by paying attention to how productivity differs between firms within a given industry, not by differences in the productivity growth of each firm. They use standard deviation, inter-quartile range and the 90-10 differential. For the period 2001-2014, they found that "The pattern of dispersion across time differs between industries. However, in all six of the selected industries productivity dispersion exhibits a downward trend, to varying degrees. Most of the decline in dispersion occurs by 2010-11 before flattening out. Downward trends are strongest in the two margin industries, Retail and Wholesale Trade, followed by Construction, Administrative and Support Services and Manufacturing..."

They discuss the point that productivity dispersion could be more useful to identify the causes of productivity growth but not much for explaining the level of the aggregate productivity growth.

In their conclusion they say "In terms of the trend in dispersion, Australia appears to differ from the international experience in that labour productivity dispersion is declining... labour productivity dispersion among smaller firms is greater than that among larger firms – and industries with a higher number of firms are generally less dispersed than those with only a few firms. Interestingly, the patterns in declining labour productivity dispersion are driven by micro, small and medium firms. This is consistent with declining dynamism driving decreasing labour productivity dispersion, as most entering firms start small... The persistence of dispersion in the six industries suggests that improving allocative efficiency and the productivity growth of low productivity firms can help lift aggregate productivity growth..."

Andrews and Hansell (2019) conclude "This paper exploits firm-level data to explore the link between productivity, labour reallocation and market selection in Australia over the period 2002-2016. We first show that the level of aggregate labour productivity is significantly higher owing to the fact that more productive firms on average account for a higher share of industry employment, particularly in sectors that are more exposed to competitive pressure. Moreover, the level of static allocative efficiency in Australia is higher than in most other OECD countries, perhaps reflecting the cumulated gains of past structural reforms, which may have enhanced the capacity of the Australian economy to reallocate scarce resources to high productivity firms. We then show that high-productivity firms are more likely to expand and low productivity firms are more likely to contract (or exit), implying a positive contribution from dynamic reallocation to aggregate productivity growth..."

There are many studies on the behavior of wages and its connection with the productivity. Dan Andrews et al. (2019) provides across firms wage variance decomposition for the period 2002-2016, were the within component explains almost 70% of total variance. They also find an association between wages and productivity. They conclude by staying that "... our results suggest that declining labour market fluidity and market dynamism are potentially relevant factors to understand changes in the relationship between firm productivity and wage growth, and weak growth more generally, As such, any explanation for weak growth probably needs to also be able to explain changing patterns of market dynamism".

7. Learning from previous work: The UK long-run data

Oulton (2021) presents the evolution of the hour labor productivity for the period 1855-2015, which is compared with GDP per capita evolution. Then for a much shorter period, 1997-2018 present the labor productivity in the market sector (14 industry groups), comparing the actual one, with the VA and Hours Weights. The behavior of these indicators shows the importance of computing labor and TFP productivity with the labor input measured in terms of hours of work and about the period's length.

In the periods 1997-2008 (boom) and 2008-2011 (after boom) the growth of the labor productivity is explained mainly by the within effects. This looks to be confirmed by the decomposition of cumulative equality growth of output per hours worked, showing the importance of labor composition.

In his conclusion he mentioned: a lot of progress in official estimates of TFP, international comparisons of labor productivity using PPPs, international comparisons of labor productivity across 9 English regions plus Scotland, Wales and Northern Ireland and Enterprise level data (confidential, similar to US Bureau of the Census). He also mentions weaknesses as: price indexes of capital goods (particularly high tech), single not double deflation of value added, and definition of the market sector by ownership, not industry (unlike EU KLEMS).

8. Learning from previous studies: Useful general results (OSD countries)

In looking for the messages and explanation of the behavior of productivity dispersion, Himbert et al. (2020) analyze the role of intangibles. Some of the motivations pushing their study were increasing productivity divergence within industries; increasing importance of intangibles investment the need to analyze the dynamics along the entire productivity dispersion.

They mention also that the broader OECD research agenda founds: frontier firms pull away in intangible intensive industries; laggard firms face difficulties and intangible-financing channel (financing factors explain 14% of the variation in productivity across firms in intangible-intensive sectors).

Their contribution "focus on the role of different intangible assets along the whole productivity distribution; evidence on the role of intangible investment in the process of diffusion of digital technologies to laggard firms; and for the first time empirical analysis combining cross-country data on productivity dispersion within industries and data on sectorial intangible investment".

For the period 2000-2015 including 10 OECD countries they found a strong increase in the productivity dispersion in manufacturing and market services. They show that this trends correlates positively with the evolution of the intangible investment intensity (intangible investment divided by gross output).

Finally they emphasize the role of regulations in these findings (competition policy, government procurement processes, and effective IPR legislation).

The work of Andrews et al. (2015) analyzes the productivity behavior of frontier firms of OECD countries for the period 2001-2009. Frontier firms are those 100 firms that are more productive in a 2-digit sector year by year. They analyze the labor productivity and the TFP using a harmonized cross-country firm level data before for 23 OECD countries. They conclude as "Productivity growth of the globally most productive firms remained robust in the 21sr century, despite the slowdown in aggregate productivity ... but firms at the global frontier have also become older, which may foreshadow a slowdown in the arrival of radical innovation and productivity growth ... the rising productivity gaps between firms at the global frontier raises more central questions about why seemingly non-rival technologies and knowledge do not diffuse to all firms" and finally "within-firm productivity gaps between national frontier firms tend to be smaller in countries in which education systems are of higher quality, product market regulations are less cumbersome, business and universities collaborative intensity, and markets for risk capital are more developed". This result implies an increase of the variance of firms productivity levels, but not necessarily in the variance of firms GSR.

9. Methodological issues

The sightseeing travel on previous results and current interest to see how to analyze productivity behavior was very useful for our objectives. In the introduction section we mentioned that our approach was going to analyze the frequency distribution of firm GSR for each sector and its behavior through time, without looking at the beginning its connection with some of its possible determinants. It is a kind of probabilistic view, as it happened with previous studies of the firm size distribution and personal income distribution, which could determine the parameter characterization of the frequency distribution. The great evolution on the collection of firm data that we saw in many countries gives some hope that in the near future we could get important advances.

Most of the studies that we presented developed important statistical information on labor and TFP productivity dispersion across firm and sectors providing also "controlled" behavior for different firm characteristic such as: age, size, foreign trade orientation, innovation, leading and laggard in productivity levels (frontier firm), intangible capital investment, human capital, firm entries and exit in the sectors, labor regulation, among others. In most of them, they use order statistic to measure dispersion, which could have some advantages to treat measurement error and scale effects, but some disadvantages with respect to parametric statistics like the operative rules.

They identified many interesting results like: young firms present higher dispersion, low convergence, in some countries what matters is within firm effects and in others between firm effects, intangible investment dispersion is also correlated with productivity dispersion.

Harberger (1998) approached this problem looking at the relevance of each sector in the size or in the GSR in different subperiods. He found what was called the "sunrise sunset phenomena". Few sectors account for most of the aggregate GSR in each subperiod, and these sectors are not the same in each subperiod. His message or vision was that the productivity behavior was most uniform as could say the behavior of the GSR at the aggregate level. Timmer, et al (2010) extended his analysis to Europe. We hope that looking at the frequency distribution of the firm's GSR in different sectors and subperiods without previous framework could be very useful to go then to the second stage with the economic framework.

The joint efforts of academic, official and private statistical institutions will be very important. Many countries already made a big advance in this line.

10. Multiplant Firms

George Stigler (see Mincer 1983) suggests that the firms arrange their production strategy to have some flexibility that allows to produce with an underlying average cost curve where the minimum cost has a certain range of output instead of only one level of output. Under this case we could observe some TFP stability besides the variability in output. We should note that Stigler developed this idea mainly to explain price stability for the firms, even with changing demands.

To generate this case we may need a multiplant firm, which could give more flexibility to the firm decision in the combination and expansion of inputs. It looks difficult to generate a cost function like this from a production function on one plant-firm.

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