Growth Accounting: Its Past, Present and Future

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I. INTRODUCTION

One of the most famous macroeconomic tools used in studying economic growth is growth accounting, ranging from accounting on the country level to firm-level analysis. Since the time of its conception, growth accounting has been widely used in many countries around the world. On the theoretical side, it is also a valid research subject of refinement for obtaining better accuracy.

One reason for the fame of this tool is that it is based on the Solow-Swan growth model, which is a simple model that explains many macroeconomic stylized facts of an economy.[1] Its simplicity in implementation is also another reason for its popularity. The calculation requires only a small number of variables which are normally available in the system of national accounts.

The growth accounting methodology has been the subject of debate since the 1990s. Empirical work by Young (1995) casts doubt on the results of the analysis of the four "Asian tigers:" Hong Kong, Republic of Korea, Singapore and Taiwan. In addition, modern growth theory (for example, Aghion and Howitt 1992; Romer 1990) recognizes the importance of the technology level as a controllable factor rather than exogenously given as in Solow-Swan's model. Still, many empirical works apply traditional growth accounting methods and their authors are unaware of potential pitfalls that could arise in the analysis.

This article has three main aims: to provide a brief account of the historical development of the growth accounting methodology; to give a modern view of this method based on endogenous growth theory; and to pose serious questions that need to be addressed in order to apply the growth accounting method in the future.

This article is divided into eight sections. Section I is the introduction; section II introduces Solow's growth accounting methodology and its standard refinements. The growth accounting of Thailand's economic growth is given as an example in section III. Section IV presents a paradox found by Young (1995). Section V gives modern refinements to address Young's problem. The example of Thailand is revisited in section VI to compare different adjustment methods. Section VII gives a modern view of this method based on endogenous growth theory and the last section concludes the article.

II. SOLOW'S GROWTH ACCOUNTING AND ITS REFINEMENTS

Growth accounting was introduced by Robert Solow (1957). It decomposes the growth rate of an economy's total output into three main drivers: change in capital utilization; change in the quantity of labor; and change in total factor productivity (TFP). The last driver is an unexplained residual or the part of growth that cannot be explained by changes in traditional inputs.

Solow's growth accounting posits that an economy's total outputs (Y) are directly related with only three inputs, namely capital stock (K), labor force (L) and technology level (A):

$$Y = Af(K, L). \qquad (1)$$

The second assumption is that the production function has a Cobb-Douglas form, i.e., $Af(K, L) = AK^{\alpha}L^{1-\alpha}, \alpha \in (0,1)$. It follows that, by taking a natural logarithm on both sides of the equation and taking a derivative with respect to time,

$$\frac{\dot{Y}(t)}{Y(t)} = \alpha\frac{\dot{K}(t)}{K(t)} + (1-\alpha)\frac{\dot{L}(t)}{L(t)} + \frac{\dot{A}(t)}{A(t)} \qquad (2)$$

where $\dot{X}(t) \equiv \frac{dX(t)}{dt}$ denotes a change in variable x over time and $\frac{\dot{X}(t)}{X(t)}$ represents a percentage change in variable x over time.

The final assumption is that both capital and labor markets are competitive. This assumption implies that the equilibrium returns on both factors are equal to their marginal products, or

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$$r = A\frac{\partial f(K,L)}{\partial K} = \alpha\frac{Y}{K}, \quad (3)$$

$$w = A\frac{\partial f(K,L)}{\partial L} = (1-\alpha)\frac{Y}{L} \quad (4)$$

where r and w represent the equilibrium returns on capital and labor respectively.

The parameter, α, can then be estimated using equations (3) or (4):

$$\alpha = \frac{rK}{Y} = 1 - \frac{wL}{Y}$$

where $\frac{rK}{Y}$ is the capital share of total income and $\frac{wL}{Y}$ is labor's share of total income.

Equation (2) is a core equation for growth accounting. It decomposes the growth rate of an economy's total output ($\frac{\dot{Y}(t)}{Y(t)}$) into three main drivers: change in capital utilization ($\alpha\frac{\dot{K}(t)}{K(t)}$); change in the quantity of labor ($(1-\alpha)\frac{\dot{L}(t)}{L(t)}$); and change in TFP ($\frac{\dot{A}(t)}{A(t)}$). In practice, TFP is calculated as a residual or the unexplained portion of growth,

$$\frac{\dot{A}(t)}{A(t)} = \frac{\dot{Y}(t)}{Y(t)} - \alpha\frac{\dot{K}(t)}{K(t)} - (1-\alpha)\frac{\dot{L}(t)}{L(t)}. \quad (5)$$

The framework has been refined in two directions. The first refinement expands the inputs of production in greater detail. For instance, the total area of land used has been included in the analysis (see, for example, Pranee and Chalongphob 1996). Kohli (2002) introduces terms-of-trade effect and non-traded goods price effect into the growth accounting framework; both variables capture international trade within the framework.

The second refinement addresses measurement errors in the data. Three groups of errors are recognized in the literature (Jorgensen and Grilliches 1967). Errors in utilization occur when the observed inputs are not good representatives of the actual usage of inputs. For example, a country with a larger labor force may actually employ less labor service (total working hours) in production than a country with a smaller labor force. Errors in aggregation stem from the fact that each input is an aggregation of many different qualities of inputs together. For example, the labor input in the production function consists of many workers with different levels of education and experience. Finally, the calculation of input usage often uses representative prices to aggregate different kinds of input. Errors in prices are the discrepancy between representative prices and "actual" prices that reflect the quality of those inputs. To some extent, each error has been addressed in empirical works. For example, input variables are now measures of flow of services instead of stock of inputs. The labor input is also commonly divided into quantity and quality variables.

III. THAILAND'S GROWTH ACCOUNTING

This section provides examples of growth accounting exercises, with Thailand having been chosen as the representative country. The aim is to express the uncertainty that occurs from applying traditional growth accounting exercises. The work of Bosworth (2005) serves this purpose quite well; it reviews the Thai literature that applies growth accounting analysis between 1977 and 1996. Four organizations, namely the Office of the National Economic and Social Development Board (NESDB), the Thailand Development Research Institute (TDRI), the Asian Productivity Organization (APO) and the Bank of Thailand (BOT), have analyzed this uncertainty within similar time periods, so the results should be somewhat comparable.

Table 1 gives a summary of the four growth accounting exercises. Notably, the overall relative significance of each input is very similar in all exercises. Capital is the most important driver of Thailand's growth during the study period. Labor and technological level (conventionally denoted as "TFP," or total factor productivity) are the next most important factors. However, the magnitude of each factor is quite different. The labor input, for example, can explain only 10 percent of the total output growth in NESDB's work but can explain 33 percent of total output growth in BOT's study.

Table 1 A Summary of Growth Accounting Exercises: All Sectors

Work	NESDB	TDRI	APO	BOT
Sectors	All	All	All	All
Time period	1980-1996	1980-1995	1977-1996	1980-1996
Real output growth (%)	8.00	8.10	7.50	8.00
Drivers:				
1. Labor	0.80	1.80	2.00	2.70
- Quantity	n.a.	1.00	1.40	0.90
- Quality	n.a.	0.80	0.60	1.80
2. Capital	6.60	5.00	3.90	4.90
3. Land	0.00	0.00	n.a.	n.a.
4. TFP	0.60	1.30	1.60	0.50

Source: Bosworth (2005).

Table 2 provides similar growth accounting exercises but the scope is limited to only the agricultural sector. Remarkably, both overall significance and the magnitude are inconsistent among the findings. For example, TDRI and APO studies found that TFP is the second most important factor that drives the growth of agricultural outputs. In contrast, the work of NESDB and BOT found that TFP played a very limited role in explaining the growth. Thus, these two comparisons suggest that the measurement errors in the growth accounting exercise could be very imminent.

IV. YOUNG'S PARADOXICAL FINDINGS

The four Asian tigers are highly developed economies, which consistently maintained their high growth rates from the early 1960s to 1990s. The literature has well documented their success (World Bank 1993). It is widely accepted that one of the main drivers of their growth is technological development, or TFP.

Young (1995) analyzed the growth of these four economies using the growth accounting method. He found that the main driver of all these economies' growth is capital accumulation. Surprisingly, TFP played a very limited role in their economic development (see Table 3). The results are paradoxical because many other countries that have tried to expand their capital inputs, before, or at the same time, or after these Asian tigers did so were unable to obtain the same level of economic growth that these economies have experienced. Also, lessons from other countries that share similar stories suggest that TFP plays a crucial role as a driver of growth (Altug et al. 2006).

V. MODERN REFINEMENTS

Many attempts have been made to refine the growth accounting framework in order to solve the paradox. However, there is still no consensus in the literature with regard to the best refinement. In this article, three refinements are considered. In our own view, each of them is based on solid foundations and stands out as a leading candidate for the best refinement.

Hsieh (2002) believed that the standard approach (equation 5) to obtain a TFP estimate involved large degrees of uncertainty. To avoid this problem, factor market data can be used to infer the TFP value instead. First, an accounting identity of income and expenditure is represented as

$$Y = rK + wL. \tag{6}$$

By taking a derivative with respect to time and dividing it by Y on both sides, the identity becomes

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{r(t)K(t)}{Y(t)}\left\{\frac{\dot{K}(t)}{K(t)} - \frac{\dot{r}(t)}{r(t)}\right\} + \frac{w(t)L(t)}{Y(t)}\left\{\frac{\dot{L}(t)}{L(t)} - \frac{\dot{w}(t)}{w(t)}\right\}. \tag{7}$$

Finally, using the definition of α and rearranging the equation, it follows that

$$\frac{\dot{Y}(t)}{Y(t)} - \alpha\frac{\dot{K}(t)}{K(t)} - (1-\alpha)\frac{\dot{L}(t)}{L(t)} = \alpha\frac{\dot{w}(t)}{w(t)} + (1-\alpha)\frac{\dot{r}(t)}{r(t)}. \tag{8}$$

Table 2 A Summary of Growth Accounting Exercises: Agricultural Sector

Work	NESDB	TDRI	APO	BOT
Sector	Agriculture	Agriculture	Agriculture	Agriculture
Time period	1980-1996	1980-1995	1977-1996	1980-1996
Real output growth (%)	3.70	3.70	3.50	3.80
Drivers:				
1. Labor	0.10	0.50	0.40	1.20
- Quantity	n.a.	0.10	n.a.	-0.10
- Quality	n.a.	0.40	n.a.	1.30
2. Capital	3.70	2.20	1.30	2.30
3. Land	0.10	0.00	n.a.	n.a.
4. TFP	-0.10	0.90	1.80	0.20

Source: Bosworth (2005).

Table 3 Growth Accounting Analysis of the Four "Asian Tigers"

Economy	Hong Kong	Singapore	Republic of Korea	Taiwan
Sectors	All	All	All*	All*
Time period	1966-1991	1966-1990	1966-1990	1966-1990
Real output growth (%)	7.30	8.70	10.30	9.40
Drivers:				
1. Labor (quality adjusted)	2.01	2.90	4.50	3.64
2. Capital (quality adjusted)	2.98	5.65	4.07	3.16
3. TFP	2.31	0.15	1.73	2.60

* Excluding the agricultural sector.

Source: Young (1995).

Notice that the left-hand side of the equation is the estimator of TFP (see equation 5). Thus, Hsieh has shown that it is possible to estimate TFP using factor market data on the right-hand side instead.

Klenow and Rodriguez-Claire (1997) addressed Young's paradox by assuming a new technology type (labor-augmenting technology) for the production function. Originally, Solow posited that the production function has TFP (equation 1), i.e., technology that works with all factors to produce output. On the contrary, empirical evidence has shown that the technology that more closely conforms with the data is labor-augmenting technology, i.e., technology that works well with labor,

$$Y = f(K, AL). \qquad (9)$$

With labor-augmenting technology, the estimator for TFP (analogous to equation 5), is

$$\frac{\dot{A}(t)}{A(t)} = \frac{1}{1-\alpha}\left\{\frac{\dot{Y}(t)}{Y(t)} - \alpha\frac{\dot{K}(t)}{K(t)} - (1-\alpha)\frac{\dot{L}(t)}{L(t)}\right\}. \qquad (10)$$

That is, to obtain a new estimate for TFP, one needs to inflate Solow's TFP estimate by a factor of $\left(\frac{1}{1-\alpha}\right)$.

It should be noted that, in both papers, the growth accounting framework is still valid for obtaining TFP. The paradox comes from measurement errors (Hsieh) or unsuitable assumptions (Klenow and Rodriguez-Claire). Both refinements then set an adjustment to obtain a better estimate for TFP. On the contrary, the last refinement in this article, as well as a modern view from endogenous growth theory (to be explained in more detail in section VII), do not share the same view. In their view, TFP cannot be estimated correctly using a standard growth accounting framework.

The last refinement is from Riedel (2007). The paper uses the idea of Scott (1989) as a starting point. In Scott's view, economic growth comes only from devoting resources to investment and the cost of investment comes in the form of a reduction in consumption today. Technological development is classified as one form of investment because its cost is similar to investment. It follows that one cannot separate technological development from capital investment. In addition, the depreciation rate of capital does not reflect the actual capital usage but it represents the reduction in capital value due to a new capital good being developed.[2] Based on these two ideas, Riedel derives a new growth accounting formula as

$$\frac{\dot{Y}(t)}{Y(t)} = \left\{1 - \frac{1-\alpha}{1-s}\right\}\frac{\dot{K}(t)+\delta}{K(t)} + \frac{(1-\alpha)}{(1-s)}\frac{\dot{L}(t)}{L(t)} \qquad (11)$$

where δ reflects capital depreciation and s denotes investment rate (investment share of total output). The term $\left\{1 - \frac{1-\alpha}{1-s}\right\}\frac{\dot{K}(t)+\delta}{K(t)}$ represents the effects on growth of both capital accumulation and technological change.

VI. TOTAL FACTOR PRODUCTIVITY ESTIMATES FOR THAILAND

In this section, the previous Thai growth accounting example is revisited to illustrate how new refinements will change the previous perspective on TFP. Table 4 summarizes the TFP estimates for Thailand before and after different adjustments. The unadjusted estimates of TFP are taken from Table 1. The adjusted TFP is made using different refinements suggested in the literature. For Hsieh's results, three proxies of capital returns are chosen, including stock dividend (definition 1), change in stock price-to-earnings (P/E) ratio (definition 2) and minimum loan rate (definition 3).

Table 4 Total Factor Productivity Estimates for Thailand (quoted as an explained portion of output growth)

Organization	NESDB	TDRI	APO	BOT
Sectors	All	All	All	All
Time period	1980-1996	1980-1995	1977-1996	1980-1996
Unadjusted TFP (%)	7.50	16.05	21.33	6.25
Adjusted TFP				
1. Hsieh (2002)				
- Def. 1: Stock dividend (%)	86	91	98	92
- Def. 2: Change in stock P/E ratio (%)	14	34	36	32
- Def. 3: Minimum loan rate (%)	92	86	105	92
2. Klenow and Rodriguez-Claire (1997) (%)	24.19	35.67	42.67	12.50
3. Riedel (2007)* (%)	84.37	63.02	55.46	43.15

* Riedel's results also include the effects of capital accumulation on growth.

Source: Author's calculation.

In the previous example, the explained portion of TFP on growth (according to Table 1) varies, ranging from 6.25 percent (BOT study) to 21.33 percent (APO study). The capital accumulation and the expansion of the labor force (both quantity and quality) have stronger impacts on growth than TFP. After adjustments (Table 4), TFP becomes a more important source of growth. However, the results show greater uncertainty about the magnitude of significance. The minimum role of TFP (12.5%) is found in the Klenow and Rodriguez-Claire's adjustment of BOT work. The highest significance level is found when adjusting the APO study using Hsieh's approach (definition 3).

The uncertainties of the results come directly from two main sources. First, the introduction of new variables exposes the analysis to a new measure error problem. Hsieh introduces a new concept that involves a calculation of labor and capital returns. It is unclear how to pick a suitable return on capital that reflects the whole economy. Riedel adds two variables in the calculation, namely the depreciation of capital and the investment share of total output. Measurement errors of these two variables can lead to substantially different results.

The second source of the uncertainty transpires from the original uncertainty sources (see section II). As some adjustments use original variables as an adjusting factor, the uncertainty of these original variables is amplified throughout the adjustment. The differences in the adjusted results using Klenow and Rodriguez-Claire's method come from the different estimates of α.

The main conclusion for this section is that all the refinements seem to face very high levels of uncertainty. It follows that the results from growth accounting are not robust. Therefore, one needs to develop a new method of refinement in order to conduct a growth accounting analysis.

VII. MODERN VIEW OF GROWTH ACCOUNTING FROM THE PERSPECTIVE OF ENDOGENOUS GROWTH THEORY

One crucial (but hidden) assumption for the growth accounting analysis is that technological progress or TFP growth is given exogenously. In other words, all technological improvements occur at a certain (predetermined) speed regardless of how input factors are allocated or how well the public policy is chosen.

In sharp contrast, endogenous growth theory rejects such an assumption and emphasizes that factor allocation as well as the choice of public policy matters in the determination of technological development. It further argues that success in technological development is a key to the miraculous growth of the four Asian tigers. Thus, it asserts that the growth accounting framework is not suitable to extract the driving sources of growth.

To see the implication, let's assume that TFP is endogenously determined. Then, TFP, $\frac{\dot{A}(t)}{A(t)}$, and capital accumulation, $\frac{\dot{K}(t)}{K(t)}$, are jointly determined within the model and so a partial estimation using equation (5) (or equation 10) is subject to an endogeneity problem. Thus, both equations are no longer a valid estimator for TFP.

In the perspective of the endogenous growth theory, one needs to theorize explicitly the process of technological development in order to obtain a correct estimate of TFP. There are many different ways to model the process. In this article, one example is given to illustrate how to estimate TFP.

Example: Aghion and Howitt (2007)

- ***Standard Production Network***

Let there be a constant population of L individuals. Each individual is endowed with one unit of skilled labor that is supplied inelastically. Labor services and intermediate inputs are used to produce the final good. The production function for the final good, Y_t, is

$$Y_t = \int_0^1 A_{it} L^{1-\alpha} x_{it}^{\alpha} di, 0 < \alpha < 1, \tag{12}$$

where x_{it} is the intermediate input of type i used at time t and A_{it} is a productivity variable representing the quality of the input.

Let's assume that the final goods market is perfectly competitive and each intermediate input producer has a monopoly power over its own product type. It follows that the demand for each intermediate input and the profit-maximization problem for the intermediate input producer are[3]

$$p_{it} = \frac{\partial Y_t}{\partial x_{it}} = \alpha A_{it} x_{it}^{\alpha-1} \tag{13}$$

and

$$\pi_{it} = \max_{x_{it}} \{p_{it} x_{it} - R_t K_{it}\} \tag{14}$$

where p_{it} and π_{it} are the price and the profit of input i at time t, R_t is the cost of renting capital, K_{it}.[4]

Now, assume that the production function for the intermediate input of type i to be

$$x_{it} = \frac{K_{it}}{A_{it}}. \tag{15}$$

Substituting p_{it} in equation (13) and K_{it} in equation (15) into equation (14),

$$\pi_{it} = \max_{x_{it}} \{\alpha A_{it} x_{it}^{\alpha} - R_t A_{it} x_{it}\}. \tag{16}$$

Using the first-order condition of equation (16) to substitute R_t in the monopolist's profit,

$$\pi_{it} = A_{it} \alpha (1-\alpha) \left(\frac{K_{it}}{A_{it}}\right)^{\alpha} \equiv \pi_{it}(A_{it}). \tag{17}$$

- ***Innovation and research***

An innovation in sector i at time t increases productivity of that sector from A_{it} to $\sigma A_{it}, \sigma > 1$. The innovation arrives at the rate proportional to the resources to research and development (R&D) in that sector, N_{it}, and inversely proportional to the current productivity level, A_{it}, i.e., new innovation is harder to achieve than previous innovation:

$$\lambda \frac{N_{it}}{A_{it}}.$$

Now, the equilibrium level of innovation must satisfy two conditions. First, it must exploit the gain from the innovation until the expected benefits of further innovating are equal to their expected costs, i.e.,

$$\lambda \frac{N_{it}}{A_{it}} V_{it} = N_{it} \tag{18}$$

where V_{it} is the value of innovation of intermediate input i at time t. The left-hand side of the equation represents the expected benefits of innovation using N_{it} on the right-hand side as a cost.

Second, successfully innovating firms must be indifferent between selling the new innovation for price V_{it} and investing it at return r_t, and merchandising the new innovation to earn extra profits until the next innovation occurs:

$$r_t V_{it} = \pi_{it}(\sigma A_{it}) - \lambda \frac{N_{it}}{A_{it}} V_{it}. \tag{19}$$

The right-hand side of the equation is the expected return from retaining ownership of the new innovation, which is equal to the profit from the new innovation, $\pi_{it}(\sigma)$,[5] minus the expected loss from a newer innovation that could occur at any future date to make the new innovation obsolete. The latter is equal to the probability that a newer innovation will occur times the value of the current innovation.

Using equation (17) to equation (19),

$$N_{it} = \sigma A_{it} \alpha (1-\alpha) \left(\frac{K_{it}}{A_{it}}\right)^{\alpha} - \frac{A_{it} r_t}{\lambda}. \tag{20}$$

Equation (20) expresses the equilibrium choice of R&D expenditures as a function of fundamental variables $(\sigma, \alpha, \lambda)$ and the current state of the economy (K_{it}, A_{it}, r_t).

Because every intermediate firm faces a similar problem with innovation choice, the intermediate firms will devote the same amount to R&D expenditure. The actual growth rate of technological progress is, on average, equal to the probability that the innovation occurs times the size of the innovation:

$$\frac{\dot{A}_t}{A_t} = (\sigma - 1)\lambda \frac{N_t}{A_t}. \tag{21}$$

or, equivalently,

$$\frac{\dot{A}_t}{A_t} = (\sigma - 1)\left\{\lambda \sigma \alpha (1-\alpha) \left(\frac{K_t}{A_t}\right)^{\alpha} - r_t\right\}. \tag{22}$$

Equation (22) states that technological progress, which depends on the choice of R&D expenditures, is also a subject of fundamental variables $(\sigma, \alpha, \lambda)$ and the current state of the economy (K_{it}, A_{it}, r_t).

To complete the model, let's assume that capital accumulation to be as in the neoclassical model:

$$\dot{K}_t = sY_t - \delta K_t \tag{23}$$

Now, substituting the production function using equations (12) and (15) and dividing both sides by K_t yields

$$\frac{\dot{K}_t}{K_t} = sA_t^{1-\alpha} K_t^{\alpha-1} - \delta. \tag{24}$$

Equations (22) and (24) imply that technological development does not come exogenously. Instead, it depends on the current value of the capital, which makes itself an endogenous variable.

The implication for growth accounting analysis is that both technological development and capital accumulation are closely interrelated. "Deep" fundamental variables are the true drivers of both variables. One cannot estimate the growth-drivers without using the data on fundamental variables. In other words, it is impossible to quantify the relative importance of each source of growth under the growth accounting framework. For example, a change in the saving rate, s, or a shift in the successful rate of innovation, λ, would drive both capital accumulation and technological development. Under the growth accounting framework, both changes would be accounted for partly by capital deepening and partly by technological development.[6] However, under this endogenous growth theory, the former should be classified fully as capital accumulation while technological development should gain full credit for the latter.

VIII. CONCLUSION

This article furnishes a review of growth accounting methodology and its refinements to counteract the paradoxical findings of Young (1995). Using Thailand as an example, three leading candidates for the best refinements are still subject to a considerable amount of uncertainty. In addition, the endogenous growth theory, which is a widely accepted approach to study growth issues, casts doubt on the ability to quantitatively extract sources of growth under the growth accounting framework.

Does this mean the end of the growth accounting methodology? The answer is "not quite." In the case of exogenous technological growth, one needs to find a new refinement that correctly disseminates the effects of changes in capital accumulation from changes in technological development. At the same time, that refinement must have a small degree of uncertainty to ensure a robust conclusion. On the contrary, if technological growth can be driven by public policy, then one needs to address the endogeneity problem by somehow incorporating fundamental variables (e.g., saving rate, rate of innovative success) into the growth accounting framework. The path is possible but not obvious.

ENDNOTES

1 For further details, see Kaldor (1957).

2 At the firm level, the depreciation rate reflects the actual usage of capital. However, at the aggregate level, new capital goods are constantly employed to replace old goods that have depreciated.

3 For simplicity, the total labor supply is normalized to 1.

4 In this model, capital can be used for any type of intermediate input production. Competition for capital service implies that the rental cost must be the same for all intermediate firms. Therefore, the subscript, i, is omitted.

5 $\pi_{it}(\sigma A_{it})$ is defined as a monopoly profit under productivity σA_{it} see equation (17).

6 Because both variables have been changed up to a certain amount according to equations (22) and (24).

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