No. 12

FEBRERO DE 2019

Documentos **CEDE**

ISSN 1657-7191 Edición electrónica.

Factor reallocation and growth:
what if there are labor saving
innovations?

Hernando Zuleta
Daniel Gamboa

Serie Documentos Cede, 2019-12
ISSN 1657-7191 Edición electrónica.
Febrero de 2019

© 2019, Universidad de los Andes, Facultad de Economía,
CEDE. Calle 19A No. 1 – 37 Este, Bloque W.
Bogotá, D. C., Colombia Teléfonos: 3394949- 3394999,
extensiones 2400, 2049, 2467
infocede@uniandes.edu.co
<http://economia.uniandes.edu.co>

Impreso en Colombia – Printed in Colombia

La serie de Documentos de Trabajo CEDE se circula con propósitos de discusión y divulgación. Los artículos no han sido evaluados por pares ni sujetos a ningún tipo de evaluación formal por parte del equipo de trabajo del CEDE.

El contenido de la presente publicación se encuentra protegido por las normas internacionales y nacionales vigentes sobre propiedad intelectual, por tanto su utilización, reproducción, comunicación pública, transformación, distribución, alquiler, préstamo público e importación, total o parcial, en todo o en parte, en formato impreso, digital o en cualquier formato conocido o por conocer, se encuentran prohibidos, y sólo serán lícitos en la medida en que se cuente con la autorización previa y expresa por escrito del autor o titular. Las limitaciones y excepciones al Derecho de Autor, sólo serán aplicables en la medida en que se den dentro de los denominados Usos Honrados (Fair use), estén previa y expresamente establecidas, no causen un grave e injustificado perjuicio a los intereses legítimos del autor o titular, y no atenten contra la normal explotación de la obra.

Universidad de los Andes | Vigilada Mineducación
Reconocimiento como Universidad: Decreto 1297 del 30 de mayo de 1964. Reconocimiento personería jurídica: Resolución 28 del 23 de febrero de 1949 Minjusticia.

Factor reallocation and growth: what if there are labor saving innovations?

Hernando Zuleta¹

Daniel Gamboa²

Abstract

We claim that the standard methodology to study the effects of the reallocation of factors on growth is not adequate in the presence of biased innovations. Labor-saving innovations increase output per worker and may decrease the marginal productivity of labor. Therefore, a reallocation of labor from a sector with higher output per worker to a sector with lower output per worker may be productivity enhancing.

JEL codes: D33, O11, O31, O33, J30.

Key words: Factor reallocation, Capital using and labor saving innovations, factor income shares, structural change.

¹ We thank Consejo Privado de Competitividad for funding this work.

Hernando Zuleta, Centro de Estudios sobre Desarrollo Económico - CEDE Universidad de los Andes, h.zuleta@uniandes.edu.co

² **Daniel Gamboa**, Universidad de los Andes, d.gamboa2654@uniandes.edu.co

Reasignación de factores y crecimiento económico ¿qué pasa si hay innovaciones ahorradoras de trabajo?

Hernando Zuleta

Daniel Gamboa

Resumen

La metodología estándar para el estudio de los efectos de la reasignación de factores de crecimiento no es adecuada en presencia de innovaciones parciales. Las innovaciones ahorradoras de trabajo aumentan el producto por trabajador y pueden disminuir la productividad marginal del trabajo. Por lo tanto, una reasignación del trabajo de un sector con mayor producto por trabajador a un sector con bajo producción por trabajador puede ser productividad mejora.

Códigos JEL: D33, O11, O31, O33, J30.

Palabras clave: Reasignación de factores, innovaciones ahorradoras de trabajo, participación factorial, cambio estructural.

I. Introduction

The differences in income and productivity between countries have been widely studied by economic literature. One line of this literature underlines the fact that aggregate productivity is equivalent to the weighted average of the productivity of the different parts of an economy (Lewis, 2004). One of the central insights of this literature is that economic growth entails structural change: growth comes together with the reallocation of factors from agriculture to manufactures and services. As production factors move from agriculture into modern economic activities, overall productivity rises and incomes expand (McMillan, Rodrik and Verduzco, 2014). When factors move from less to more productive activities, the economy grows even if there is no productivity growth within sectors. This growth-enhancing structural change can be an important contributor to overall economic growth. In addition, among the positive effects of reallocating factors within sectors, it has been proved that competition brought by trade liberalization has forced manufacturing industries to become more productive.³

In this literature, the aggregate productivity growth may occur in two ways: (i) "inside" of sectors, either through a greater accumulation of capital, technical progress or minimizing the misallocation of production factors between firms: (ii) "between" of the sectors, i.e., through the mobilization of labor from low productivity to activities with higher productivity sectors. Both increase the aggregate productivity of an economy.⁴

In general, the traditional method to calculate components "inside" and "between" only considers mobility and reallocation of labor and identifies labor productivity with product per worker. Therefore, using this methodology yields mixed results for different countries. In some cases, reallocation of workers towards the services sector has not involved a gain in terms of productivity or growth. Some studies have found that in countries of Latin America

³ This effect has been called industry rationalization, "the least productive firms exit the industry, and remaining firms shed "excess labor." See Cavalcanti Ferreira and Rossi (2003), Eslava, Haltiwanger, Kugler, and Kugler (2013) and Paus, Reinhardt and Robinson, (2003) among others.

⁴ See McMillan, Rodrik and Verduzco-Gallo (2014).

factors move to unproductive sectors (McMillan et., 2014), thereby limiting the economic growth and development of the region.⁵

The present work intends to reformulate the calculation of the evolution of the product per worker, and disaggregate this change in contributions derived from the reallocation of labor and capital as productive inputs. We break down the changes in the product per worker at the sector level into 6 elements: (1) Changes in the marginal product of labor at the sector level. (2) Changes in the sectoral allocation of labor. (3) The cross effect, product of the first two resulting changes, which shows evidence of decreasing marginal productivity across the sectors. (4) Changes in the marginal product of capital at the sectoral level. (5) Changes in the sectoral allocation of capital. (6) The cross effect, product of the previous two.

Why it is important?

According to Pagés (2010), understanding the behavior of the parts (sectors and firms) involved in these reallocations makes easier to identify those sectors of the economy that are becoming obstacles and thus put an extra effort to prepare better public policies, making improvements in productivity and thus achieve greater economic well-being.

There exists a growing body of research on factor-saving or factor-eliminating innovations. According to this theory, non-reproducible factors (like raw labor) limit the effect of capital accumulation: as the ratio of reproducible to non-reproducible factors rises, the marginal productivity of reproducible factors fall until the incentives for accumulation disappear. In this setting, factor-saving technical progress relaxes the constraint on growth by reducing the importance of non-reproducible factors in production. In other words, biased innovations may increase the marginal product of capital while reducing the need for labor.⁶

⁵ Studies in this field have explained disparities of income between countries, mobility of factors (especially labour) and miracles and economic failures of recent years. See Rodrik and Welch (2004), Rodrik (2011), Jones and Olken (2005), Duarte and Restuccia (2010), Buera and Kaboski (2012), McMillan et al (2014), among others.

⁶ Recently, many authors have studied causes and effects of factor saving innovations. See Zeira (1998), Boldrin and Levine (2002), Boldrin (2009), Seater (2005), Acemoglu (2007 and 2010), Acemoglu and Restrepo (2016 and 2017), Zuleta (2008 and 2012) and Peretto and Seater (2013) and Sturgill (2012 and 2014) among others.

Suppose that the manufacturing sector massively adopts labor-saving technologies such as 3D printers and robots. Consequently, firms in the sector require less work and increase their output per worker. In this context, it is convenient that the manufacturing sector release work while increasing its productivity. However, under the traditional methodology, the fact that employment decreases in a sector with high output per worker is associated with an inefficient allocation of work.

Under the methodology we propose, the adoption of labor-saving technologies is reflected in a fall in the marginal productivity of labor and an increase in the marginal productivity of capital so that both a reduction in the amount of labor and an increase in capital allocated to this sector represents an efficient reallocation of factors.

II. Methodological proposal.

The theoretical framework of Fabricant (1942) has been widely used by the literature on structural change. Let Y_i be the value added of sector i , L_i , employment and S_i the labor share of sector i in total labor. Thus, the change in aggregate product per worker (P) at time T in a multisector economy can be expressed as:

$$\Delta P = \sum_{i=1}^n (P_i^T - P_i^0) S_i^0 + \sum_{i=1}^n (S_i^T - S_i^0) P_i^0 + \sum_{i=1}^n (P_i^T - P_i^0) * (S_i^T - S_i^0) \quad (1.1)$$

The first term on the right side of equation 1.1 shows the proportion of the change explained by the changes in productivity within each sector, weighted by the relative number of workers who work in that activity at the beginning of the period ("within" term). The second component, known as the "between" factor, indicates to what extent the change in the product per worker is due to the reallocation of labor among sectors, in turn, weighted by the product per initial worker of each sector at the beginning of the period. This representation of the aggregate change in labor productivity incorporates a third component: the interaction of the effect within and between, "crossed" which is known in the literature as the across or dynamic component, positive when there is a shift of workers towards sectors that are experiencing productivity growth. Otherwise, the "crossed" component is negative.

In this literature, output per worker is usually identified with labor productivity. This implies ignoring the existence of biased technological change. In the case of perfect competition, the marginal productivity of labor in sector i , period t is given by $(1 - \alpha_{i,T})P_i^T$ and the marginal productivity of capital is given by $\alpha_{i,T} \frac{P_i^T}{k_i^T}$ where k_i^T is the capital-labor ratio in sector i period t , $\alpha_{i,T}$ is the elasticity of output with respect to capital and $1 - \alpha_{i,T}$ is the elasticity of output with respect to labor. Thus, the between effect and the cross effect must be decomposed in order to independently identify the effect of labor reassignment and the effect of reallocating capital.

Starting from equation 1.1 it is possible to rewrite the components of the change in the product per worker:

$$\Delta P = \left\{ \begin{array}{l} \sum_{i=1}^n ((1 - \alpha_{i,T})P_i^T - (1 - \alpha_{i,0})P_i^0) S_i^0 + \sum_{i=1}^n (S_i^T - S_i^0)(1 - \alpha_{i,0})P_i^0 \\ \quad + \sum_{i=1}^n ((1 - \alpha_{i,T})P_i^T - (1 - \alpha_{i,0})P_i^0) * (S_i^T - S_i^0) \\ \sum_{i=1}^n \left(\frac{\alpha_{i,T}P_i^T}{k_i^T} k_i^T - \frac{\alpha_{i,0}P_i^0}{k_i^0} k_i^0 \right) S_i^0 + \sum_{i=1}^n (S_i^T - S_i^0) \frac{\alpha_{i,0}P_i^0}{k_i^0} k_i^0 \\ \quad + \sum_{i=1}^n \left(\frac{\alpha_{i,T}P_i^T}{k_i^T} k_i^T - \frac{\alpha_{i,0}P_i^0}{k_i^0} k_i^0 \right) * (S_i^T - S_i^0) \end{array} \right. \quad (1.2)$$

Now, define the marginal productivity of factors in each sector:

- Marginal productivity of labor at time 0: $PML_i^0 = (1 - \alpha_{i,0})P_i^0$
- Marginal productivity of labor at time T: $PML_i^T = (1 - \alpha_{i,T})P_i^T$
- Marginal productivity of capital at time 0: $PMK_i^0 = \frac{\alpha_{i,0}P_i^0}{k_i^0}$
- Marginal productivity of capital at time T: $PMK_i^T = \frac{\alpha_{i,T}P_i^T}{k_i^T}$

So, equation (1.2) can be written as,

$$\Delta P = \left\{ \begin{array}{l} \sum_{i=1}^n (\Delta PML_i) S_i^0 + \sum_{i=1}^n (\Delta S_i) PML_i^0 + \sum_{i=1}^n (\Delta PML_i) * (\Delta S_i) \\ + \\ \sum_{i=1}^n \left(PMK_i^T \left(1 + \frac{\Delta k_i}{k_i^0} \right) - PMK_i^0 \right) k_i^0 S_i^0 + \sum_{i=1}^n (S_i^T k_i^0 - S_i^0 k_i^0) PMK_i^0 \\ + \sum_{i=1}^n \left(PMK_i^T \left(1 + \frac{\Delta k_i}{k_i^0} \right) - PMK_i^0 \right) * (S_i^T k_i^0 - S_i^0 k_i^0) \end{array} \right. \quad (1.3)$$

Rearranging,

$$\Delta P = \left\{ \begin{array}{l} \sum_{i=1}^n (\Delta PML_i) S_i^0 + \sum_{i=1}^n (\Delta S_i) PML_i^0 + \sum_{i=1}^n (\Delta PML_i) * (\Delta S_i) \\ + \sum_{i=1}^n (\Delta PMK_i) k_i^0 S_i^0 + \sum_{i=1}^n PMK_i^0 \Delta(k_i S_i) + \sum_{i=1}^n (\Delta PMK_i) * \Delta(k_i S_i) \end{array} \right. \quad (1.4)$$

The terms of the first line explain the change in output per worker generated by increases in marginal productivity of labor within sectors, $\sum_{i=1}^n (\Delta PML_i) S_i^0$, by labor reassignment between sectors $\sum_{i=1}^n (\Delta S_i) PML_i^0$ and by the cross effect $\sum_{i=1}^n (\Delta PML_i) * (\Delta S_i)$.

The first term of the second line is the change generated by increases in the marginal productivity of capital within sectors, $\sum_{i=1}^n (\Delta PMK_i) k_i^0 S_i^0$, which depends on the stock of capital in each sector. The second term is the effect of the change in the stock of capital $\sum_{i=1}^n (\Delta PMK_i) * \Delta(k_i S_i)$, given the marginal productivity and the last term is the cross effect $\sum_{i=1}^n (\Delta PMK_i) * \Delta(k_i S_i)$.

This methodology makes it possible to disaggregate the changes in aggregate productivity per worker in components such as sectorial reallocation, changes in labor participation, as well as in the participation of capital. By differentiating these specific effects, one can understand the importance of the different components with respect to the total change in productivity.

In order to apply this methodology, we need to assume that wages are a good proxy of labor productivity, namely $w_i^t = (1 - \alpha_{i,t}) P_i^t$, and calculate labor shares residually, $(1 - \alpha_{i,t}) = \frac{w_i^t}{P_i^t}$. We also need to know sectoral capital stocks and assume that production functions are homogeneous of degree in all sectors in order to calculate the marginal productivity of capital.

III. The case of Colombia: an example.

The calculation of productivity requires information on the aggregate product, the number of workers and capital by sector. In addition, the share of labor and capital in the product must be calculated. Two main sources of information were used: DANE National Accounts, with information for all the years between 2005 and 2014, and *Gran Encuesta Integrada de Hogares* (GEIH) with information for all the years between 2008 and 2014.

National Accounts provide information on "production and income generation" for nine sectors of the economy: 1) Agriculture, livestock, hunting, forestry and fishing, 2) Exploitation of mines and quarries, 3) Manufacturing industries, 4) Supply of electricity, gas, and water, 5) Construction, 6) Commerce, repair, restaurants and hotels, 7) Transportation, storage and communications, 8) Financial establishments, insurance, real estate activities, and services companies; and 9) Social, community and personal service activities. The "Production and income generation account" provides nominal information measured in billions of pesos of the value of production, intermediate consumption, added value, compensation to employees, taxes less subsidies on production, mixed-income and gross surplus of exploitation.

Taking this into account, in order to construct the capital series for the period, initial capital must be estimated first. In this case, the year of 2005 was chosen to generate the initial capital, because National Accounts also offers information on Gross Formation of Fixed Capital (FBKF) since that year. Based on the assumption that the marginal productivity of capital must be equal to the product between the share of capital and the ratio between production and capital, $Pmk = \alpha_i \left(\frac{Y_i}{K_i} \right)$, rewriting this expression can be obtained a measure of the capital of the form: $K_i = \frac{\alpha_i Y_i}{Pmk}$

Now, to compute this expression we made two assumptions: (1) marginal productivity in the initial period is equal for all sectors, and (2) a value of 0.12 is assumed given the results that Zuleta, Parada, Garcia, and Campo (2010) obtained on the series of capital, GDP and capital share aggregated for the year 2005. These assumptions can generate underestimation of capital in sectors that are not very productive, although the magnitude of this problem decreases as time passes and affects the level of variables more than their growth rates.

With this information, the value of the capital is obtained for each of the nine sectors from 2005 to 2014. However, the period to use the capital information by sector is 2008-2014.

Based on Bernanke and Gürkaynak (2001), we estimated the labor share as:

$$(1 - \alpha_i) = \frac{\text{Employee Compensation}}{\text{GDP} - \text{TPILS} - \text{Gross Mixed Income}}$$

Gross Mixed Income refers to self-employed income as defined by the United Nations' Statistics. Subtracting Gross Mixed Income from GDP implies that the share of labor income in Gross Mixed Income is assumed to be the same as the share of labor income generated in the corporate sector.

Taxes on production and imports less subsidies (TPILS) include but are not limited to taxes payable on goods when they are produced, taxes on imports, taxes on fixed assets and taxes on the total wage bill. TPILS should be allocated to either capital or labor compensation depending on the tax type. However, we have only the aggregate tax value without any detailed breakdown of the various taxes so it is impossible to know exactly how TPILS should be allocated. By subtracting TPILS, the implicit assumption is that the fraction of TPILS attributable to capital compensation is equivalent to total capital's share, and the fraction of TPILS attributable to labor compensation is equivalent to total labor's share.

From the GEIH, the population employed by each sector was estimated using its expansion factor with the information of the Employed module, which includes the workers categorized as formal. The total number of workers was divided among the nine sectors to be studied after the third revision of the International Standard Industrial Classification (ISIC), considering the two-digit coding, which is representative at the national level.

The above allows us to obtain all the necessary data to calculate the change in productivity per worker, following equation (1.4) and compare these results with the ones obtained with the traditional methodology. The results are summarized in Table 1.

Table 1. Decomposing the growth of GDP per worker (millions of pesos)

		1	2	3	4
		within	between	Interaction	Total (1+2+3)
A	Traditional Methodology - Equation 1.1	58,5	21,5	-55,1	25
B	Labor - Equation 1.4	23,9	3,7	-14,7	12,9
C	Capital - Equation 1.4	34,6	17,9	-40,4	12,1
D	Contribution of labor (B/A)	41%	17%	27%	52%
E	Contribution of capital (C/A)	59%	83%	73%	48%

The results indicate that: (i) the change in marginal productivity of capital within the sectors generates the greatest contribution to growth, (ii) capital flows to sectors where its marginal productivity is higher and (iii) the marginal productivity of capital is reduced in the sectors that attract more capital. This last result is consistent with the assumption of marginal productivity of decreasing capital.

According to the traditional methodology labor movements between sectors have a very important effect on the growth of aggregate product per worker. However, with the proposed methodology it seems that the contribution is marginal. Moreover, capital movements explain the lion part of the between effect.

References

1. Acemoglu, D. (2010). When Does Labor Scarcity Encourage Innovation? *Journal of Political Economy*, Vol. 118(6), 1037-1078
2. Acemoglu, D. (2007). Equilibrium Bias of Technology. *Econometrica* 75, 1371–1410.
3. Acemoglu, D. and Restrepo, P. (2017). Robots and Jobs: Evidence from US Labor Markets. *NBER Working Paper* No. 23285.
4. Acemoglu, D. and Restrepo, P. (2018). The Race Between Machine and Man: Implications of Technology for Growth, Factor Shares and Employment. *American Economic Review*, 108(6): 1488-1542
5. Cavalcanti Ferreira, P., and Rossi, J. L. (2003). New evidence from Brazil on trade liberalization and productivity growth. *International Economic Review*, 44(4), 1383–1405.
6. Boldrin, M. (2009). Growth And Cycles, In The Mode Of Marx And Schumpeter. *Scottish Journal of Political Economy*, Scottish Economic Society, vol. 56(s1), pages 415-442.
7. Boldrin, Michele and Levine, David K., 2002. Factor Saving Innovation. *Journal of Economic Theory*, Elsevier, vol. 105(1), pages 18-41, July.
8. Buera, J. F. and Kaboski, P. J. (2012). The Rise of the Service Economy. *American Economic Review*, Vol. 102(6), pp. 2540-
9. Duarte, M. and Restuccia, D. (2010). The Role of Structural Transformation in Aggregate Productivity. *The Quarterly Journal of Economics*, Vol.125 (1), pp. 129-173.
10. Eslava, M., Haltiwanger, J., Kugler, A. D., and Kugler, M. (2013). Trade reforms and market selection: Evidence from manufacturing plants in Colombia. *Review of Economic Dynamics*, vo. 16, (1), Pages 135-158
11. Fabricant, S. (1942). Employment in Manufacturing, 1899-1939. *NBER*, New York.

12. Hsieh, C.-T., and Klenow, P. J. (2009). Misallocation and manufacturing TFP in China and India. *Quarterly Journal of Economics*, 124(4), 1403–1448.
13. Lewis, W. (2004). “The Power of Productivity: Wealth, Poverty and the Threat to Global Stability”. Chicago: The University of Chicago Press.
14. McMillan, M. S., D. Rodrik and Verduzco-Gallo, I. (2014). “Globalization, structural change and productivity growth: with an update on Africa”. *World Development*, Vol. 63, pp. 11-32.
15. Pagés, C. (Ed). (2010). The Age of Productivity. *Inter-American Development Bank*. Washington, DC.
16. Peretto, P., and Seater, J., 2013. Factor-eliminating technical change. *Journal of Monetary Economics*, 60 (4), 459-473.
17. Paus, E., Reinhardt, N., and Robinson, M. D. (2003). Trade liberalization and productivity growth in Latin American manufacturing, 1970–98. *Journal of Policy Reform*, 6(1), 1–15.
18. McMillan, M., Rodrik, D., and Welch, K. H. (2004). When economic reform goes wrong: Cashew in Mozambique. *Brookings Trade Forum 2003*, Washington, DC.
19. McMillan, M. and Rodrik, D. (2011). Globalization, structural change and productivity growth. In M. Bacchetta, and M. Jense (Eds.), Making globalization socially sustainable (pp. 49–84). *Geneva: International Labour Organization and World Trade Organization*.
20. Rogerson, R. 2008. Structural Transformation and the Deterioration of European Labor Market Outcomes. *Journal of Political Economy*, 116(2): pp 235-259
21. Seater, J., 2005. Share-Altering Technical Progress. In Economic Growth and Productivity, L. A. Finley, ed., *Nova Science Publishers*, Hauppauge, 59-84.
22. Sturgill, B., 2012. The relationship between factor shares and economic development. *Journal of Macroeconomics*, 34 (4), 1044–1062.
23. Sturgill, B., 2014. Back to the basics: Revisiting the development accounting methodology. *Journal of Macroeconomics*, 42, 52-68.
24. Zeira, J. 1998. Workers, Machines and Economic Growth. *Quarterly Journal of Economics*, 113 (4), 1091-1117.
25. Zuleta, H., 2008. Factor Saving Innovations and Factor Income Shares, *Review of Economic Dynamics*, 11 (4), 836-851.
26. Zuleta, H. 2012. Variable Factor Shares, Measurement and Growth Accounting. *Economic Letters*, 114, 91–93.