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A Generalized Exactly Additive Decomposition of Aggregate Labor Productivity Growth*

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Aggregate labor productivity (ALP) growth—i.e., growth of output per unit of labor—may be decomposed into additive contributions due to *within-sector productivity growth effect*, *dynamic structural reallocation effect* (Baumol effect), and *static structural reallocation effect* (Denison effect) of cross-sectional components (e.g., industry or region) of output and labor. This paper implements ALP growth decomposition that is “generalized” to output in constant prices and to output in chained prices (i.e., chained volume measure or CVM) and “exactly additive” since with either output the sum of contributions exactly equals “actual” ALP growth. It compares this “generalized exactly additive” (GEAD) decomposition to the “traditional” (TRAD) ALP growth decomposition devised for output in constant prices. The results show GEAD and TRAD are exactly additive when output is in constant prices but GEAD is exactly additive while TRAD is not when output is in CVM. Also, GEAD components are *empirically purer* than or *analytically superior* to those from TRAD. Moreover, considering that contributions to ALP growth can be classified by industry or region *each year over many years*, GEAD provides a more well-grounded picture over time of industrial or regional transformation than TRAD. Therefore, GEAD should replace TRAD in practice.

KEY WORDS: Labor productivity; Output in constant prices; Chained volume measures; Reallocation effects

JEL classification: C43

1. INTRODUCTION

Aggregate labor productivity (ALP) growth or growth of output per unit of labor is a major factor in achieving the economy’s overall goals such as improving living standards, by increasing incomes, as well as enhancing market competitiveness, by improving efficiency. Thus, ALP growth analysis may be of interest to both technical researchers and policy makers.

However, this paper focuses on methodological issues of ALP growth decomposition in current practice and, hence, may be of interest mainly to technical practitioners. The objective is

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to compare two different ALP growth decomposition procedures in practice to determine which one is “better” empirically and analytically.

To pursue the above objective, this paper applies the ALP growth decomposition originally devised by Tang and Wang (2004) for output in CVM in Canada and the US to output in constant prices in other countries. In this paper, the Tang-Wang ALP growth decomposition is called the “generalized exactly additive” (GEAD) decomposition since it is “generalized” here from CVM to output in constant prices and “exactly additive” because with either output measure the sum of contributions exactly equals “actual” ALP growth. For comparison, this paper applies the “traditional” (TRAD) ALP growth decomposition originally devised for output in constant prices (Denison, 1962) to output in CVM.

Section 2 of this paper presents GEAD and Section 3 presents TRAD. Section 4 compares them empirically and analytically. Three empirical illustrations show the differences between GEAD and TRAD. They cover current practices in measuring real output: in constant prices (Thailand) using *fixed-base* Laspeyres quantity and Paasche price indexes; in CVM (US) based on *chained* Fisher quantity and Fisher price indexes; and also in CVM (Italy) based on *chained* Laspeyres quantity and Paasche price indexes. The results show GEAD and TRAD are exactly additive when output is in constant prices but GEAD is exactly additive while TRAD is not when output is in CVM. Moreover, GEAD yields empirically purer or analytically superior components than TRAD for measuring *within-sector productivity growth effect*, *dynamic structural reallocation effect* (Baumol effect), and *static structural reallocation effect* (Denison effect)—regardless of the measure of real output and of the behavior of relative prices.¹ However, GEAD and TRAD are identical when relative prices are constant. But considering that relative prices do change in reality, the findings support the recommendation in the concluding Section 5 that GEAD replace TRAD in practice. This recommendation motivates this paper given the widespread application and persistent use of TRAD in ALP growth decomposition, for example, in recent studies by ADB (2010) and IMF (2006).

2. “GEAD” DECOMPOSITION OF ALP GROWTH

Let the economy be subdivided into N cross-sections, e.g., industry sectors or regions, each indexed by j . Also, let Y_t be the economy’s *nominal* output (in current prices); X_t be *real* output

¹ The names of the above effects in italics are adopted from the study by ADB (2010).

either in constant prices or in CVM. Output is net of intermediate inputs and, thus, could be GNP, GDP, or value-added.² Moreover, let L_t be the economy's labor employment which could be hours worked or number of "full-time equivalent" persons. Their corresponding sectoral values are given by Y_t^j , X_t^j , and L_t^j over a period, $t = 1, 2, \dots, T$.

Nominal output as well as labor are additive. Hence,

$$Y_t = \sum_j Y_t^j \quad ; \quad L_t = \sum_j L_t^j \quad ; \quad j = 1, 2, \dots, N \quad ; \quad t = 1, 2, \dots, T. \quad (2.1)$$

However, additivity of real output is not necessary. The following analysis is valid either when X_t and X_t^j are in constant prices so that additivity holds ($X_t = \sum_j X_t^j$) or when they are CVMs and, hence, non-additive ($X_t \neq \sum_j X_t^j$) in present practice (Ehemann, Katz, & Moulton, 2002; Schreyer, 2004).

For analytical purposes, define the following ratios,

$$X_t = \frac{Y_t}{P_t} \quad ; \quad X_t^j = \frac{Y_t^j}{P_t^j} \quad ; \quad p_t^j = \frac{P_t^j}{P_t} \quad ; \quad Z_t = \frac{X_t}{L_t} \quad ; \quad Z_t^j = \frac{X_t^j}{L_t^j} \quad ; \quad l_t^j = \frac{L_t^j}{L_t}. \quad (2.2)$$

P_t^j and P_t are output price deflators. Their ratio p_t^j reflects relative price differences between a sector and the entire economy. Moreover, Z_t is *aggregate* labor productivity (ALP) while Z_t^j is *sectoral* labor productivity and l_t^j is a sector's share of total labor.

It follows from (2.1) and (2.2) that $Y_t = \sum_j Y_t^j = \sum_j P_t^j X_t^j$. Therefore, the relationship between Z_t and Z_t^j in any two adjoining periods t and $t-1$ may be expressed as,

$$Z_t = \sum_j \frac{P_t^j}{P_t} \frac{L_t^j}{L_t} \frac{X_t^j}{L_t^j} = \sum_j p_t^j l_t^j Z_t^j \quad ; \quad Z_{t-1} = \sum_j p_{t-1}^j l_{t-1}^j Z_{t-1}^j. \quad (2.3)$$

It may be emphasized that (2.3) is *generally valid* because $X_t = Y_t/P_t$ and $X_t^j = Y_t^j/P_t^j$ are true by definition of real output as a deflated value whatever the formula for the deflators P_t and P_t^j .³

Let G_t be the growth rate of Z_t and G_t^j be the growth rate of Z_t^j . That is,

$$G_t = \frac{Z_t - Z_{t-1}}{Z_{t-1}} \quad ; \quad G_t^j = \frac{Z_t^j - Z_{t-1}^j}{Z_{t-1}^j}. \quad (2.4)$$

² ALP growth decomposition involves cross-sections of industries or regions. Hence, outputs should be net of intermediate inputs—which are inter-industry or inter-regional transactions—to avoid double counting.

³ Formulas for aggregate and sectoral deflators should be the same. For constant prices, they are *fixed-base* Paasche price indexes while for CVMs, they could be *chained* Paasche, Fisher or other price index formulas.

To decompose G_t into contributions from G_t^j , substitute (2.3) into (2.4); add and subtract $p_t^j l_t^j Z_{t-1}^j$ to the numerator of the result and then use G_t^j in (2.4) to obtain,

$$G_t = \sum_j \frac{Z_{t-1}^j}{Z_{t-1}} [p_t^j l_t^j G_t^j + (p_t^j l_t^j - p_{t-1}^j l_{t-1}^j)]. \quad (2.5)$$

In expanding (2.5), use the fact from (2.1) and (2.2) that,

$$\frac{Z_{t-1}^j}{Z_{t-1}} p_{t-1}^j l_{t-1}^j = \frac{Y_{t-1}^j}{Y_{t-1}}. \quad (2.6)$$

Notice that (2.6) is a sector's share of output in current prices. Using this share and adding and subtracting $\sum_j (Z_{t-1}^j/Z_{t-1}) p_{t-1}^j l_{t-1}^j G_t^j$ to (2.5) yield the GEAD ALP growth decomposition,

$$G_t = \sum_j \left[\frac{Y_{t-1}^j}{Y_{t-1}} G_t^j + \frac{Z_{t-1}^j}{Z_{t-1}} (p_t^j l_t^j - p_{t-1}^j l_{t-1}^j) G_t^j + \frac{Z_{t-1}^j}{Z_{t-1}} (p_t^j l_t^j - p_{t-1}^j l_{t-1}^j) \right]. \quad (2.7)$$

Except for differences in notation, (2.7) is the decomposition formula devised by Tang and Wang (2004) for ALP growth in Canada and the US where real outputs are CVMs.⁴ However, as shown later, (2.7) is also applicable to output in constant prices.

The first term in (2.7), $\sum_j (Y_{t-1}^j/Y_{t-1}) G_t^j$, is similar to the *pure productivity growth effect* (Nordhaus, 2002). To see why, suppose there are no changes in relative prices and in labor shares so that $(p_t^j l_t^j - p_{t-1}^j l_{t-1}^j) = 0$. In this case, the second and third terms equal zero and, thus, the first term measures the contribution to ALP growth from productivity growth *alone* of individual sectors, without interaction effects captured by the second and third terms.

However, in the presence of changes in relative prices and in labor shares, the second term, $\sum_j (Z_{t-1}^j/Z_{t-1}) (p_t^j l_t^j - p_{t-1}^j l_{t-1}^j) G_t^j$, is non-zero. This is like the *Baumol effect* (Nordhaus, 2002) based on the finding (Baumol, 1967; Baumol, Blackman, and Wolff, 1985) that resources could be absorbed predominantly by stagnant industries. This is possible since industries with a low value of $(Z_{t-1}^j/Z_{t-1}) G_t^j$, i.e., stagnant, could have a high value of $(p_t^j l_t^j - p_{t-1}^j l_{t-1}^j)$.

⁴ An exact decomposition using similar data was also devised by Reinsdorf and Yuskavage (2010). However, they decomposed "value added" ALP growth indirectly, i.e., based on GDP by using gross output but netting out the contributions of intermediate inputs. Thus, the Tang and Wang ALP growth decomposition is more "direct" and requires "less" data than Reinsdorf and Yuskavage's decomposition. Moreover, the former decomposition applies to the "arithmetic" rate of ALP growth while the latter applies to the "log-change" of ALP growth.

Moreover, with the above changes, the third term, $\sum_j (Z_{t-1}^j / Z_{t-1}) (p_t^j l_t^j - p_{t-1}^j l_{t-1}^j)$, is also non-zero. This term is similar to the *Denison effect* (Nordhaus, 2002) after Denison (1962) who pointed out that movement of resources from a low-productivity industry to a high-productivity industry could raise ALP growth even if the productivity growth rates of the two industries were the same. To illustrate, suppose there are two industries a and b with the same productivity growth rates or $G_t^a = G_t^b$ but a has a higher productivity, i.e., $Z_{t-1}^a > Z_{t-1}^b$. In this case, the third term above yields the Denison effect that the ALP growth rate G_t may rise if resources (e.g., labor) move from b to a when $(p_t^a l_t^a - p_{t-1}^a l_{t-1}^a) > (p_t^b l_t^b - p_{t-1}^b l_{t-1}^b)$.

3. “TRAD” DECOMPOSITION OF ALP GROWTH

Let X_t^* stand for aggregate real output and X_t^{*j} for sectoral real output measured in constant prices. In this case, the sums in (2.1) still hold but the ratios in (2.2) become,

$$X_t^* = \frac{Y_t}{P_t^*} \quad ; \quad X_t^{*j} = \frac{Y_t^j}{P_t^{*j}} \quad ; \quad p_t^{*j} = \frac{P_t^{*j}}{P_t^*} \quad ; \quad Z_t^* = \frac{X_t^*}{L_t} \quad ; \quad Z_t^{*j} = \frac{X_t^{*j}}{L_t^j} \quad ; \quad l_t^j = \frac{L_t^j}{L_t}. \quad (3.1)$$

Under constant prices, additivity of real output holds. That is,

$$X_t^* = \sum_j X_t^{*j}. \quad (3.2)$$

Using (3.2), let overall ALP level and ALP growth be Z_t^* and G_t^* . For a sector, let labor productivity level and growth be Z_t^{*j} and G_t^{*j} . Hence, (2.3) and (2.4) become,

$$Z_t^* = \sum_j \frac{L_t^j X_t^{*j}}{L_t L_t^j} = \sum_j l_t^j Z_t^{*j} \quad ; \quad Z_{t-1}^* = \sum_j l_{t-1}^j Z_{t-1}^{*j}; \quad (3.3)$$

$$G_t^* = \frac{Z_t^* - Z_{t-1}^*}{Z_{t-1}^*} \quad ; \quad G_t^{*j} = \frac{Z_t^{*j} - Z_{t-1}^{*j}}{Z_{t-1}^{*j}}. \quad (3.4)$$

Combining (3.1) to (3.4) yields the TRAD ALP growth decomposition given by,⁵

$$G_t^* = \sum_j \left[\frac{Y_{t-1}^j P_{t-1}^*}{Y_{t-1} P_{t-1}^{*j}} G_t^{*j} + \frac{Z_{t-1}^{*j}}{Z_{t-1}^*} (l_t^j - l_{t-1}^j) G_t^{*j} + \frac{Z_{t-1}^{*j}}{Z_{t-1}^*} (l_t^j - l_{t-1}^j) \right]. \quad (3.5)$$

Formula (3.5) can be shown to be equivalent to the formulas in the IMF (2006) study, page 98, and in the ADB (2010) study, page 5, although they look different. In the ADB study, the

⁵ This dates back to Denison (1962 and 1967) and has been employed in many studies, for example, by Bloom, Canning, and Maloney (1999), Dekle and Vandenbroucke (2006), IMF (2006), and ADB (2010).

first term of (3.5) is the *within-sector productivity growth effect* (WSPGE); the second term is the *dynamic structural reallocation effect* (DSRE); and the third term is the *static structural reallocation effect* (SSRE). Recalling the names for similar “effects” by Nordhaus (2002) in the GEAD ALP growth decomposition in (2.7), WSPGE corresponds to *pure productivity growth effect*; DSRE corresponds to *Baumol effect*; and SSRE corresponds to *Denison effect*.

4. COMPARING “GEAD” AND “TRAD”

To compare GEAD in (2.7) and TRAD in (3.5), these ALP growth decomposition formulas are applied to the agriculture sectors in Thailand where real output is GNP in constant prices; in the US where it is value-added in CVM; and in Italy where it is also value-added in CVM but based on different chained indexes than in the US. These applications were chosen for convenience, given that the output and employment data for the agriculture sector in each country are disaggregated into only two subsectors, which will suffice for illustrative purposes.

Table 1-A presents GNP and employment data (2008-2009) in the agriculture sector of Thailand. The “actual” ALP growth of 1.3788 percent in 2009 is decomposed in Table 2-A.

Table 1-A. Agriculture Sector GNP and Employment in Thailand, 2008-09

	GNP in Current Prices (Million Baht)		GNP in Constant Prices (Million 1988 Baht)		Employed Persons (Thousand)	
	2008	2009	2008	2009	2008	2009
	Agriculture, hunting and forestry	955,710.0	931,907.0	320,058.0	322,342.0	14,283.3
Fishing	94,033.0	104,679.0	65,167.0	68,020.0	415.9	464.2
Total	1,049,743.0	1,036,586.0	385,225.0	390,362.0	14,699.1	14,692.5

Source: Data on GNP in current prices and in constant prices are from the National Economic and Social Development Board, Office of the Prime Minister. Data on employed persons are from the Report of the Labor Force Survey, National Statistical Office, Ministry of Information and Communication Technology.

Table 2-A. Decomposition of Thai Agriculture Sector Labor Productivity Growth of 1.3788 Percent in 2009

	WSPGE (Pure Productivity Growth Effect)		DSRE (Baumol Effect)		SSRE (Denison Effect)		Total (Labor Productivity Growth)	
	GEAD	TRAD	GEAD	TRAD	GEAD	TRAD	GEAD	TRAD
	Agriculture, hunting and forestry	1.0035	0.9158	-0.0099	-0.0031	-0.8948	-0.2823	0.0989
Fishing	-0.5813	-1.0979	-0.1292	-0.1281	1.9905	1.9745	1.2800	0.7485
Total	0.4222	-0.1821	-0.1390	-0.1313	1.0957	1.6922	1.3788	1.3788

Source: Author's calculations based on procedures (noted below) applied to data in Table 1-A.

Note: WSPGE is *within-sector productivity growth effect*; DSRE is *dynamic structural reallocation effect*; and SSRE is *static structural reallocation effect*. These terms are used in the ADB study (October 2010) and these terms correspond to *pure productivity growth effect*, *Baumol effect*, and *Denison effect* (Nordhaus, 2002). This paper's adaptation of the Tang and Wang (2004) decomposition formula in (2.7) yields the results reported in the columns headed by GEAD while ADB's (2010) and IMF's (2006) decomposition formulas, which are equivalent to (3.5), yield the results reported in the columns headed by TRAD.

The results from (2.7) are in the columns under GEAD while those from (3.5) are in the columns under TRAD in Table 2-A. This table shows that GEAD and TRAD components could be different in size and in sign. For example, WSPGE by GEAD is positive, 0.4222, while that by TRAD is negative, -0.1821. Moreover, GEAD and TRAD yield slightly different DSREs

although these are both negative. Finally, while the SSREs are positive, GEAD yields 1.0957 while TRAD yields a larger value, 1.6922.

If output is in constant prices, the last two columns of Table 2-A show that GEAD and TRAD are exact by yielding the “actual” overall labor productivity growth of 1.3788 percent. However, the components are different. “Agriculture, hunting and forestry” contributed only 0.0989 from GEAD but a larger 0.6303 from TRAD. “Fishing” contributed 1.2800 according to GEAD but a much smaller 0.7485 contribution according to TRAD.

Considering that the decompositions in Table 2-A can be done *each year over many years*, the above results show that GEAD and TRAD could paint very different pictures of the economy’s industrial transformation. In turn, GEAD and TRAD will have different implications for policy. Therefore, choosing one over the other needs to be analytically well-grounded.

The empirical differences between GEAD and TRAD components in Table 2-A may be explained analytically by the way prices are incorporated in their respective formulas. To see this, substitute (2.2) and (2.4) into (2.7) as well as (3.1) to (3.4) into (3.5) to obtain,

$$G_t = \sum_j \left[\frac{Y_{t-1}^j}{Y_{t-1}} G_t^j + \frac{Z_t^j}{Z_{t-1}} (p_t^j l_t^j - p_{t-1}^j l_{t-1}^j) \right]; \quad (4.1)$$

$$G_t^* = \sum_j \left[\frac{Y_{t-1}^j P_{t-1}^*}{Y_{t-1} P_{t-1}^{*j}} G_t^{*j} + \frac{Z_t^{*j}}{Z_{t-1}^{*j}} (l_t^j - l_{t-1}^j) \right]. \quad (4.2)$$

The first terms of GEAD in (4.1) and TRAD in (4.2) measure WSPGE as before in (2.7) and (3.5). However, DSRE and SSRE are now combined in the second terms of (4.1) and (4.2).

GEAD’s WSPGE given by the first term of (4.1) involves only sectoral deflators in the real growth term G_t^j , i.e., no overall deflator is involved. But TRAD’s WSPGE given by the first term of (4.2) involves sectoral deflators in the real growth term G_t^{*j} and the *overall* deflator P_{t-1}^* . The presence of P_{t-1}^* implies that TRAD’s WSPGE is not purely a “within sector” measure. In contrast, all deflators in GEAD’s WSPGE are sector j ’s own and, thus, a purely “within sector” measure. Thus, GEAD yields an *empirically purer* WSPGE than TRAD.

Comparing the second terms measuring the combined DSRE and SSRE, GEAD in (4.1) recognizes the role of relative prices in reallocation by the presence of the price index ratios, p_{t-1}^j and p_t^j . In contrast, TRAD in (4.2) gives no role to relative prices in reallocation by the absence of the above price index ratios. If labor shares are constant, the second term of TRAD

equals zero, implying no reallocation effects. In contrast, the second term of GEAD could still be non-zero provided that relative prices change, implying non-zero reallocation effects. This is possible because changes in relative prices could change the output mix and, hence, induce reallocation effects from more intensive use of other inputs (e.g., capital equipments) even though labor may be immobile, in which case labor shares are constant. These considerations make GEAD *analytically superior* to TRAD in measuring DSRE and SSRE in the preceding empirical illustrations for the general case when relative prices are not constant.

If relative prices are constant, all price indexes are equal to a positive constant α . Hence, $P_t^j = P_t = P_t^{*j} = P_t^* = \alpha$ so that $p_t^j = P_t^j / P_t = p_t^* = P_t^{*j} / P_t^* = 1$, all (j, t) . Therefore, GEAD in (2.7) or (4.1) and TRAD in (3.5) or (4.2) become identical. But if relative prices are not constant *over time* while real output is measured in constant prices of a *fixed* base year (Table 1-A), GEAD and TRAD are equal but not identical (Table 2-A).⁶ That is, GEAD and TRAD components add up to the same (i.e., equal) “actual” overall ALP growth but the corresponding components are different. However, GEAD is superior to TRAD, as shown above.

For another contrasting feature, GEAD is exact but TRAD is not when real output is measured in CVM. For illustration, these formulas were applied to value added and FTE employment data (2008-2009) in the agriculture sector of the US (Table 1-B).

Table 1-B. Agriculture Sector Value Added and Employment in the US, 2008-09

	Value Added in Current Prices (Million Dollars)		Value Added in CVM (Million Chained 2005 Dollars)		Full-Time Equivalent (Thousand)	
	2008	2009	2008	2009	2008	2009
	Farms	131,142.0	103,964.0	102,346.0	108,544.0	627.0
Forestry, fishing, and related activities	28,989.0	29,174.0	26,219.0	26,830.0	456.0	425.0
Total	160,131.0	133,138.0	129,366.0	136,180.0	1,083.0	1,059.0

Source: Data on value added in current prices and in chained prices (CVM) and FTE employment are from the US Bureau of Economic Analysis. Note that value added in CVM is not additive. Thus, in CVM valued in chained 2005 dollars, the sum of the value added of farms, forestry, fishing, and related activities is not equal to the sector total value added in US agriculture in 2008 and in 2009 above.

Table 2-B. Decomposition of US Agriculture Sector Labor Productivity Growth of 7.6529 Percent in 2009

	WSPGE (Pure Productivity Growth Effect)		DSRE (Baumol Effect)		SSRE (Denison Effect)		Total (Labor Productivity Growth)	
	GEAD	TRAD	GEAD	TRAD	GEAD	TRAD	GEAD	TRAD
	Farms	4.0006	3.8647	-0.0854	0.1317	-1.7486	2.6962	2.1666
Forestry, fishing, and related activities	1.7731	1.9851	0.3312	-0.0930	3.3819	-0.9497	5.4862	0.9423
Total	5.7737	5.8497	0.2458	0.0387	1.6333	1.7465	7.6529	7.6349

Source: Author's calculations based on procedures (noted below) applied to data in Table 1-B.

Note: WSPGE is *within-sector productivity growth effect*; DSRE is *dynamic structural reallocation effect*; and SSRE is *static structural reallocation effect*. These terms are used in the ADB study (October 2010) and these terms correspond to *pure productivity growth effect*, *Baumol effect*, and *Denison effect* (Nordhaus, 2002). This paper's adaptation of the Tang and Wang (2004) decomposition formula in (2.7) yields the results reported in the columns headed by GEAD while ADB's (2010) and IMF's (2006) decomposition formulas, which are equivalent to (3.5), yield the results reported in the columns headed by TRAD.

⁶ Relative prices are not constant since deflators changed from 2008 to 2009. In Thailand (Table 1-A), for example, the deflator for “fishing” changed from $94,033/65,167 = 1.4430$ in 2008 to $104,679/68,020 = 1.5389$ in 2009. It can be verified that relative prices are also not constant in the US (Table 1-B) and in Italy (Table 1-C).

In Table 2-B, the sum of GEAD components exactly equals “actual” 2009 US agricultural sector labor productivity growth of 7.6529 percent. In contrast, the sum of TRAD components is 7.6349 percent, which is different. This is not surprising because TRAD applies only to real output in constant prices but US real output is a CVM based on the chained Fisher quantity-Fisher price index framework. In this case, given that TRAD is “inexact” while GEAD is “exact,” the latter is analytically superior to the former.

For another illustration of the exactness of GEAD but inexactness of TRAD in ALP growth decomposition, consider Table 1-C and Table 2-C for the agriculture sector of Italy where real output is also a CVM based on the chained Laspeyres quantity-Paasche price index framework adopted by EU countries (Schreyer, 2004).

Table 1-C. Agriculture Sector Value Added and Employment in Italy, 2008-09

	Value Added in Current Prices (Million Euros)		Value Added in CVM (Million Chained 2000 Euros)		Full-Time Equivalent (Thousand)	
	2008	2009	2008	2009	2008	2009
	Agriculture, hunting and forestry	27,313.5	24,536.7	28,447.9	27,663.0	454.6
Fishing	1,203.6	1,349.0	759.3	817.8	33.4	34.7
Total	28,517.1	25,885.6	29,052.0	28,378.7	488.0	470.5

Source: Data on value added in current prices and in chained prices (CVM) and FTE employment are from Istat - Istituto Nazionale di Statistica. Note that value added in CVM is not additive. Thus, in CVM valued in chained 2000 euros, the sum of the value added of agriculture, hunting and forestry and fishing is not equal to the sector total value added in Italian agriculture in 2008 and in 2009 above.

Table 2-C. Decomposition of Italian Agriculture Sector Labor Productivity Growth of 1.3160 Percent in 2009

	WSPGE (Pure Productivity Growth Effect)		DSRE (Baumol Effect)		SSRE (Denison Effect)		Total (Labor Productivity Growth)	
	GEAD	TRAD	GEAD	TRAD	GEAD	TRAD	GEAD	TRAD
	Agriculture, hunting and forestry	1.3752	1.4060	-0.0158	-0.0080	-1.1026	-0.5580	0.2568
Fishing	0.1550	0.0960	0.0320	0.0074	0.8721	0.2027	1.0592	0.3062
Total	1.5303	1.5020	0.0162	-0.0006	-0.2305	-0.3553	1.3160	1.1461

Source: Author's calculations based on procedures (noted below) applied to data in Table 1-C.

Note: WSPGE is *within-sector productivity growth effect*; DSRE is *dynamic structural reallocation effect*; and SSRE is *static structural reallocation effect*. These terms are used in the ADB study (October 2010) and these terms correspond to *pure productivity growth effect*, *Baumol effect*, and *Denison effect* (Nordhaus, 2002). This paper's adaptation of the Tang and Wang (2004) decomposition formula in (2.7) yields the results reported in the columns headed by GEAD while ADB's (2010) and IMF's (2006) decomposition formulas, which are equivalent to (3.5), yield the results reported in the columns headed by TRAD.

In similar manner to Table 2-B, Table 2-C shows that the sum of GEAD components exactly equals “actual” 2009 Italian agricultural sector labor productivity growth of 1.3160 percent. Moreover, GEAD components differ from TRAD components and the latter sum to 1.1461 percent, which is different from the above actual labor productivity growth.

Table 2-B and Table 2-C complete the illustration of the exactness of GEAD and the inexactness of TRAD in ALP growth decomposition in the CVM framework in current practice.⁷

⁷ Presumably, the same results will follow from the CVM framework based on chained Paasche quantity and Laspeyres price indexes. However, no country appears to have adopted this framework. The reason could be that fixed-base Laspeyres quantity and Paasche price indexes underlie real output in constant prices. Thus, it seems natural or logical for countries converting output from constant prices to CVM-like the countries in the EU—to adopt the chained Laspeyres quantity and Paasche price indexes.

5. CONCLUSION

This paper showed that in ALP growth decomposition, GEAD is exact if real (net) output—e.g., GNP, GDP, or value-added—is measured either in constant prices or in CVM. In contrast, TRAD is exact only if real output is in constant prices. In the latter case, with changing relative prices, GEAD and TRAD are both exact but their components (i.e., WSPGE, DSRE, and SSRE) are different. However, the components from GEAD were shown empirically purer than or analytically superior to those from TRAD. On the above grounds, considering that the contributions to ALP growth can be classified by industry or region *each year over many years*, GEAD provides a more analytically well-grounded picture over time of the economy's industrial or regional transformation than TRAD. The overall implication is that GEAD should replace TRAD in practice. This finding motivates this paper given the widespread application and persistent use of TRAD in ALP growth decomposition, for example, in recent studies by ADB (2010) and IMF (2006).

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