

Corrigendum: Calculating a Total Technology Vector

The suggested procedure for calculating a total technology vector τ in Appendix B is incorrect¹ and is here corrected. It is also corrected in the software, a revised version of which has been posted to replace the older one.

Note that the total technology vector's development is not central to CECANT. CECANT users can use any method for developing τ , including arbitrarily choosing a τ to test its effect, and most of CECANT's output measures do not involve it. It is required only for calculating Total Technology Rebound, R_τ (Test #1) and Total Change in Fuel Use (and the inter-sectoral tendencies labeled "For this Technology"). All other output measures are independent of τ . Also note that none of CECANT's methodology for calculating output measures – whether those that depend on τ or those that do not – is affected by this corrigendum.

Recall that τ represents an *ex ante* depiction of some particular new or prospective technology, which CECANT then uses to calculate its *ex post* impact on fuel use. It thus reflects the engineering efficiency gain made available by the new technology, not its impact on fuel use.

The τ to be used depends on where the user has measured the cost function – at the segment level, the sector level, or the economy-wide level. Here we describe a procedure for each, using the same example used in Appendix B.

Segment Level

If the cost function has been measured at the segment level, the derivation of a total technology vector can begin with either native units (e.g., million tons of steel output per year, billions of BTUs input per year ...etc.) or in value units (e.g., \$ millions of steel produced per year, \$ millions of labor per year ... etc.). For generality, we use native inputs for both output and inputs at this segment level.

Table 2: Comparison of Factor Uses and Outputs for Integrated Steel Mill and EAF Mini-mill

	Factor Use				Steel Output
	K	L	F	M	Y
	\$ Millions	Million Man- hours per year	Billion BTUs per year	Million Tons per year	Million Tons per year
Integrated Steel Mill	\$2,000	33.6	65.0	4.0	3.5
EAF Mini-mill	\$10	3.2	5.0	1.1	1.0

¹ My thanks to John Feather for alerting me to this.

We first choose units so as to normalize the old technology's values. That is, from here forward output Y is expressed in units of 3.5 million tons per year, labor L is in units of 33.6 million man-hours per year, and so forth.² Thus, we have a normalized vector for the old technology:

$$\mathbf{\epsilon}_O \equiv \mathbf{1} = (1, 1, 1, 1)$$

Next, using the same units for inputs and output, we create a similar vector for the new technology. In this case we see that this technology puts out 1/3.5 of the old technology's steel production (Y), requires 10/2000 of the capital (K), 3.2/33.6 of the labor (L), and so forth. We form a vector of these quantities and an associated scalar of output:

$$\mathbf{q}_N \equiv (0.005, 0.095, 0.077, 0.286)$$

with

$$Y_N \equiv 0.286$$

Next, we renormalize this vector to account for the larger output and place it on a basis comparable to the old technology, simply dividing the elements by Y_N :

$$\mathbf{\epsilon}_N^{-1} \equiv (0.018, 0.333, 0.269, 0.875)$$

The notation used for this vector suggests an inverse because to translate it into effective use parameters requires us to invert each of the vector elements in a later step. Next, we estimate the share of the steel segment captured by the new technology. Suppose we say it will be 30%:

$$s_{seg} = 0.3$$

We can now calculate the weighted average combined vector of old and new technologies in the segment:

$$\mathbf{q}_{weightedaverage} = (1 - s_{seg})\mathbf{\epsilon}_O + s_{seg}\mathbf{\epsilon}_N^{-1}$$

or

$$\mathbf{q}_{weightedaverage} = (0.705, 0.800, 0.781, 0.963)$$

Finally, we invert each element of $\mathbf{q}_{weightedaverage}$ to give us the total technology vector:³

$$\boldsymbol{\tau}_{seg} = (1.42, 1.25, 1.28, 1.04)$$

The screenshot below illustrates CECANT's automation of this procedure. On the Technology Vector Calculation view, one would click on the hyperlink labeled "Segment Level" and would see the following:

² Note that the fact that capital is a "stock" and other factors are "flows" does not matter to the calculation since we are working with ratios.

³ The sequence of these last two steps was incorrectly inverted in Appendix B.

Technology Vector Calculation

Segment Level	Use (click on) this if your cost function has been measured at the <u>segment</u> level
Sector Level	Use (click on) this if your cost function has been measured at the <u>sector</u> level
Economy-wide Level	Use (click on) this if your cost function has been measured at the <u>economy-wide</u> level

Segment level Technology Vector

Inputs:

For this segment:

Projected Share of New Technology

Note: at the segment level, both output (Y) and inputs (K,L ...) can be in native units (e.g., millions of tons of steel per year, billions of BTUs per year) or value units (i.e., currency units)

	Y	K	L	F	M	...					
Existing Technology	3.5	\$2,000.0	33.6	65.0	4.0						
New Technology	1.0	\$10.0	3.2	5.0	1.0						
Units	10 ⁶ Tons/yr	\$ Millions	10 ⁶ Man- hours/yr	10 ⁹ BTU/yr	10 ⁶ Man- hours/yr						

Calculations:

ε_0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Y_0	1.000									

New Technology Ratios

q_N	0.005	0.095	0.077	0.250	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
I_N	0.286									

ε_N^{-1}	0.018	0.333	0.269	0.875	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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q Weighted Average

	0.705	0.800	0.781	0.963	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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Output:

τ_{seg}	1.42	1.25	1.28	1.04	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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In conformity with CECANT protocol, the white cells indicate inputs. The total technology vector at the segment level is highlighted in yellow. Note also that the white cells designated “Units” are provided for the convenience of the user; these do not affect the calculations in any way.⁴

Sector Level

If the cost function has been measured at the sector level, the derivation of the total technology vector is similar, but in this case we must use value units for the output (e.g. \$ millions of primary metal). Input units can be either in native units or value units.⁵

The procedure follows in exactly analogous fashion to the segment level procedure. The only real difference is that outputs are here expressed in value units. The projected share of the new technology in the sector is a value share, but this is not a real difference. At the segment level it was also a value share, owing to the presumption that output is undifferentiated (e.g., tons of steel) that commands a single market price.⁶

⁴ All cells except the white cells are protected to prevent inadvertent changes to the formulas. However, they are not password protected: the user can unprotect all cells by selecting in the menu bar Tools/Protection/Unprotect Sheet... This may be useful if one wishes to reformat the input cells, for example.

⁵ In Appendix B, account was not taken of potentially differing factor proportions at the Sector and Economy-wide levels. These two sections correct this.

⁶ If this is not a correct presumption, a value units approach would be required at the segment level also.

Upon selecting the hyperlink labeled “Sector Level” the user will see the following:

[Home](#)

Technology Vector Calculation

Segment Level Use (click on) this if your cost function has been measured at the segment level

Sector Level Use (click on) this if your cost function has been measured at the sector level

Economy-wide Level Use (click on) this if your cost function has been measured at the economy-wide level

Sector level Technology Vector

Inputs:

For this sector:
Projected Share of New Technology

Note: at the sector level, output (Y) must be in value units (i.e., currency units); inputs can be in native units (e.g., million tons per year of ore, billions of BTUs per year) or value units (i.e., currency units)

	Y	K	L	F	M	...				
Sector	\$8,500	\$3,490	74.7	92.9	\$5					
New Technology	\$1,700	\$10.0	3.2	5.0	\$1					
Units	\$ Billions/yr	\$ Millions	10 ⁶ Man-hours/yr	10 ⁹ BTU/yr	\$ Billions /yr					

Calculations:

ε_θ

γ_θ

New Technology Ratios

q_N

γ_N

ε_N^{-1}

q Weighted Average

Output:

τ_{sect}

Here we see that the reference input reflects total sector-wide output along with individual sector-wide inputs. The new technology inputs are as before. We see that if the projected share of the new technology in the sector is 15%, the total technology vector is:

$$\tau_{sect} = (1.17, 1.13, 1.12, 1.00)$$

Economy-wide Level

If the cost function has been measured at the economy-wide level, the derivation follows that for the sector level. Upon selecting the hyperlink labeled “Economy-wide Level” one would see the following:

[Home](#)

Technology Vector Calculation

Segment Level

Sector Level

Economy-wide Level

Use (click on) this if your cost function has been measured at the segment level

Use (click on) this if your cost function has been measured at the sector level

Use (click on) this if your cost function has been measured at the economy-wide level

Economy-wide level Technology Vector

Inputs:

For this economy:

Projected Share of New Technology

Note: at the economy-wide level, output (Y) must be in value units (i.e., currency units); inputs can be in native units (e.g., million tons per year of ore, billions of BTUs per year) or value units (i.e., currency units)

	Y	K	L	F	M	...				
<i>Economy</i>	\$457,000	\$87,250	2,490.0	3,316.3	\$208					
<i>New Technology</i>	\$1,700	\$10.0	3.2	5.0	\$1					
<i>Units</i>	\$ Billions/yr	\$ Millions	10 ⁶ Man-hours/yr	10 ⁶ BTU/yr	\$ Billions /yr					

Calculations:

ε_0

Y_0

	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.000									

New Technology Ratios

q_N

Y_N

	0.000	0.001	0.002	0.005	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	0.004									

ε_N^{-1}

	0.031	0.345	0.405	1.290	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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q Weighted Average

	0.990	0.993	0.994	1.003	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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Output:

$\tau_{economy}$

	1.010	1.007	1.006	0.997	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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If the projected share of the new technology in the economy is 1%, the total technology vector is:

$$\tau_{economy} = (1.010, 1.007, 1.006, 0.997)$$

A Note on the Approximate Nature of the Procedure

Once again, it must be stressed that the values shown in this document are for illustration purposes only; the purpose is to demonstrate the procedure, not argue the numbers. Further, this procedure is necessarily approximate due to aggregation issues, but the approximation is very close even with widely-varying factor use proportions between segment, sector, and economy. Production function-based aggregation tests⁷ indicate any errors are likely to be insignificant compared to those associated with estimating the cost function, and the procedure is certainly adequate for purposes of approximating a technology vector.

Moreover, users employing this or any total technology vector approach will be able to use CECANT to quickly analyze the sensitivity of energy consumption to uncertainty in the specification of the total technology vector.

We offer the above procedure to those CECANT users who wish to have a simple, convenient method. Users may wish to use a different procedure. But whether

⁷ Available from the author.

they wish to bypass total technology calculations altogether and rely solely on CECANT's various rebound elasticities for the insights they contain, or test some arbitrary τ , or use the procedure given here, or use a different procedure entirely, they will be able to derive insight as to how engineering efficiency changes will translate into energy consumption changes in a way not possible without CECANT or something like it.