The Case of the Missing Trade and Other Mysteries: Reply

By Daniel Trefler*

It is by now well known that the Heckscher-Ohlin-Vanek model performs reasonably well for natural resources, less well for capital, and poorly for labor. These facts are dwarfed, Patrick J. Conway (2002) teaches us, by the enormous differences in the performance of the Heckscher-Ohlin-Vanek model across types of labor. This is an important observation and Conway is to be congratulated for bringing it to the fore. Conway follows up his observation with an explanation of it that appeals to unobserved differences in the mobility of labor across industries. I am not persuaded by his explanation, in part because there is a more obvious one involving differences in human capital. Thus, I will contest his explanation by providing a smoking gun in the form of new evidence on human capital and trade.

To this end, I analyze the Werner Antweiler and Trefler (2002) data on the educational content of trade. Four facts emerge from this analysis. First, the data display skill bias in the sense that the model performs much better for educated labor than for less educated labor. Second, this skill bias increased dramatically from 1972 to 1992. Third, the data display a form of capital-skill complementarity in the sense that capital behaves very similarly to educated labor and very differently from less educated labor. Fourth, this capital-skill complementarity held in both 1972 and 1992, which implies a robust long-term comovement between capital and educated labor. *In short, the performance of the Heckscher-Ohlin-Vanek model displays skill bias and capital-skill complementarities both in levels and in changes.* These facts should help attach Heckscher-Ohlin-Vanek empirics to a cluster of issues that includes inequality, capital-skill complementarities, skill-biased technical change, and endogenously induced technical change, e.g., Eli Berman et al. (1994), Claudia Goldin and Lawrence F. Katz (1998), Daron Acemoglu (1999), and Robert C. Feenstra and Gordon H. Hanson (1999).

This Reply is organized as follows. Section I distills what I believe to be Conway's main contribution and deepens his insight with new results regarding human capital. In Section II, I evaluate Conway's labor-immobility hypothesis and find little support for it. In large part, the problem is that his hypothesis is unlikely to fully account for key facts about human capital and trade. (It is thus essential that I provide these facts early on, even though this is a Reply rather than a new article.) In Sections III–IV, I evaluate all of Conway's other claims and find them to be of little interest. This should not be misconstrued as a serious criticism of Conway. By documenting new facts and insisting that they be explained, Conway has advanced our understanding of the factor content of trade.

I. Education and Capital

Conway is interested in the Heckscher-Ohlin-Vanek (HOV) prediction

$$F_{fc} = V_{fc} - s_c V_{fw} + \varepsilon_{fc} \tag{1}$$

where F_{fc} is the factor content of trade for factor f in country c, V_{fc} is the endowment of factor f in country c, $V_{fw} \equiv \Sigma_c V_{fc}$ is the world endowment, and s_c is country c's purchasing-power-parity-adjusted and trade-balance-adjusted share of world income. Following Trefler (1995), F_{fc} and $(V_{fc} - s_c V_{fw})$ are scaled to control for size differences across factors and across countries. (See the Appendix for details.) For factor f, let ρ_f be the correlation between F_{fc} and $(V_{fc} - s_c V_{fw})$ i.e., fix f and correlate across countries. Likewise for factor f, let σ_{Ff} be the standard deviation of F_{fc} and let σ_{Vf} be the standard deviation of $(V_{fc} - s_c V_{fw})$. $(\sigma_{Ff}/\sigma_{Vf})$ is the "missing trade" statistic. If it is less

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TABLE 1—MISSING TRADE (σ_{Ff}/σ_{Vf}) BY FACTOR

	28 Richer Countries			All 71 Countries		
	1992 (1)	1972 (2)	Growth (3)	1992 (4)	1972 (5)	Growth (6)
Labor	0.10	0.05	123	0.01	0.01	40
High school not completed	0.05	0.03	48	0.00	0.00	−9
High school completed	0.24	0.14	80	0.17	0.12	50
No education	0.00	0.01	−60	0.00	0.00	−81
Primary education	0.03	0.04	−29	0.00	0.01	−57
Secondary education	0.22	0.12	83	0.09	0.08	22
Postsecondary education	0.18	0.12	54	0.11	0.08	38
Capital	0.26	0.14	85	0.25	0.14	77
Energy	0.70	0.12	470	0.16	0.17	−5
Land	0.20	0.14	40	0.05	0.04	21

Notes: Columns (1), (2), (4), and (5) present the missing trade statistic σ_{Ff}/σ_{Vf} i.e., the standard deviation of F_{fc} divided by the standard deviation of $(V_{fc} - s_c V_{fw})$. Columns (3) and (6) present the growth, in percents, from 1972 to 1992 in the missing trade statistic. Column (3) cannot be recovered from columns (1)–(2) because of rounding errors. Likewise for column (6). Note that Conway's (2002) missing trade statistic is $R_{MT} = (\sigma_{Vf}/\sigma_{Ff})^2$ and Trefler's (1995) missing trade statistic is $\sigma_{Ff}/\sigma_{Vf})^2$.

than one then there is less trade than predicted by the HOV model.[1]

In his Table 2, Conway observes that the missing trade and correlation statistics vary dramatically across the six types of labor recorded in the Trefler database. Why this should be is a puzzle that Conway rightly insists be solved. To my mind, this is Conway's major contribution.

I would, however, have been even more deeply impressed if the cross-factor variation in the performance of the HOV model had been explored thoroughly and if a satisfying explanation of the variation had been offered. For the remainder of this section, I therefore explore the cross-factor variation that is at the heart of Conway's contribution and offer a satisfying human-capital explanation of it. I then argue in the next section that my human-capital explanation is not particularly consistent with Conway's "factor-mobility" explanation.

To get at human-capital and mobility issues it is best to abandon the older Trefler (1995) database in favor of the richer Antweiler and Trefler (2002) database. The latter provides data on the factor content of trade in a form that is consistent with the Robert J. Barro and Jong-Wha Lee (1993) data on national educational attainment levels.[2] Also included in the database are national endowments for capital, land, and energy. The data cover the years 1972–1992. The sample consists of 71 countries. I also consider a subsample of 28 countries that consists of all 23 OECD countries in the sample plus the five largest newly industrialized countries.[3]

Table 1 reports the missing trade statistics by factor. Columns (1)–(2), which deal with the 28-country sample for 1992 and 1972, show yet again that missing trade is a pronounced feature of the data. The missing trade statistic is much less than unity. Trade is missing most for labor and least for energy. There are four striking features of Table 1. *First,* trade is missing much more for less educated labor than for educated labor. For example, there is a fivefold difference between those workers who completed high

[1] In Trefler (1995), I defined the missing trade statistic as $(\sigma_{Ff}/\sigma_{Vf})^2$. Here I work with its square root since it makes the tables easier to read. Note that Conway defines his missing trade statistic as $(\sigma_{Vf}/\sigma_{Ff})^2$.

[2] I consider four educational attainment categories: (i) no education, (ii) some primary education (up to 6 years), (iii) some secondary education (up to 12 years), and (iv) some postsecondary education. I also consider two educational attainment categories: (i) high school not completed (less than 12 full years) and (ii) high school completed (at least 12 full years).

[3] See Antweiler and Trefler for a list of all 71 countries and the 23 OECD countries. The five newly industrialized countries are Hong Kong, Israel, Korea, Malaysia, and Singapore.

TABLE 2—THE CORRELATION OF F_{fc} WITH $V_{fc} - s_c V_{fw}$ BY FACTOR

	28 Rich Countries		All 71 Countries	
	1992	1972	1992	1972
Labor	0.17	0.07	0.06	0.10
High school not completed	0.11	0.12	0.01	0.06
High school completed	0.35	0.14	0.11	0.11
No education	0.16	−0.04	−0.07	−0.06
Primary education	0.04	0.22	0.01	0.05
Secondary education	0.41	0.17	0.15	0.12
Postsecondary education	0.14	0.08	0.01	0.07
Capital	0.54	0.10	0.34	−0.01
Energy	0.84	0.40	0.28	0.52
Land	0.21	0.37	0.16	0.16

school and those who did not. I will refer to this fact as skill bias in missing trade. *Second,* in terms of missing trade statistics, capital behaves very similarly to educated labor, but very differently from less educated labor. This fact almost immediately falls out of a standard HOV model in which, for each good, capital and skilled labor are perfect complements. I therefore refer to this phenomenon as a general-equilibrium capital-skill complementarity.

For the next two observations I move from levels to growth rates. Column (3) reports the growth of the missing trade statistic between 1972 and 1992. From column (3), the *third* observation is that skill bias has become more pronounced over time. For example, the missing trade statistic fell by 60 percent for those with no education and rose by 83 percent for those with a secondary education. *Fourth,* the growth for high-school graduates (80 percent) is almost identical to the growth for capital (85 percent). This is a remarkable long-term comovement and is entirely consistent with what we expect from the literature on skill-biased technical change. *To summarize these four facts, missing trade displays skill bias and general-equilibrium capital-skill complementarities both in levels and in changes.*

When we move from the sample of 28 high- and middle-income countries to the sample of 71 rich and poor countries the same pattern emerges. This can be seen from columns (4)–(6). Skill bias and, to a lesser extent, capital-skill complementarities are features of missing trade for both rich and poor countries.[4]

Table 2 reports the correlations between F_{fc} and $V_{fc} - s_c V_{fw}$. These correlations show another interesting pattern, at least for the sample of 28 rich- and middle-income countries. The correlations have not changed for high-school dropouts and have risen for both capital and high-school graduates. This reinforces the Table 1 results on skill bias and capital-skill complementarities.

The results of this section are suggestive of why the performance of the HOV model varies so much across different types of labor. Conway's explanation is very different. I turn to it next.

II. Factor Immobility

Conway proposes the following "factor-bias" model:

$$F_{fc} = \kappa_f (V_{fc} - s_c V_{fw}) + \eta_{fc} \tag{2}$$

where κ_f is a slope parameter and η_{fc} is an error term.[5] The presence of missing trade leads one to expect κ_f that are close to 0. While Conway

[4] On a separate note, there has been a smooth growth in the missing trade statistic over the 1972–1992 period with no evidence of any acceleration during the 1980's. This is relevant for the United States where the acceleration hypothesis has been a key issue in thinking about the evolution of the college premium.

[5] Equation (2) is equivalent to Conway's equation (14b) with $\boldsymbol{\lambda}_c = \mathbf{0}$. To see this, divide my equation (2) by V_{fw} and note that F_{fc}/V_{fw} is a typical element of Conway's $\mathbf{a}_c$ vector, $(V_{fc} - s_c V_{fw})/V_{fw}$ is a typical element of Conway's $\mathbf{v}_c - \mathbf{s}_c$ vector, η_{fc}/V_{fw} is a typical element of Conway's $\mathbf{e}_c$ vector, and κ_f is a typical diagonal element of Conway's diagonal $\boldsymbol{\kappa}_j$ matrix. On an empirical note, any results reported by factor (e.g., my Tables 1–2) will be independent of the way in which factors are scaled (e.g., independent of whether or not one scales by V_{fw}).

does not report estimates of the κ_f, it is easy to back out their least-squares estimates using

$$\kappa_f = \rho_f(\sigma_{Ff}/\sigma_{Vf}). \quad (3)$$

That is, the estimated κ_f are the product of the correlation statistics of Table 2 and the missing trade statistics of Table 1. Given the small values of ρ_f and $(\sigma_{Ff}/\sigma_{Vf})$, it should come as no surprise that the estimated κ_f are all less than 0.10. Clearly, this cannot be Conway's contribution. Rather, the contribution is his observation that the κ_f vary dramatically across factors.

I have five concerns about what Conway does with this observation. *First,* he does not examine the cross-factor variation in any meaningful way. He thus unnecessarily diminishes the scope of his contribution. As the results of the previous section on factor bias and capital-skill complementarity show, the cross-factor variation is systematic.

Second, while Conway's equation (2) model must do well as judged by sum of squared errors, it is equally true that the model must do poorly as judged by missing trade. It can be shown analytically that the missing trade statistic for equation (2) must equal $|1/\rho_f|$.[6] Since this exceeds 1, Conway's model necessarily predicts the opposite of missing trade, namely *too much* trade relative to the HOV prediction! Indeed, rows 9–10 of Conway's Table 1 show that there is ten times too much trade. Clearly, this is an unacceptable feature of equation (2).

My remaining concerns deal with Conway's economic interpretation or explanation of equation (2). It is crucial that such an interpretation be offered. Otherwise, equation (2) is just another statistical way of indicating that there is missing trade. Restated, equation (2) with $\kappa_f < 1$ rather than $\kappa_f = 1$ is just another way of showing that there is missing trade. Any *new* insights must come from how the κ_f vary across factors.

Conway posits the presence of factor-mobility costs i.e., it is costly for factors to migrate across industries, thus reducing the willingness of factor owners to reallocate their factors in response to changing world prices. This leads to κ_f that are less than unity.[7] I have a number of concerns about this explanation.

First, while Conway's explanation is consistent with small κ_f, a far more rigorous test of his explanation would explore whether the variation in the estimated κ_f is consistent with independent information on how mobility varies across factors. A quick check of my Tables 1–2 provides relatively little evidence supporting this more rigorous test.[8]

Second, any explanation must be consistent with my Table 1–2 observations about skill bias and capital-skill complementarities. Yet Conway's factor-immobility model is silent on these facts. For example, is it really plausible that growing skill bias can be explained by differential growth rates in mobility costs? I think not.

Third, the estimates of the κ_f are very different from what one expects if the κ_f are interpreted with reference to the considerable body of evidence on labor immobility. We know that trade has been missing for at least a century (Antoni Estevadeordal and Alan M. Taylor, 2002) so that Conway's estimated κ_f must be capturing steady-state immobility. Yet steady-state analysis suggests values of the κ_f that are an order of magnitude larger than what Conway estimated. In particular, we know from U.S. data that about 5 percent of the workforce is displaced each year (Henry S. Farber, 1997). We also know that the returns to tenure are about 25 percent over ten years (Robert H. Topel, 1991), suggesting that a displaced worker has a κ_f of 0.75 in the first year following displacement and that this rises by 0.025 per year until it plateaus at 1.0. With these numbers it is straightforward to work out that in steady state the average productivity in the workforce is $\kappa_f = 0.94$.[9] In contrast, Conway's κ_f are all less than

[6] The standard deviation of the left-hand side of equation (2) is σ_{Ff}. The standard deviation of the right-hand side of equation (2) is $|\kappa_f|\sigma_{Vf}$ which by equation (3) equals $|\rho_f(\sigma_{Ff}/\sigma_{Vf})|\sigma_{Vf} = |\rho_f|\sigma_{Ff}$. Thus, the missing trade statistic is $\sigma_{Ff}/(|\kappa_f|\sigma_{Vf}) = 1/|\rho_f|$.

[7] To his credit, Conway is careful to note in his conclusions that "other factor-specific explanations will also be consistent with the data" (Conway, 2002 p. 403).

[8] Conway has pointed out to me that these arguments about the levels of the κ_f ignore the fact that the relative ranking of the κ_f do to some degree support his interpretation. I am much less sanguine about this claim, but leave it to the reader to check and decide.

[9] Let $\pi(n)$ be relative productivity in year n of displacement. Then $\pi(1) = 0.75$, $\pi(n) = \pi(n-1) + 0.025$ for $2 \leq n \leq 10$, and $\pi(n) = 1$ for $n > 10$. Let $p(n)$ be the proportion of the population in year n of displacement. Assuming that $p(n)$ is independent of the number of years since the last displacement (an assumption favorable to Conway's position since it overstates the productivity loss),

0.01. Thus, the estimated κ_f are unrelated to existing empirical measures of labor immobility.

To summarize, Conway does not deeply explore the cross-factor variation in the estimated κ_f, he adopts a specification which can algebraically be shown to imply *too much* trade, and he offers an interpretation of the estimated κ_f that is not particularly consistent with factor bias, capital-skill complementarity, or empirical estimates of labor immobility.

III. Expenditure Adjustments

Factor bias is just one of Conway's two main points. Expenditure mismeasurement is the other. Specifically, Conway allows the s_c to be mismeasured by an unknown parameter λ_c that is to be estimated. This leads to the model

$$(4) \qquad F_{fc} = V_{fc} - (s_c - \lambda_c)V_{fw} + \zeta_{fc}$$

where ζ_{fc} is an error term. [Equation (4) follows from multiplying Conway's equation (14b) by V_{fw} and setting his $\boldsymbol{\kappa}_j$ to zero. See my footnote 5 for details.] Equation (4) is the equation underlying row 7 of Conway's Table 1. Define $\beta_c \equiv s_c - \lambda_c$. Then as Conway notes, equation (4) is observationally equivalent to $F_{fc} = (V_{fc} - \beta_c V_{fw}) + \zeta_{fc}$ which in turn is just the C_1 model of my 1995 paper. I thus find it puzzling that Conway sees equation (4) as an alternative explanation of the HOV mysteries. Indeed, the only reason that Conway's results differ from mine is that he chooses the λ_c to maximize the number of correct signs whereas I choose the β_c to minimize the sum of squared errors. My personal feeling is that his objective function is not very useful because, with missing trade, the number of correct signs seems largely irrelevant to the big picture on model performance. This point is brought home in rows 7 and 8 of Conway's Table 1 which show that the estimates of the λ_c that maximize the number of correct signs also *worsen* the missing trade problem.

I have two other problems with Conway's expenditure mismeasurement model. First, as Conway notes in the last line of his Section IV, part 1, the estimated λ_c are too large to be interpreted as corrections to expenditure shares. Second, in his conclusions Conway argues that the λ_c can equally be interpreted as a restatement of relative productivity. I fail to see this.[10]

IV. Conway's "Reinterpretation" of Trefler

Conway's Section III is filled with a number of lesser points. Part 1 deals with the use of purchasing-power-parity (PPP) adjustments when constructing the expenditure shares s_c. First, Conway argues that one needs to make a PPP adjustment. This is certainly sensible and I have followed it in my Tables 1–2. However, note that whether such a correction is theoretically justified depends on whether the theory under consideration allows for nontradables. Except under strong assumptions, the HOV model does not handle nontradables very well and so does not allow for them. Second, Conway claims that Trefler's T_1 productivity adjustments (the δ_c) should be reinterpreted. What he really means is that by using non-PPP-adjusted s_c my estimates of the δ_c are subject to specification bias. This is an empirical claim and, short of performing a specification test, I simply note that when using Trefler's (1995) methodology the PPP adjustment makes little difference except for raising the δ_c of the poorest countries. From Conway's Table 1, it also seems to make little difference for Conway's conclusions. (In his Table 1, compare row 1 with row 5 and row 2 with row 6.) Third, Conway claims that the use of non-PPP-adjusted s_c induces the "endowments paradox." That this is false can be seen from his Table 1. The paradox is significant with or without a PPP adjustment. In short, the discussion of PPP adjustments is interesting, but of a secondary importance.

Part 2 of Section III makes a number of neat observations about my home-bias parameters α_c^*. Most important of these is the claim that the

$p(1) = 0.05$, $p(n) = 0.95p(n-1)$ for $2 \leq n \leq 10$, and $\Sigma_{n>10}p(n) = 1 - \Sigma_{n\leq 10}\, p(n)$. A quick spreadsheet calculation shows that $\kappa_f = \Sigma_n\, p(n)\pi(n) = 0.94$.

[10] If I understand correctly, Conway explains this in Section IV, part 1, by noting that if λ_c is chosen to equal

$$\lambda_{fc}^0 \equiv \{(\delta_c V_{fc} - s_c \Sigma_j \delta_j V_{fj}) - (V_{fc} - s_c V_{fw})\}/V_{fw}$$

then one obtains Trefler's (1995) T_1 productivity model $F_{fc} = \delta_c V_{fc} - s_c \Sigma_j \delta_j V_{fj}$. This is problematic. For one, Conway does not estimate λ_c that vary with f as in λ_{fc}^0. For another, I have no idea how to interpret λ_{fc}^0 as an expenditure adjustment. Thus, I cannot make sense of Conway's claim.

α_c^* are largely driven by the size of the trade balance. I find this intriguing. To properly establish this, one must recognize that trade balances are a country characteristic (Germany perennially runs surpluses) so that one needs to regress the α_c^* not only on trade balances, but also on country fixed effects of the kind considered by Trefler [1995 equation (15)]. Nevertheless, I found this discussion intriguing.

V. Conclusions

Conway has written a provocative paper about factor bias in an HOV framework. His major finding is that the HOV model performs much better for some categories of labor than for others. I argued that he did not explore this finding as deeply as he should have. In particular, I showed that the performance of the HOV model displays skill bias and capital-skill complementarities both in levels and in changes. These facts should be of independent interest to those investigating inequality, capital-skill complementarities, skill-biased technical change, and endogenously induced technical change. I also argued that his factor-mobility explanation is inadequate. In its place I offered evidence strongly supporting an alternative, human-capital explanation.

Conway has put forward a number of other ideas in his paper that I have criticized. Undoubtedly I have been too harsh and can only be glad that he does not get a chance to reply! Further, my criticism obscures Conway's main contribution. He has introduced factor bias into the ongoing HOV dialogue. This by itself is tremendously important.

Appendix

Let t index the year. Throughout this paper, F_{fct} and $(V_{fct} - s_{ct}V_{fwt})$ have been scaled by a generalized least-squares correction ω_{fct}. Following Trefler (1995), Antweiler and Trefler (2002), and Conway (2002), I assume that ω_{fct} contains a factor-variance component ν_{ft} and a country-variance component ν_{ct} so that $\omega_{fct} = \nu_{ft}\nu_{ct}$. Since the missing trade and correlation statistics of Tables 1–2 are reported by factor and year, it is easy to show that they are independent of ν_{ft}. The only issue is how to specify ν_{ct}. I considered the form $\nu_{ct} = (s_{ct})^{\gamma}$ and found that the results are insensitive to whether γ is chosen to equal 0.5 as in Trefler (1995) or 0.9 as in Antweiler and Trefler. (See Antweiler and Trefler for their maximum-likelihood method of estimating γ.) Since I am using the Antweiler and Trefler data, I chose $\gamma = 0.9$.

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