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# Transfers, nontraded goods, and unemployment

*An analysis of the Keynes-Ohlin debate*

By Steven Brakman and  
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# Transfers, Nontraded Goods, and Unemployment: An Analysis of the Keynes-Ohlin Debate

Steven Brakman and Charles Van Marrewijk

The economics of international transfers has repeatedly given rise to interesting debates that have increased our understanding of the issues involved. The most famous of these was the discussion between John Maynard Keynes and Bertil Ohlin in 1929 regarding the terms-of-trade effect and Germany's capacity to pay reparations after the First World War; see Keynes 1929a, 1929b, and 1929c, and Ohlin 1929a and 1929b.<sup>1</sup> Ever since he wrote the *Economic Consequences of the Peace* in 1919, Keynes had pondered Germany's ability to pay reparations.<sup>2</sup> The occasion for the famous 1929 debate was a new committee of experts under the American Owen Young. The committee had to reorganize Germany's reparation payments of the Dawes plan of 1924, scheduling payments of

Correspondence may be addressed to Steven Brakman, University of Groningen, P. O. Box 800, 9700AV Groningen, The Netherlands; e-mail: S.Brakman@eco.rug.nl. We would like to thank seminar participants at the University of Groningen, Radboud University Nijmegen, and Erasmus University Rotterdam, and two anonymous referees for useful comments and suggestions. Any errors are, of course, our own.

1. Two other debates were the bullionist controversy, regarding the convertibility of gold and payments by Great Britain to its allies around 1800, involving, among others, Henry Thornton, David Ricardo, and John Wheatley, and the debate in 1980–83 concerning the importance of third parties, involving, for instance, Graciela Chichilnisky, Jagdish Bhagwati, and T. N. Srinivasan.

2. Keynes (1919) calculated that Germany could not possibly pay what the European Allies demanded. He thought that Germany could pay a total of £1500 million, in thirty annual instalments of £50 million. See Skidelsky 1992 for details on the evolution of Keynes's thinking between 1919 and the debate of 1929.

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increasing magnitude. In this 1929 debate, Keynes represented a classical, partial equilibrium view and argued that a transfer would cause a terms-of-trade deterioration for the donor. Ohlin, however, pointed at the importance of income effects on demand as a result of the transfer to conclude that there was no presumption for the terms of trade to move either in favor of, or against, the donor.

The focus of the literature soon moved to the welfare effects of a transfer. Since Wassily Leontief (1936) pointed out, by means of an example, the possibility of transfer paradoxes (in which the donor gains and/or the recipient loses from the transfer), the main point of reference has been Paul Samuelson's (1947) assertion that Leontief's example requires unstable markets. More specifically, in a perfectly competitive, Walrasian, stable, two-country world with two traded goods, the donor's welfare falls and the recipient's welfare rises (see also Kemp 1964 and Mundell 1960). We refer to this result (which was hiding in a footnote) as "Samuelson's theorem."<sup>3</sup>

Samuelson's theorem does not hold if productive resources are transferred instead of purchasing power, if distortions are present in the system, if aid is tied, or if there are more than two countries. Transfer paradoxes are thus quite possible in more general settings (see, for example, Jones 1967, 1985; Ohyama 1974; Gale 1974; Chichilnisky 1980; Bhagwati, Brecher, and Hatta 1983; Kemp and Kojima 1985; Schweinberger 1990; Kemp 1995; and Kemp and Shimomura 2003).

In their debate Keynes and Ohlin both acknowledged that nontraded goods exist and that their presence complicates the analysis considerably, even more so if unemployment or price rigidities are present. Without either party changing its point of view, Keynes and Ohlin focused on the terms-of-trade effect of a transfer in the presence of nontraded goods, as did the subsequent literature on the transfer problem analyzing nontraded goods; see, among others, McDougall 1965, Samuelson 1971a, Samuelson 1971b, Chipman 1974, and Jones 1975. Makoto Yano and Jeffrey B. Nugent (1999) analyze the small-country case in which prices of international goods are given. In this case, transfer paradoxes can arise if tariffs are introduced as an additional distortion. They show that in practice transfer paradoxes are unlikely in these special cases.

This article presents and investigates the nontraded goods and unemployment confusion by analyzing international transfers in a simple, but

3. See Samuelson 1947, 29, and Brakman and Van Marrewijk 1998.

general, two-country dual framework. We focus attention on the welfare effects of a transfer, on the terms-of-trade effect, and on the price of traded goods relative to nontraded goods, a point emphasized by Ohlin. Section 1 gives a brief overview of the historical discussion on transfers between Keynes and Ohlin. We summarize their positions at the end of the section in four statements. Section 2 briefly provides the analytic framework of four separate models: (1) the standard model, (2) the nontraded goods model, (3) the unemployment model, and (4) the complete model. Section 3 derives and discusses the analytic consequences of a unilateral transfer in these four models in the light of the four assertions made by Keynes and Ohlin identified in section 1. Section 4 summarizes the results and concludes.

## 1. Historical Overview

Discussions on transfers often give rise to confusion and misunderstandings. This also holds for the discussion on the effects of transfers in the presence of nontraded goods, particularly in conjunction with unemployment. The first example of this particular confusion is the famous discussion on transfers between Keynes and Ohlin in the *Economic Journal* in 1929 in which Keynes analyzed the problem of German war reparation payments as a classical economist. In essence this means that the current account surplus is the transfer. If this surplus is absent or fails to materialize, the terms of trade (or the exchange rate) deteriorates. If the price elasticity of exports is smaller than 1.0, as Keynes believed to be the case for Germany, a paying country is confronted with declining terms of trade. If the paying country has to pay reparations over a longer period of time, the terms of trade will decline from year to year. It is important to note that not only Keynes and Ohlin discussed these matters in the 1929 volume of the *Economic Journal*. Most notably Jacques Rueff (1929, 394) added additional concerns to the debate that anticipated the monetary approach to the balance of payments that was developed later.<sup>4</sup> He argued, contrary to Keynes, that “the commercial balance has shown a tendency to adjust itself to the necessities of the equilibrium of the balance of payments, whatever they might be and whatever their origin.” After further

4. The introduction of money requires that time be introduced explicitly—money is only held if it can be used to buy commodities tomorrow; this, however, does not affect the general conclusions of the models described in the next section (see Brakman and Van Marrewijk 1998, sec. 10.3).

discussing the history of France, he concludes: “What is remarkable in the case of France after 1870 is that a surplus appeared in the commercial balance at precisely the moment when theory would lead one to expect it. This only constitutes a presumption—but a very strong presumption—in favour of the said theory” (395 n. 1).

However, according to Keynes this is not the only problem that faced Germany. One of the main problems is that “when the foreign borrowing [of Germany] comes to an end, it will be a question, not of reducing current consumption in Germany, but of transferring labour from capital works in Germany to the export trades. . . . where the outcome of capital improvements . . . is not in an exportable form (and much of it will not be in such a form), the diversion of production out of other employments into export trades . . . will have to be on a greater scale than is required by the payment of Reparations alone” (Keynes 1929a, 3). Keynes then concludes that one of the main problems is not “the . . . release to foreign consumers of goods now consumed by Germans . . . , but . . . the diversion of German factors of production from other employments into the export industries” (3). The increase of exports is crucial in Keynes’s thinking. He considered this as “a formidable task” and even if efficiency wages are reduced this may not help to increase Germany’s exports, or might even make her worse off, in the case “where the output, *e.g.* personal services or buildings, cannot be exported anyhow” (5).

So, in the eyes of Keynes the existence of nontraded goods very much reduced Germany’s capacity to pay. In Keynes’s analysis this is a major concern, because (relative) prices in the traded goods sector must decrease in order to make the transfer possible, making such a diversion of German factors of production into the traded goods sector unlikely. Ohlin (1929b, 175), in his comment to Keynes, points out that the existence of a non-tradable sector does not alter his (Ohlin’s) main point, namely, that income effects can make terms-of-trade adjustments redundant in principle.

The presence of nontraded goods complicates the analysis considerably and certainly has not made the discussion between Keynes and Ohlin more transparent. Keynes thought that their presence strengthened his case. The consequences of nontraded goods for the transfer problem are still problematic, as the latest edition of the bestselling textbook of Paul Krugman and Maurice Obstfeld (2006) shows. They point out that the United States spends only a fraction of income on foreign goods, just as Keynes pointed this out for Germany in 1929. Obviously, this gives us no information at all on the marginal propensities to consume

a particular good for Germany or the United States.<sup>5</sup> Moreover, as Krugman and Obstfeld (2006, 98) argue, “here the crucial point is that a country’s non-traded goods compete with exports for resources. A transfer of income from the United States to the rest of the world lowers the demand for non-traded goods in the United States, releasing resources that can be used to produce U.S. exports. As a result, the supply of U.S. exports rises. . . . The result is that a transfer by the United States to other countries may lower the price of U.S. exports relative to foreign, worsening U.S. terms-of-trade.”

They then conclude on the basis of this reasoning that “Keynes was right in practice.” However, the quotation from Krugman and Obstfeld suffers from two omissions. First, resources released from the production of nontraded goods in the United States could also be used for the production of goods otherwise imported. Second, and more importantly, the transfer to the rest of the world has increased the demand for U.S. exports, as stressed time and again by Ohlin. Indeed, Ohlin (1929b, 175) argues that

home market prices tend to rise in A [that is: the recipient] and fall in B [that is: the donor], relative to prices of export and import goods and prices of the goods which compete with import goods. . . .

It is not necessary that A’s *export* prices should rise and B’s fall. Thus, B need not offer its goods on cheaper terms of exchange to induce A to take a greater quantity of them. Indirectly, however, it is probable that a certain shift of the terms of exchange will take place.

So, he notes that in the presence of nontraded goods price changes might happen but that they are not necessary, as Keynes believed. Ohlin concludes that “this erroneous conclusion is reached because of the fact that the shift in buying power is ignored, except in so far as it *directly* affects demand for international goods” (175).

To be fair to Keynes, we also deal with the possibility of unemployment and rigidity.<sup>6</sup> As Keynes (1929a, 6) stresses, “In the case of German Reparations . . . , we are trying to fix the volume of foreign remittance and

5. Suppose, for example, that there are two countries with an income level of 100, each spending 50 on traded good *x* and 50 on traded good *y*, while one country produces (in value terms) 60 of *x* and 40 of *y* and the other 40 of *x* and 60 of *y*. Then the observation that both countries only spend 10 percent on foreign goods says nothing about the average propensities to consume, let alone the marginal propensities to consume.

6. We are grateful to one of the anonymous referees for drawing our attention to Rueff 1929.

compel the balance of trade to adjust itself thereto. Those who see no difficulty in this . . . are applying the theory of liquids to what is, if not a solid, at least a sticky mass with strong internal resistances.” Rueff (1929, 390) quotes those very words as he forcefully puts forward the same point.

To settle the issue of the terms-of-trade effect of an international transfer and its relationship to nontraded goods we first need to extend Samuelson’s result on the welfare effects of a transfer to nontraded goods. Furthermore, we allow for the possibility of unemployment and rigidity. At this point it is fair to point out that Keynes was not the ignoramus he is sometimes portrayed to be in this debate: “If £1 is taken from you and given to me and I choose to increase my consumption of precisely the same goods as those of which you are compelled to diminish yours, there is no Transfer Problem” (Keynes 1929a, 2).

However, he thought that this was only a special case. Keynes was very much a practical man in this discussion and he was convinced that Germany could never pay the total of war reparations.

For Keynes this was not the first time he was worried about the possibilities of Germany to pay war reparations, as is illustrated in his *Economic Consequences of the Peace* (1919). In the transfer debate of 1929 he was uneasy that the debate became more and more theoretical instead of practical: “The controversy . . . moves, quite inevitably, from the particular [that is, Germany] to the general” (Keynes 1929b, 404). From a practical point of view he turned out to be right: Germany could never pay the huge amount it should pay and the fact that it was forced to do so helped to pave the way for Hitler. As Ian Kershaw (1999, 355) notes, “With the Brüning government under siege, ruling by emergency decree, its policies—calculated to demonstrate Germany’s inability to pay reparations—sending the economy plummeting to disaster in a catastrophic downward spiral of cascading production levels and soaring levels of unemployment and social misery, more and more voters were cursing the wretched Republic [the Weimar republic].”

Our analysis below is general. The analysis is simplified, however, if we make the standard assumption in international economics of an identical demand structure.<sup>7</sup> For ease of reference, we label this assumption 1.

- Assumption 1: Donor and recipient have an identical demand structure,  $\bar{m}_u^A = \bar{m}_u^B$ .

7. See, for example, page 6 in Bowen, Hollander, and Viaene 1998.

Moreover, we summarize the assertions made by Keynes and Ohlin as discussed above in four statements:

- Keynes's concern: Transfers impose a (large) burden on the donor; this holds particularly for Germany in the presence of nontraded goods and price rigidities.
- Keynes's presumption: A transfer deteriorates the donor's terms of trade, specifically in the presence of nontraded goods.
- Ohlin's presumption 1: There is no reason for a transfer to affect the donor's terms of trade either favorably or unfavorably.
- Ohlin's presumption 2: The price of nontraded relative to traded goods will rise for the recipient and fall for the donor.<sup>8</sup>

## 2. The Models

We analyze international transfers under four different settings of perfect competition if there are two countries (donor  $A$  and recipient  $B$ ) and two traded goods (numéraire good  $x$  and good  $y$  with price  $p$ ). The settings are referred to as (1) the *standard model* (no unemployment or nontraded goods), (2) the *nontraded goods model* (with a nontraded good for both donor and recipient), (3) the *unemployment model* (with unemployment in the donor country), and the *complete model* (with both nontraded goods and donor unemployment). We let  $J = A, B$  be the country index,  $q^J$  is the price of the locally provided nontraded good,  $E^J$  is the expenditure function,  $R^J$  is the revenue function,  $T$  is the transfer from country  $A$  to country  $B$ ,  $u^J$  is the welfare level,  $v^A$  is employment in country  $A$ ,  $w^A$  is the real wage in country  $A$ , and  $m^J$  is the net demand for good  $y$ , that is,  $m^J = E_p^J - R_p^J$ , where subscripts refer to derivatives.<sup>9</sup> The equations below are used to construct the various models mentioned above.

$$E^A(p, q^A, u^A) = R^A(p, q^A, v^A) - T. \quad (1)$$

$$E_q^A(p, q^A, u^A) = R_q^A(p, q^A, v^A). \quad (2)$$

8. It is interesting to note that Harry Johnson concurred with this presumption. In the final section of Johnson 1976 he notes that additional income for the recipient increases the demand for nontraded goods, which (initially) leads to price increases of nontradables. He argues that the subsequent substitution process can be in the direction of importables or exportables, but "since there is no reason to assume that the effect is biased one way or the other" (Johnson 1976, 219), the introduction of nontradables has no bearing on the discussion. In the sections below we show the importance of Ohlin's second presumption in the debate.

9. Note that the model assumes nonsatiable wants. The case of satiable wants in the context of transfers was analyzed by Johnson (1976).

$$R_v^A(p, q^A, v^A) = w^A. \quad (3)$$

$$E^B(p, q^B, u^B) = R^B(p, q^B) + T. \quad (4)$$

$$E_q^B(p, q^B, u^B) = R_q^B(p, q^B). \quad (5)$$

$$m^A(p, q^A, u^A, v^A) + m^B(p, q^B, u^B) = 0. \quad (6)$$

Equation (1) is the donor's budget constraint. It indicates that total expenditure  $E^A$ , which is a function of the prices  $p$  and  $q^A$  and the attained welfare level  $u^A$ , is equal to total revenue  $R^A$ , which is a function of the prices  $p$  and  $q^A$  and the employment level  $v^A$ , after subtracting the transfer to country  $B$  (measured in terms of good  $x$ ). Similarly, equation (4) is the recipient's budget constraint. As we do not analyze unemployment for the recipient, the argument  $v^B$  is suppressed. Equation (2) is the donor's market-clearing condition for nontraded goods. Making use of the derivative properties of expenditure and revenue functions, domestic demand  $E_q^A$  must be equal to domestic supply  $R_q^A$ . Similarly, equation (5) is the recipient's market-clearing condition for nontraded goods, where the argument  $v^B$  is again suppressed. If we analyze unemployment in the donor country, we will always assume that the sticky real wage rate  $w^A$  is a binding restriction, such that actual employment  $v^A$  is endogenously (demand) determined; see equation (3). Finally, using again the derivative properties, equation (5) is the market-clearing condition for traded good  $y$ . The four models mentioned above can now be summarized as follows.

- The standard model ignores nontraded goods and unemployment; it consists of equations (1), (4), and (6), with the endogenous variables  $p$ ,  $u^A$ , and  $u^B$ .
- The nontraded goods model ignores unemployment; it consists of equations (1), (2), (4), (5), and (6), with the endogenous variables  $p$ ,  $q^A$ ,  $q^B$ ,  $u^A$ , and  $u^B$ .
- The unemployment model ignores nontraded goods; it consists of equations (1), (3), (4), and (6), with the endogenous variables  $p$ ,  $v^A$ ,  $u^A$ , and  $u^B$ .
- The complete model incorporates nontraded goods and unemployment; it consists of equations (1)–(6), with the endogenous variables  $p$ ,  $q^A$ ,  $q^B$ ,  $v^A$ ,  $u^A$ , and  $u^B$ .

For the models incorporating nontraded goods, we will simplify the analysis by eliminating equations (2) and (5), which can be solved for

the price of nontraded goods  $q^J$  for donor and recipient as a function of the price  $p$  of good  $y$ , employment  $v^A$ , and domestic welfare  $u^J$ :

$$\begin{aligned}
 q^A &= q^A(p, u^A, v^A); & q^B &= q^B(p, u^B); & \text{with} \\
 q_v^A &= \frac{R_{qv}^A}{(E_{qq}^A - R_{qq}^A)}; & q_v^B &= \frac{E_{qp}^J - R_{qp}^J}{(E_{qq}^J - R_{qq}^J)}, & (7) \\
 q_u^J &= -\frac{E_{qu}^J}{(E_{qq}^J - R_{qq}^J)}, & J &= A, B.
 \end{aligned}$$

Note that if there is any substitution at all in either production or consumption of the nontraded good in country  $J$ , then equation (7) is well defined for that country (that is,  $E_{qq}^J - R_{qq}^J < 0$ ), as we henceforth assume. Also note that if the traded good  $y$  and the nontraded good are net substitutes (that is,  $E_{qp}^J - R_{qp}^J < 0$ ), then  $q_p^J$  is positive, while if the nontraded good is a normal good (that is,  $E_{qu}^J > 0$ ), then  $q_u^J$  is also positive.

### 3. The Results

For each of the models introduced in section 2 we now briefly provide and discuss the main analytic results, identified by subindices *st*, *nt*, *un*, and *co* for the standard, nontraded goods, unemployment, and complete model, respectively.

#### 3.1. The Standard Model

The basic economic implications of international transfers are most easily understood by restricting attention to the standard model, that is, by allowing for two traded goods, two countries, perfect competition, and no imperfections. We normalize such that  $E_u^J = 1$  and define  $\Omega$  and  $\Delta$  for notational convenience as follows:

$$\Omega \equiv \sum_J m_p^J < 0; \quad -1/\Delta \equiv \sum ({}_J m_p^J - m^J m_u^J) < 0. \quad (8)$$

The term  $\Omega$  is always nonpositive as it is the derivative of the compensated net demand for good  $y$  with respect to its own price  $p$ . If there is some substitutability in either demand or supply (or both) between good  $y$  and good  $x$ , the term will be strictly negative, as we henceforth assume. The positively defined term  $\Delta$  is associated with Walrasian stability, based on a dynamic adjustment process where the price falls (rises) if it is higher



(lower) than the equilibrium price; see Brakman and van Marrewijk 1998, 39–41, for details. Differentiating equations (1), (4), and (6) with respect to  $p$ ,  $u^A$ ,  $u^B$  and  $T$ , solving these equations, and imposing Walrasian stability gives the following the terms-of-trade and welfare effects:

$$\left. \frac{dp}{dT} \right|_{st} = (m_u^B - m_u^A)\Delta > 0 \Leftrightarrow m_u^B > m_u^A. \quad (9)$$

$$\left. \frac{du^A}{dT} \right|_{st} = \Omega\Delta < 0; \quad \left. \frac{du^B}{dT} \right|_{st} = -\Omega\Delta > 0; \quad \left. \frac{du^A}{dT} \right|_{st} + \left. \frac{du^B}{dT} \right|_{st} = 0. \quad (10)$$

Equation (9) indicates that the price of good  $y$  will rise, if and only if  $m_u^B < m_u^A$ , that is, if the recipient's marginal propensity to consume good  $y$  is higher than the donor's propensity to consume this good. Obviously, there is no terms-of-trade effect if the demand structure is identical (assumption 1). Even if there are demand differences, however, the donor may either export or import good  $y$ , so there is no presumption that the terms of trade will move against the donor. Equation (10) indicates that the transfer indeed imposes a burden on the donor as its welfare decreases. Similarly, the transfer is welcomed by the recipient, whose welfare increases. Finally, as there are no imperfections in the standard model, there is no room for Pareto improvements.

- Result 1: In the standard model, Keynes's concern is valid (donor burden), as is Ohlin's presumption 1 (neutral terms-of-trade effect)

### 3.2. The Nontraded Goods Model

One of the central points in section 2 is that the discussion between Keynes and Ohlin was complicated by the presence of nontraded goods. The nontraded goods model provided in section 2 is used to analyze these issues. It is convenient to define analogous terms as in the standard model:

$$\begin{aligned} \bar{m}_r^J &\equiv m_r^J + m_q^J q_r^J, \quad r = u, p; & \Omega &\equiv \sum_J m_p^J; & (8') \\ -1/\bar{\Delta} &\equiv \sum ({}_J m_p^J - m^J \bar{m}_u^J) < 0. \end{aligned}$$

The inequality in the last term of equation (8') is again based on Walrasian stability. All the definitions take the nontraded goods effects into consideration. Take, for example, the term  $\bar{m}_u^A = m_u^A + m_q^A q_u^A$ . It consists of the sum of  $m_u^A$  and  $m_q^A q_u^A$ . The former is the regular marginal propensity to

consume good  $y$ , while the latter is the indirect effect on this marginal propensity through the nontraded goods sector. If good  $y$  and the nontraded good are substitutes, the term  $m_q^A$  is positive. If the nontraded good is a normal good, the term  $q_u^A$  is positive; see section 2. Under those circumstances, then, the total marginal propensity to consume good  $y$  is positive if the direct effect dominates the indirect effect.

For analytic purposes, it is important to sign the term  $\bar{\Omega}$ . From the definition of  $\bar{\Omega}$  and equation (7) it follows that

$$\bar{\Omega} \equiv \sum_J \left( m_p^J - \frac{(m_q^J)^2}{(E_{qq}^J - R_{qq}^J)} \right). \tag{11}$$

Thus, using the definition of  $m^J$  in (11), a sufficient condition for  $\bar{\Omega}$  to be negative is for each term in the summation in (11) to be negative, that is,

$$E_{pp}^J - R_{pp}^J - \frac{(E_{pq}^J - R_{pq}^J)^2}{(E_{qq}^J - R_{qq}^J)} < 0 \quad \text{for } J = A, B. \tag{12}$$

Since the net expenditure function  $E^J - R^J$  is concave in prices, both conditions in (12) are satisfied.<sup>10</sup> The term  $\bar{\Omega}$  is therefore unambiguously negative. Differentiating equations (1), (2), (4), (5), and (6) with respect to  $p$ ,  $q^A$ ,  $q^B$ ,  $u^A$ ,  $u^B$ , and  $T$ , solving the equations, and imposing Walrasian stability gives

$$\left. \frac{dp}{dT} \right|_{nt} = (\bar{m}_u^B - \bar{m}_u^A) \bar{\Delta} > 0 \quad \Leftrightarrow \quad \bar{m}_u^B > \bar{m}_u^A. \tag{9'}$$

$$\left. \frac{du^A}{dT} \right|_{nt} = \bar{\Omega} \bar{\Delta} < 0; \quad \left. \frac{du^B}{dT} \right|_{nt} = -\bar{\Omega} \bar{\Delta} > 0; \quad \left. \frac{du^A}{dT} \right|_{nt} + \left. \frac{du^B}{dT} \right|_{nt} = 0. \tag{10'}$$

Equation (9') indicates that the price of good  $y$  will rise, if and only if  $\bar{m}_u^B > \bar{m}_u^A$ , that is, if the recipient's direct plus indirect marginal propensity to consume good  $y$  is higher than the donor's direct plus indirect propensity to consume this good. Again, there is no terms-of-trade effect if the demand structure is identical (assumption 1), and even if there are demand differences, the donor may either export or import good  $y$ , so there is no presumption that the terms of trade will move against the donor. Equation

10. The matrix of second-order price derivatives is negative semi-definite, such that  $(E_{pp}^J - R_{pp}^J)(E_{qq}^J - R_{qq}^J) - (E_{pq}^J - R_{pq}^J)^2 > 0$ . This, in conjunction with  $(E_{qq}^J - R_{qq}^J) < 0$ , gives (12).



(10') indicates that the transfer also imposes a burden on the donor in a nontraded goods setting (as its welfare decreases) and is welcomed by the recipient (as its welfare increases). Since the marginal rate of substitution is equal to the marginal rate of transformation both internationally (between traded goods) and domestically (between traded and nontraded goods), Pareto improvements are again not possible.

What about relative prices? Keynes was convinced that a major aspect of the transfer problem was to divert factors of production from the nontraded to the traded goods sector. This problem becomes more important if relative prices of traded versus nontraded goods decline. Suppose, then, that there is no terms-of-trade effect as a result of the transfer. How about the price of nontraded goods? From (7) it follows that

$$\left. \frac{q^J}{dT} \right|_{nt} = q_u^J \left. \frac{du^J}{dT} \right|_{nt} + q_p^J \left. \frac{dp}{dT} \right|_{nt}. \quad (13)$$

Thus, if  $dp/dT|_{nt} = 0$  we can conclude for the recipient that the sign of  $dq^B/dT|_{nt}$  is the same as the sign of  $q_u^B$  (since  $du^B/dT|_{nt}$  is positive; see equation (10')), which in turn is the same as the sign of  $E_{qu}^B$ ; see (7). Therefore, the recipient's price of nontraded goods rises if, and only if, the marginal propensity to consume nontraded goods is positive. Similar reasoning with a reverse effect holds for the donor of the transfer, which therefore experiences a fall in the price of nontraded goods. Even if the price  $p$  of traded good  $y$  changes, it is obvious from equation (13) that the above conclusions on the changes in the price of nontraded relative to traded goods for donor and recipient still hold if we construct a price index of traded goods in which the weight given to good  $y$  equals  $q_p^J$  (this weight is positive if nontraded goods and good  $y$  are net substitutes).<sup>11</sup> To summarize the above discussion:

- Result 2: In the nontraded goods model, Keynes's concern is valid (donor burden), as is Ohlin's presumption 1 (neutral terms-of-trade effect) and Ohlin's presumption 2 (the price of nontraded goods rises for the recipient and falls for the donor)

### 3.3. The Unemployment Model

As discussed in section 1, Keynes's concern regarding Germany's ability to pay for the imposed international transfers was partially based on a

11. See also McDougall 1965, which uses a Divisia price index for traded goods.

potential exacerbation of Germany’s high unemployment rate at the time of the debate. In effect, the transfer may shift resources into or out of the unproductive “unemployment” sector (see Bhaduri and Skarstein 1996). Before turning to the interaction between nontraded goods and unemployment, we first analyze the model of sticky-wage unemployment outlined in section 2 in the absence of nontraded goods (see also Berthélemy 1988 and Beladi 1990). It is convenient to define the following elasticities:

$$\begin{aligned} \varepsilon^A &\equiv (\partial w^A / \partial p)(p/w^A) = R_{pv}^A (p/R_v^A); \\ \eta^A &\equiv -(\partial w^A / \partial v)(v/w^A) = -R_{vv}^A (v/R_v^A) > 0; \\ -1/\tilde{\Delta} &\equiv -1/\Delta + (\varepsilon^A w^A v / \eta^A p^2)(pm_u^A - \varepsilon^A) < 0. \end{aligned} \tag{8''}$$

The terms  $\varepsilon^A$  and  $\eta^A$  are two elasticities, where  $\varepsilon^A$  is the donor’s Stolper-Samuelson factor price elasticity for good  $y$ . In a standard Heckscher-Ohlin model,  $\varepsilon^A$  will be larger than 1 if good  $y$  uses factor  $v$  (labor in this case) intensively and negative if good  $x$  uses factor  $v$  intensively. Alternatively,  $\varepsilon^A$  will be positive but smaller than 1 in a Ricardo-Viner model; see Dixit and Norman 1980. The positively defined elasticity  $\eta^A$  indicates how quickly the real wage rate falls if employment rises. The last inequality is again based on Walrasian stability. Differentiating equations (1), (3), (4), and (6), with respect to  $p$ ,  $v^A$ ,  $u^A$ ,  $u^B$ , and  $T$ , solving the equations, and imposing Walrasian stability gives

$$\begin{aligned} \left. \frac{dp}{dT} \right|_{un} &= (m_u^B - m_u^A) \tilde{\Delta} > 0 \Leftrightarrow m_u^B > m_u^A. \tag{9''} \\ \left. \frac{du^A}{dT} \right|_{un} &= -1 - m^A \left. \frac{dp}{dT} \right|_{un} + w^A \left. \frac{dv^A}{dT} \right|_{un}; \quad \left. \frac{du^B}{dT} \right|_{un} = 1 - m^B \left. \frac{dp}{dT} \right|_{un} \tag{10''} \\ \left. \frac{du^A}{dT} \right|_{un} + \left. \frac{du^B}{dT} \right|_{un} &= w^A \left. \frac{dv^A}{dT} \right|_{un} = w^A \left( \frac{\varepsilon^A v^A}{\eta^A p} \right) \left. \frac{dp}{dT} \right|_{un}. \end{aligned}$$

The first thing to note from equation (9'') is that the price of good  $y$  rises if and only if  $m_u^B > m_u^A$ , that is, if the recipient’s marginal propensity to consume good  $y$  is higher than the donor’s propensity to consume this good, just as in the standard model. Our conclusions regarding the terms-of-trade effect are therefore not affected by incorporating unemployment in the model. The welfare effects, however, are less clear-cut. Since



unemployment represents a distortion in the model, neither the donor's nor the recipient's welfare effect can be signed in general. For that reason, equation (10'') is written to identify the main welfare effects. The recipient is confronted with a positive direct welfare effect from receipt of the transfer (term 1 in equation (10'')) and a terms-of-trade effect (the term  $-m^B(dp/dT|_{un})$  in equation (10'')), which is positive if the price of the recipient's export good rises. The donor is confronted with a similar terms-of-trade effect and a negative direct transfer effect. In addition, the donor faces an employment effect (the term  $w^A(dv^A/dT|_{un})$  in equation (10'')), which is positive if total employment rises. If the latter is the case, the transfer causes a positive total welfare effect. In theory, this employment effect can be so large that a Pareto improvement is possible (welfare increase for both donor and recipient). The employment effect, however, may also work in the opposite direction, by reducing total welfare and making the donor even worse off, which was one of Keynes's concerns (in which case there could be a welfare decrease for both donor and recipient). Note, however, that under identical demand conditions (assumption 1) none of this is relevant. In that case, both the terms-of-trade effect and the employment effect are zero. This leads to the following result:

- Result 3: In the unemployment model, Keynes's concern is valid (donor burden), as is Ohlin's presumption 1 (neutral terms-of-trade effect).

### 3.4. The Complete Model

The effect of international transfers in the presence of nontraded goods and unemployment can be analyzed in the complete model. The analysis in the preceding sections is useful for understanding the main effects of the complete model, particularly under assumption 1. As we did when moving from the standard to the nontraded goods model (from section 3.1 to section 3.2), we define analogous terms incorporating the direct and indirect (nontraded goods) effects when moving from the unemployment model to the complete model (from section 3.3 to this section); see equation (8''') below. In this case, however, there is an additional complication, arising from the interaction between nontraded goods and unemployment. This can be most easily understood by looking at equation (3):  $R_v^A(p, q^A, v^A) = w^A$ .

- In the absence of nontraded goods, this reduces to  $R_v^A(p, v^A) = w^A$ , implying that any changes in employment are caused exclusively

by changes in the terms of trade. Under assumption 1, there are no changes in the terms of trade, and hence no employment effects (see section 3.3).

- If there are nontraded goods, however, changes in employment can be caused either by changes in the terms of trade  $p$  or by changes in the price of nontraded goods  $q$ . Now recall from the nontraded goods section 3.2 that even if there is no change in the terms of trade (assumption 1), there still is a change in the price of nontraded goods. In the complete model, then, this change in the price of nontraded goods will affect employment, and hence indirectly the terms of trade.<sup>12</sup>

$$\begin{aligned} \bar{m}_v^A &= (m_v^A + m_q^A q_v^A); \quad \bar{R}_{vr}^A \equiv (R_{vr}^A + R_{vq}^A q_r^A), \quad r = p, u, v \\ -1 / \hat{\Delta} &\equiv \left(1 + w^A \bar{R}_{vu}^A / \bar{R}_{vv}^A\right) (-1 / \bar{\Delta}) + \\ &\quad \left(m^A \bar{R}_{vu}^A - \bar{R}_{vp}^A\right) (w^A \bar{m}_u^A + \bar{m}_v^A) / \bar{R}_{vv}^A < 0. \end{aligned} \quad (8''')$$

The inequality denotes Walrasian stability.<sup>13</sup> Differentiating equations (1)–(7) with respect to  $p$ ,  $q^A$ ,  $q^B$ ,  $v^A$ ,  $u^A$ ,  $u^B$ , and  $T$ , and solving the equations gives

$$\left. \frac{dp}{dT} \right|_{co} = \left[ (\bar{m}_u^B - \bar{m}_u^A) + (\bar{R}_{vu}^A / \bar{R}_{vv}^A) (w^A \bar{m}_u^A + \bar{m}_v^A) \right] \hat{\Delta}. \quad (9''')$$

$$\left. \frac{du^A}{dT} \right|_{co} = -1 - m^A \left. \frac{dp}{dT} \right|_{co} + w^A \left. \frac{dv^A}{dT} \right|_{co}; \quad + \left. \frac{du^B}{dT} \right|_{co} = 1 - m^B \left. \frac{dp}{dT} \right|_{co} \quad (10''')$$

$$\left. \frac{du^A}{dT} \right|_{co} + \left. \frac{du^B}{dT} \right|_{co} = w^A \left. \frac{dv^A}{dT} \right|_{co} = w^A \left[ (\bar{m}_u^B - \bar{m}_u^A) + (\bar{R}_{vu}^A / \bar{\Delta}) \right] \left( \hat{\Delta} / \bar{R}_{vv}^A \right).$$

It is evident from equation (9''') that even with an identical demand structure (assumption 1) there will be a change in the terms of trade caused by the indirect effect of the change in the price of nontraded goods, as outlined above. In general, as in the case of the unemployment model, no

12. This result is exactly what Ohlin (1929b, 175) had in mind, as seen in a passage quoted above in the text-proper: "It is not necessary that A's *export* prices should rise and B's fall. Thus, B need not offer its goods on cheaper terms of exchange to induce A to take a greater quantity of them. Indirectly, however, it is probable that a certain shift of the terms of exchange will take place."

13. Note that we could define elasticities analogous to those of section 3.3 on the basis of  $\bar{R}_{vr}^A$ .

definite conclusions regarding the welfare effects can be drawn. As a result of the interaction between nontraded goods and unemployment, this even holds under an identical demand structure.<sup>14</sup> We can, however, draw conclusions on the employment effects under assumption 1, and hence on the total welfare effect. From the last equation in (10''') it is clear that the employment effect depends crucially on the sign of  $\bar{R}_{vu}^A/\bar{R}_{vv}^A$  since  $\bar{\Delta}$  and  $\hat{\Delta}$  are positive. Assuming that the direct effect dominates the indirect effect, we know that  $\bar{R}_{vv}^A > 0$ . From the definition, it follows that  $\bar{R}_{vu}^A \equiv (R_{vu}^A + R_{vq}^A q_u^A) = R_{vq}^A q_u^A$ . If nontraded goods are normal goods, then  $q_u^A > 0$ . Finally, we know that depending on the labor intensity of nontraded goods  $R_{vq}^A$  can be positive or negative (see the discussion with respect to equation 8''). In a Ricardo-Viner model, which reflects Keynes's world of rigidities better than the neoclassical world,  $R_{vq}^A > 0$ , and hence  $\bar{R}_{vu}^A > 0$ . Under assumption 1, therefore, the employment effect is positive. The transfer tends to alleviate the distortion imposed on the donor economy, and thereby mitigates the negative welfare effect imposed on the donor, weakening Keynes's concern.

- Result 4: In the complete model, Keynes's concern is weakened (donor burden) and Ohlin's presumption 1 (neutral terms-of-trade effect) is valid.

#### 4. Summary and Conclusions

Keynes's concern regarding the economic burden imposed on Germany after World War I with respect to the reparation payments can be based on four effects:

- A. The direct burden of the transfer, indicating that Germany had to give up real resources that could have been used for its own consumption and reconstruction.
- B. The indirect burden of a transfer through a deteriorating terms of trade.
- C. The indirect burden of a transfer through rising unemployment.
- D. The indirect burden of a transfer through a change in the price of nontraded goods, which may exacerbate the unemployment problem.

14. We do not think it is very likely that the indirect effect is large enough to cause a welfare paradox (donor enrichment or recipient impoverishment), but we are unable to rule this out analytically.

**Table 1** Summary of Results for the Four Models

	Standard model	Nontraded model	Unemployment model	Complete model
<i>Summary of effects under assumption 1</i>				
Donor terms of trade	0	0	0	?
Donor welfare	-	-	-	?
Recipient welfare	+	+	+	?
Donor price nontraded goods	n.a.	-*	n.a.	?
Recipient price nontraded goods	n.a.	+*	n.a.	?
Donor employment	n.a.	n.a.	0	+**
<i>Summary of results under regular supply and demand conditions</i>				
Keynes's concern	Valid	Valid	Valid	Weakened
Keynes's presumption	Not valid	Not valid	Not valid	Not valid
Ohlin's presumption 1	Valid	Valid	Valid	Valid
Ohlin's presumption 2	n.a.	Valid	n.a.	Unclear

n.a. = Not applicable.

\* If nontraded goods are normal ( $q_n^d > 0$ ).

\*\* If nontraded goods are normal and  $\bar{R}_w^A > 0$ .

We analyze these concerns using four different settings incorporating nontraded goods and unemployment, as summarized in table 1. On the basis of assumption 1, we now briefly relate these results to the Keynes-Ohlin debate (as reviewed in section 1). See the main text, however, for details of the analysis. From a practical point of view, Keynes's concern regarding the burden imposed on Germany certainly seems to be valid. The donor is worse off and the recipient is better off in the standard model, the nontraded goods model, and the unemployment model. Since the interaction between nontraded goods and unemployment in the complete model in general leads to a reduction of unemployment, thus mitigating this distortion, Keynes's concern is weakened in the complete model.

In the presence of nontraded goods, Ohlin's presumption 2, that the price of nontraded relative to traded goods will rise for the recipient and fall for the donor, is also valid. It is readily understood from the fact that, other things equal, the transfer increases demand for nontraded goods for the recipient and reduces demand for the donor. Although this force

is also operative in the complete model, no clear conclusions can be drawn in this setting because both the terms of trade and the employment level will change, and both these changes will also affect the price of non-traded goods relative to traded goods.

Ohlin's presumption 1, that there is no reason for a transfer to affect the donor's terms of trade either favorably or unfavorably, is valid under all circumstances. This implies, simultaneously, that Keynes's presumption that a transfer worsens the donor's terms of trade is not valid. In most cases, a terms-of-trade change is not necessary at all in response to an international transfer because the recipient's increase in demand is offset by the donor's decrease in demand. Only in the complete model is a change in the terms of trade necessary; this follows from the fact that, in the absence of any other changes, the reduction in the donor's demand for nontraded goods causes a price change for nontraded goods, starting off a series of indirect price effects through the production and demand structure.

Finally, it is clear from the top part of table 1 that the most important economic effects of an international transfer cannot be unambiguously signed in the complete model, incorporating both nontraded goods and unemployment. This makes the largely unresolved Keynes-Ohlin discussion understandable. Our analysis discusses not only the most important economic consequences in a framework of nontraded goods and a framework of unemployment, but also how the interaction between these two phenomena complicate the analysis in the complete model. In short, it shows the value of analytic model building in guiding the discussion and our understanding.

## Appendix

This appendix briefly derives the main results for the four models. The equation numbers refer to the equivalent numbers in the paper.

### A1. Standard Model

$$E^A(p, u^A) = R^A(p) - T. \quad (1)$$

$$E^B(p, u^B) = R^B(p) + T. \quad (4)$$

$$m^A(p, u^A) + m^B(p, u^B) = 0. \quad (6)$$

Normalize  $E_u^J = 1$  and define  $\Omega = \sum_J m_p^J < 0$  and  $-1/\Delta \equiv \Omega - m^A m_u^A - m^B m_u^B < 0$ . Differentiate with respect to  $p$ ,  $u^A$ ,  $u^B$  and  $T$  and solve:

$$\begin{bmatrix} m^A & 1 & 0 \\ m^B & 0 & 1 \\ \Omega & m_u^A & m_u^B \end{bmatrix} \begin{bmatrix} dp \\ du^A \\ du^B \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix} dT.$$

$$\frac{dp}{dT} = (m_u^B - m_u^A)\Delta > 0 \Leftrightarrow m_u^B > m_u^A.$$

$$\frac{du^A}{dT} = \Omega\Delta < 0; \quad \frac{du^B}{dT} = -\Omega\Delta > 0; \quad \frac{du^A}{dT} + \frac{du^B}{dT} = 0.$$

### A2. Nontraded Goods Model

$$E^A(p, q^A, u^A) = R^A(p, q^A) - T. \tag{1}$$

$$E_q^A(p, q^A, u^A) = R_q^A(p, q^A) - T. \tag{2}$$

$$E^B(p, q^B, u^B) = R^B(p, q^B) + T. \tag{4}$$

$$E_q^B(p, q^B, u^B) = R_q^B(p, q^B). \tag{5}$$

$$m^A(p, q^A, u^A) + m^B(p, q^B, u^B) = 0. \tag{6}$$

Solve (2) and (5) for the price of nontraded goods and substitute in (1), (4), and (6):

$$E^A(p, q^A(p, u^A), u^A) = R^A(p, q^A(p, u^A)) - T. \tag{1}$$

$$E^B(p, q^B(p, u^B), u^B) = R^B(p, q^B(p, u^B)) + T. \tag{4}$$

$$m^A(p, q^A(p, u^A), u^A) + m^B(p, q^B(p, u^A), u^B) = 0. \tag{6}$$

Define  $q_p^J \equiv -(E_{qp}^J - R_{qp}^J)/(E_{qq}^J - R_{qq}^J)$ ;  $q_u^J \equiv -E_{qu}^J/(E_{qq}^J - R_{qq}^J)$ ;  $\bar{m}_u^J = m_u^J + m_q^J q_u^J$ ;  $\bar{\Omega} = \sum_J (m_p^J - (m_q^J)^2/(E_{qq}^J - R_{qq}^J)) < 0$ ; and  $-1/\bar{\Delta} \equiv \bar{\Omega} - m^A \bar{m}_u^A - m^B \bar{m}_u^B < 0$ . Differentiate with respect to  $p$ ,  $u^A$ ,  $u^B$  and  $T$  and solve:

$$\begin{bmatrix} m^A & 1 & 0 \\ m^B & 0 & 1 \\ \bar{\Omega} & \bar{m}_u^A & \bar{m}_u^B \end{bmatrix} \begin{bmatrix} dp \\ du^A \\ du^B \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix} dT.$$

$$\frac{dp}{dT} = (\bar{m}_u^B - \bar{m}_u^A)\bar{\Delta} > 0 \Leftrightarrow \bar{m}_u^B > \bar{m}_u^A.$$

$$\frac{du^A}{dT} = \bar{\Omega}\bar{\Delta} < 0; \quad \frac{du^B}{dT} = -\bar{\Omega}\bar{\Delta} > 0; \quad \frac{du^A}{dT} + \frac{du^B}{dT} = 0.$$



A3. Unemployment Model

$$E^A(p, u^A) = R^A(p, v^A) - T. \tag{1}$$

$$R_v^A(p, v^A) = w^A. \tag{3}$$

$$E^B(p, u^B) = R^B(p) + T. \tag{4}$$

$$m^A(p, u^A, v^A) + m^B(p, u^B) = 0. \tag{6}$$

Let  $\varepsilon^A \equiv (\partial w^A / \partial p)(p/w^A) = R_{pv}^A(p/R_v^A)$ ;  $\eta^A \equiv -(\partial w^A / \partial v)(v/w^A) = -R_{vv}^A(v/R_v^A)$ ; and  $-1/\tilde{\Delta} \equiv -1/\Delta + (\varepsilon^A w^A v / \eta^A p^2)(pm_u^A - \varepsilon^A) < 0$ . (note:  $m_v^A = -R_{pv}^A$ ). Differentiate with respect to  $p, u^A, u^B, v^A$  and  $T$  and solve:

$$\begin{bmatrix} m^A & 1 & 0 & -w^A \\ m^B & 0 & 1 & 0 \\ \Omega & m_u^A & m_u^B & m_v^A \\ R_{vp}^A & 0 & 0 & R_{vv}^A \end{bmatrix} \begin{bmatrix} dp \\ du^A \\ du^B \\ dv^A \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \\ 0 \\ 0 \end{bmatrix} dT.$$

$$\frac{dp}{dT} = (m_u^B - m_u^A)\tilde{\Delta} > 0 \Leftrightarrow m_u^B > m_u^A.$$

$$\frac{du^A}{dT} = -1 - m^A \frac{dp}{dT} + w^A \frac{dv^A}{dT}; \quad \frac{du^B}{dT} = 1 - m^B \frac{dp}{dT}.$$

$$\frac{du^A}{dT} + \frac{du^B}{dT} = w^A \frac{dv^A}{dT} = \frac{\varepsilon^A w^A v^A}{\eta^A p} \frac{dp}{dT}.$$

A4. Complete Model

$$E^A(p, q^A, u^A) = R^A(p, q^A, v^A) - T. \tag{1}$$

$$E_q^A(p, q^A, u^A) = R_q^A(p, q^A, v^A). \tag{2}$$

$$R_v^A(p, q^A, v^A) = w^A. \tag{3}$$

$$E^B(p, q^B, u^B) = R^B(p, q^B) + T. \tag{4}$$

$$E_q^B(p, q^B, u^B) = R_q^B(p, q^B). \tag{5}$$

$$m^A(p, q^A, u^A, v^A) + m^B(p, q^B, u^B) = 0. \tag{6}$$

Solve (2) and (5) for the price of nontraded goods; substitute in (1), (3), (4), and (6):

$$E^A(p, q^A(p, u^A, v^A), u^A) = R^A(p, q^A(p, u^A, v^A) - T. \tag{1}$$

$$R_v^A(p, q^A(p, u^A, v^A), v^A) = w^A. \tag{3}$$



$$E^B(p, q^B(p, u^B), u^B) = R^B(p, q^B(p, u^B)) + T. \quad (4)$$

$$m^A(p, q^A(p, u^A), u^A) + m^B(p, q^B(p, u^A), u^B) = 0. \quad (6)$$

$q_v^A \equiv R_{qv}^A / (E_{qq}^J - R_{qq}^A)$ ;  $\bar{m}_v^A = (m_v^A + m_q^A q_v^A)$ ;  $\bar{R}_{pv}^A \equiv (R_{pv}^A + R_{vq}^A q_v^A)$ ;  $\bar{R}_{vv}^A \equiv (R_{vv}^A + R_{vq}^A q_v^A)$ ;  $\bar{R}_{vu}^A \equiv R_{vu}^A q_u^A$ ;  $-1/\hat{\Delta} \equiv (1 + w^A \bar{R}_{vu}^A / \bar{R}_{vv}^A)(-1/\bar{\Delta}) + (m^A \bar{R}_{vu}^A - \bar{R}_{vp}^A)(w^A \bar{m}_u^A + \bar{m}_v^A) / \bar{R}_{vv}^A < 0$ . Differentiate with respect to  $p, u^A, u^B, v^A$  and  $T$  and solve:

$$\begin{bmatrix} m^A & 1 & 0 & -w^A \\ m^B & 0 & 1 & 0 \\ \bar{\Omega} & \bar{m}_u^A & \bar{m}_u^B & \bar{m}_v^A \\ \bar{R}_{vp}^A & \bar{R}_{vu}^A & 0 & \bar{R}_{vv}^A \end{bmatrix} \begin{bmatrix} dp \\ du^A \\ du^B \\ dv^A \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \\ 0 \\ 0 \end{bmatrix} dT.$$

$$\frac{dp}{dT} = \left[ (\bar{m}_u^B - \bar{m}_u^A) + (\bar{R}_{vu}^A / \bar{R}_{vv}^A)(w^A \bar{m}_u^A + \bar{m}_v^A) \right] \hat{\Delta}.$$

$$\frac{du^A}{dT} = -1 - m^A \frac{dp}{dT} + w^A \frac{dv^A}{dT}; \quad \frac{du^B}{dT} = 1 - m^B \frac{dp}{dT}.$$

$$\frac{du^A}{dT} + \frac{du^B}{dT} = w^A \frac{dv^A}{dT}.$$

$$\frac{dv^A}{dT} = \left[ (\bar{m}_u^B - \bar{m}_u^A) - (\bar{R}_{vu}^A / \bar{\Delta}) \right] (\hat{\Delta} / \bar{R}_{vv}^A).$$

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