CENTRE of POLICY STUDIES and the IMPACT PROJECT

Eleventh Floor
Menzies Building
Monash University Wellington Road
CLAYTON Vic 3168 AUSTRALIA

Telephone:
(03) 990 52398, (03) 990 55112
from overseas:
61 3 990 55112

Fax numbers:
(03) 990 52426, (03)990 55486
from overseas:
61 3 990 52426 or
61 3 990 55486

e-mail
impact@vaxc.cc.monash.edu.au

How Reliable are Intra-industry Trade Measures as Indicators of Adjustment Costs?

by

Jayant MENON

Centre of Policy Studies
Monash University

General Paper No. G-119 March 1996

ISSN 1 031 9034 ISBN 0 7326 0734 5

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ABSTRACT

A number of recent papers have examined measures of intra-industry trade (IIT) and related indicators such as matched and unmatched changes in trade (MCIT and UCIT) as indicators of adjustment costs associated with trade expansion or contraction. We make three contributions to this literature. First, we clarify what is meant by adjustment costs in the context of these IIT-related measures. Second, we present new measures of MCIT and UCIT. Third, we compare our measures with existing measures using some simple numerical examples and data on Irish chemicals trade. We find that previous IIT-related measures tend to overestimate the extent of MCIT, and underestimate UCIT. We also find that the extent of the bias in these measures can be substantial. Thus, they are unreliable as indicators of adjustment costs. Our measures overcome these limitations.

Keywords: intra-industry trade, matched changes in trade, adjustment costs.

J.E.L. Classification numbers: F31, F32

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1. Introduction

A number of recent papers such as Hamilton and Kniest (HK, 1991), Greenaway, Hine, Milner and Elliot (GHME, 1994) and Brulhart (1994), have examined the measurement of intra-industry trade (IIT) when assessing adjustment cost associated with trade expansion or contraction. As indicators of adjustment cost, IIT measures should accurately capture the extent to which the expansion or contraction in trade over a period consists of matched changes in trade (MCIT) as opposed to unmatched changes in trade (UCIT). The link between adustment cost and MCIT and UCIT relates to the fact that MCIT does not require inter-industry factor movement, whilst UCIT must be accomodated by the transfer of factors either in to or out of the industry. In this sense, UCIT is considered to incur costs as a result of the disruption it causes to factor markets.

How accurate are existing IIT-related measures of adjustment in capturing the extent of MCIT and UCIT? In a recent review, Brulhart (1994) found that both the HK and GHME measures fail to capture accurately the extent of MCIT. He proposes three new measures. However, we find that these measures can overestimate the extent of MCIT, and underestimate the extent of UCIT and adjustment cost. In this paper, we present new measures of MCIT and UCIT that overcome problems associated with Brulhart's and other measures.

The paper is organised in 5 sections. In Section 2, we examine the issue of adjustment costs. In particular, we clarify what exactly summary measures of IIT can tell us about adjustment cost in the context of trade expansion or contraction. Section 3 presents our measures of MCIT and UCIT. In Section 4, we compare our measures with previous contributions using a number of simple numerical examples and Brulhart's data on Irish chemicals trade. A final section summarises the main points, and indicates a number of limitations of using summary measures of adjustment cost with a view to motivating future research.

2. Adjustment Costs

Adjustment costs in the context of trade expansion or contraction is a complex issue. The first-best method of measuring adjustment cost requires a fully specified multi-sectoral model containing detailed regional,

[*] I am grateful to Peter Dixon for comments on an earlier draft. Any errors are mine.

occupational and industry dimensions. Building and implementing such a model is a major task (see Section 5). Until we have such a model, we must make do with the second-best method of using summary measures such as IIT indexes as indicators. These measures can be useful indicators of adjustment cost if they capture the extent to which trade expansion or contraction is disruptive to factor markets.

The assumption made when using measures of MCIT and UCIT as indicators of adjustment costs is that intra-industry factor re-allocations are costless relative to inter-industry factor movements. In other words, we assume that both capital and labour can be moved easily between activities *within* an industry, but not *between* industries. Movement of workers, for instance, between industries might require some re-training, and the adjustment cost would include the cost of this training, loss of output during this period of re-skilling, or any resultant loss in productivity associated with this factor transfer. Movement of workers between activities within the industry, on the other hand, is assumed not to incur any such costs. This is the definition of adjustment costs employed in previous studies. With this definition, it is clear that the measures of MCIT and UCIT should capture accurately the extent of intra- versus inter-industry factor movement associated with the expansion or contraction in trade over a given period.

To illustrate the rationale underlying this definition of adjustment costs, consider a simple case where one unit of labour is required in the production of both the export good (or export variety) and the import-competing good (domestic variety) within an industry. Now, if both imports and exports increase by one unit, then the demand for an extra unit of labour required to facilitate the increase in exports can be met within the industry by the unit of labour released/displaced by the increase in imports. There is no inter-industry factor movement required to facilitate this growth in trade, and thus our notional measure of adjustment cost is zero. Similarly, if both exports and imports decrease by one unit, then the unit of labour released from the export sector could move into the import-competing sector, and adjustment cost is again zero. If it is only exports that decrease by one unit, then one unit of labour would have to leave the industry; likewise, if it is imports that decrease by one unit, then one unit of labour would have to move into the industry. In either case, inter-industry factor movement would equal 1, and our notional measure of adjustment cost should also equal 1.

3. *New and Existing Measures of MCIT and UCIT*

Before we present our measures of MCIT and UCIT, we consider some of the more important properties that such measures should possess. Brulhart (1994) identifies the following four properties: (i) they should be defined in all cases; (ii) they should be capable of being "scaled" relative to measures such as gross or total trade, sales or production; (iii) they should provide information on the proportions of intra- versus inter-industry trade; and (iv) they should be easily interpretable. The HK index is undefined whenever ΔX or ΔM is negative, thus violating property (i). Brulhart's B index violates property (ii), while the GHME and Brulhart's C index violate property (iii). The most serious limitation of all of these measures, however, is that they are subject to error; there are situations in which these measures overestimate the extent of MCIT, and thus underestimate both UCIT and adjustment costs. Our measure overcomes this limitation, while retaining properties (i) to (iv).

We start by explaining the *change* in total trade (TT) in commodity i over any period as the sum of dynamic intra-industry trade ($DIIT$) and dynamic inter-industry or net trade (DNT). $DIIT_i$ is that part of ΔTT_i which is composed of matched changes in imports and exports. DNT_i is that part of ΔTT_i consisting of the residual unmatched change in either imports or exports. That is:

$$\Delta TT_i = DIIT_i + DNT_i \ , \tag{1}$$

$$\text{where } TT_i = X_i + M_i \tag{2}$$

$$DIIT_i = 2 \min (\Delta X_i, \Delta M_i) \tag{2}$$

$$\text{and } DNT_i = |\Delta X_i - \Delta M_i| \ . \tag{3}$$

DNT is our measure of adjustment cost because it is a direct indicator of inter-industry factor movements required to facilitate the growth in trade. Consistent with this,

$$DNT_i \geq 0 \ . \tag{4}$$

DNT_i is necessarily non-negative because it indicates the part of ΔTT_i which must be accommodated either by movement of factors out of or into industry i. $DIIT_i$, on the other hand, can have either sign (Dixon and Menon, 1995).

Most previous measures of IIT have been expressed as *shares*. Shares are often used to provide information on variables measured at a point in time. In the context of adjustment costs, we are dealing with *changes* in variables. In this context, it would be useful to have information on the percentage point contributions of DIIT and DNT to the (percentage) growth in trade over any period. From (1) to (3), we decompose the percentage growth in TT of commodity i into the percentage point contributions of DIIT and DNT according to:

$$tt_i = Cdiit_i + Cdnt_i \ , \tag{5}$$

$$\text{where } Cdiit_i = 100\,(DIIT_i \,/\, TT_i) \tag{6}$$

$$\text{and } Cdnt_i = 100\,(DNT_i \,/\, TT_i) \ . \tag{7}$$

C*diit* and C*dnt* provide information on the percentage point contributions of DIIT and DNT to the percentage growth in trade over any period.

C*diit* and C*dnt* can be scaled relative to total trade, sales, production or any other relevant variable. The formulas for scaling C*diit* and C*dnt* relative to total trade, for instance, are as follows. We begin by defining the following aggregates:

$$TT(j) = \Sigma_{i \in s(j)} TT_i \,, \tag{8}$$

$$DIIT(j) = \Sigma_{i \in s(j)} DIIT_i \,, \tag{9}$$

$$DNT(j) = \Sigma_{i \in s(j)} DNT_i \,. \tag{10}$$

where the s(*j*)'s are sets of products.

Using these equations, we obtain:

$$tt(j) = \Sigma_{i \in s(j)} tt_i \, (TT_i \,/\, TT(j)) \,, \tag{11}$$

$$Cdiit(j) = 100 \, (DIIT(j) \,/\, TT(j)) \,, \tag{12}$$

$$Cdnt(j) = 100 \, (DNT(j) \,/\, TT(j)) \,. \tag{13}$$

where lower-case letters refer to percentage growth rates in the variables.

Cdiit(*j*), for instance, is the trade-weighted average of the percentage point contribution of DIIT to the percentage growth in TT in sector *j*.

Finally, to facilitate the comparison in Section 6 with previous measures of IIT, we can define share-type versions of DIIT and DNT as follows:

$$SDIIT_i = DIIT_i \,/\, |\Delta TT_i| \,, \tag{14}$$

and $$SDNT_i = DNT_i \,/\, |\Delta TT_i| \,.$$ [1] (15)

4. Comparison with Previous Measures of MCIT and UCIT

In this section, we compare our measures of MCIT and UCIT with previous measures using: (i) some simple numerical examples and (ii) Brulhart's 3-digit SITC data on Irish chemicals trade for the period 1985 to 1990. We chose to use Brulhart's data to retain comparability to his earlier work, and to focus attention away from the data and towards the measurement of MCIT and UCIT. Both sets of results are contained in Table 1.

We begin by identifying the relevant comparators for the various measures reported in Table 1. *GHME* and *C* are unscaled MCIT measures, and thus should be compared with *DIIT*. *A* is a share index based on MCIT, and should be compared with *SDIIT*. *B* is a share index based on UCIT, and its absolute value should be compared with *SDNT*.[2] The *HK* index has no relevant comparator, and is reported for completeness only. We also report

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[1] These share-type versions of DIIT and DNT are valid provided that $\Delta TT \neq 0$.

[2] Brulhart's *B* index can vary between -1 and 1: if $\Delta X \geq \Delta M$, $0 \geq B \geq 1$, and if $\Delta X < \Delta M$, $0 > B \geq -1$ (see Appendix). Brulhart (1994) claims that this feature of the index enables it to provide information on sectoral performance. Since the sign of *B* is not relevant in assessing adjustment costs, our comparison relates *SDNT* to |*B*|.

our preferred measures, *Cditt* and *Cdnt*, together with *tt*.[3] The formulas for these measures are presented in the Appendix.

The first four rows of numbers in Table 1 contain our hypothetical data. The first row (case (1)) is the "control", where all measures come up with the correct estimate of MCIT and UCIT. In case (2), where only X increases by 3, we find that *HK* is undefined and *GHME* is 6. The correct amount (in units) of the MCIT in this instance is 0, and the UCIT is 3. This is correctly identified by our measures of *DIIT* and *DNT*. The error in the *GHME* measure occurs in this instance because the following condition applies:

$$M(0) \;>\; X(0), \quad \text{but } \Delta M \;<\; \Delta X \,. \tag{16}$$

Alternatively, the GHME would also be in error if

$$X(0) \;>\; M(0), \quad \text{but } \Delta X \;<\; \Delta M \,. \tag{17}$$[4]

Whenever either of these conditions apply, the *GHME* measure will overestimate the extent of MCIT, and thus underestimate the extent of UCIT and adjustment cost. Note, however, that Brulhart's *A*, *B* and *C* measures are not subject to this limitation, and provide an accurate estimate of MCIT or UCIT in case (2). Case (3) differs from case (2) in that imports now decrease by 1 over the period (exports still increase by 3). Brulhart's *A*, *B* and *C* measures all indicate that all the growth in trade is unmatched. In fact, the values for all three measures are identical to case (2), and are again unchanged in case (4), where imports decrease by 2 over the period (with the increase in exports still at 3). While these indexes provide the correct qualitative information (ie. all trade growth is unmatched), they are unable to distinguish the obvious differences in the degree of adjustment cost in each of the three cases. Looking at *DNT*, which accurately measures the extent of UCIT, we find that the extent of inter-industry factor movements required increases from 3 to 4 to 5 units as we go from case (2) to (3) to (4). Brulhart's *A* and *C* measures underestimate the extent of adjustment cost whenever:

$$\Delta M \;<\; 0 \,, \tag{18}$$

and/or

$$\Delta X \;<\; 0 \,, \tag{19}$$

while the *B* index underestimates adjustment cost whenever *either*:

$$\Delta M \;<\; 0 \,, \tag{20}$$

or

$$\Delta X \;<\; 0 \,. \tag{21}$$

[3] In this paper, we do not consider the Grubel and Lloyd (GL, 1976) index of IIT in our comparison. The GL index is a *static* share index that measures the importance of IIT in total trade at a point in time. Its limitations as an indicator of adjustment cost have been established in earlier works, and is now widely recognised. See Milner (1988), Hamilton and Kniest (1991), Greenaway *et al.* (1994), Brulhart (1994), Menon and Dixon (1996a), (1996b) and Dixon and Menon (1995).

[4] The proof of this and other propositions (that relate our measure to previous measures of MCIT and UCIT) is in the Appendix.

That is, the *A* and *C* measures overestimate MCIT and underestimate UCIT whenever imports and/or exports decline over a period, whilst the *B* index overestimates MCIT and underestimates UCIT whenever either imports or exports decline over a period (but not when both decline). These conditions, as well as those that produce errors in the *GHME* measure, appear quite general. The seriousness of these limitations needs to be assessed in the light of real-world data. This is required to determine whether these limitations are simply of academic interest, or if they seriously limit the usefulness of these measures as indicators of adjustment cost in a practical sense. To answer these questions, we turn now to the results for Irish chemicals trade between 1985 and 1990.

We begin by assessing the *HK* index. The most serious problem with the *HK* index is that it is so often undefined; in our sample of 23 3-digit chemical industries, the *HK* index is undefined in 11 cases. The *GHME* measure, on the other hand, underestimates adjustment cost in 10 out of the 23 industries.[5] Brulhart's *A* and *C* measures underestimate the extent of adjustment cost in 11 out of the 23 industries, while his *B* measure underestimates adjustment cost in 8 industries. The correlation coefficient between *A* and *SDIIT* is 0.45, and 0.53 between $|B|$ and *SDNT*. From our growth contribution measures (C*diit* and C*dnt*), we find that MCIT play a very minor role in the growth in total trade for the chemicals sector over this period. MCIT contributes only 1.61 percentage points to the growth in total trade of 38.42 percent.[6] The remaining 36.82 percentage points is made up of UCIT. Thus, it is clear that previous measures of MCIT and UCIT are quite unreliable as indicators of adjustment costs.

5. Conclusions and Qualifications

This paper has made three contributions to the growing literature on IIT-related measures of adjustment cost. First, we clarified what is meant by "adjustment cost" in the context of these measures. Second, we developed new measures of MCIT and UCIT. Third, we compared our measures with

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[5] The values for these 10 industries appear in bold-italics in Table 1. Similarly, the values for other measures that are in error also appear in bold-italics. The extent of the bias in this and other measures of IIT is quantified in the Appendix.

[6] It would be interesting to compare our measure of $Cdiit(j)$ (for total chemicals trade) with similar measures based on *GHME* and *C*. To obtain sectoral growth contribution type measures of *GHME* and *C*, we begin by defining the following two aggregates:

$$GHME(j) = \Sigma_{i \in s(j)} GHME_i$$

$$C(j) = \Sigma_{i \in s(j)} C_i$$

where the *i* subscript refers to a 3-digit SITC product, while $s(j)$ is the set of 3-digit products belonging to the SITC 1-digit grouping (SITC 5, chemicals).

With these aggregates, we obtain the contributions of *GHME* (C*ghme*) and *C* (C*c*) to the growth in total trade in chemicals as:

$$Cghme(j) = 100\,(GHME(j)\,/\,TT(j)) \;,$$

and $$Cc(j) = 100\,(C(j)\,/\,TT(j)) \;.$$

Applying these measures to Brulhart's data, we find that the contribution of *GHME* to the growth in total trade in chemicals was 19.60 percentage points, whilst the contribution of *C* was 19.07 percentage points. In both cases, these estimates greatly exceed the contribution of *DIIT* of 1.61 percentage points.

existing measures using some simple numerical examples and Brulhart's (1994) data on Irish chemicals trade. We found that previous IIT-related measures of adjustment cost tend to overestimate the extent of MCIT, and underestimate UCIT and adjustment cost, in a variety of relatively general and common situations. We also found that the extent of the bias in these measures is considerable.

Although we think that our measure is superior to other indicators of trade-related adjustment cost, we should emphasise that our argument is theoretical. In common with other writers in this area, we have not provided empirical evidence linking these indicators of adjustment cost with estimates of factor market disruption. This would be a major task involving the construction of a model containing detailed estimates of the costs of factor transfers between industries, regions and occupations (Dixon and Menon, 1995). With such a model, we could simulate the effects of trade liberalisation, regional trading agreements or other shocks affecting trade growth. Then we could correlate movements implied by the model for the IIT measures with the model's estimates of adjustment costs.

Such a model could also relax two assumptions that are implicitly made when working with IIT-related indicators of adjustment costs. First is the assumption of fixed domestic demand. To elucidate, consider a case where exports of industry i remain constant but the increase in imports is due to an increase in domestic demand; that is, a spill-over into imports as a result of domestic production being unable to meet the increase in demand. While the IIT measure would suggest that this unmatched increase in imports is disruptive to factor markets, it is clear that it is not in this case. Imports increase in this instance purely because domestic factors in industry i are fully-employed. The second implicit assumption is that all imports are competitive, in the sense that an increase in imports would displace domestic production. If imports are complementary in the sense that they are an input, without a domestically produced alternative, into domestic production, then any increase is likely to be less disruptive than indicated by our IIT measure. These two assumptions, and the complications that they introduce when relaxed, are common to all IIT-related indicators of adjustment costs. These assumptions, in fact, derive from treating changes in imports and exports as exogenous. The only solution to this problem is to work with a model of suitable detail and empirical content as described above. Until we have such a model, however, we must make do with theoretical justifications of our indicators.

Table 1: Comparison of Measures of MCIT and UCIT using Hypothetical and Irish Chemicals Trade Data (1985 to 1990).

Hypothetical Data																		
Case	X(0)	M(0)	X(1)	M(1)	ΔX	ΔM	*HK*	*GHME*	*A*	*B*	*C*	*DIIT*	*DNT*	*SDIIT*	*SDNT*	*tt*	*Cdiit*	*Cdnt*
(1)	1	1	4	4	3	3	1	6	1	0	6	6	0	1	0	300	300	0
(2)	1	4	4	4	3	0	Und.	6	0	1	0	0	3	0	1	60	0	60
(3)	1	4	4	3	3	-1	Und.	4	0	1	0	-2	4	-1	2	40	-40	80
(4)	1	4	4	2	3	-2	Und.	2	0	1	0	-4	5	-4	5	20	-80	100
Irish Chemicals Trade, 1985 to 1990																		
SITC	X(85)	M(85)	X(90)	M(90)	ΔX	ΔM	*HK*	*GHME*	*A*	*B*	*C*	*DIIT*	*DNT*	*SDIIT*	*SDNT*	*tt*	*Cdiit*	*Cdnt*
511	780	8572	557	9255	-223	683	Und.	-446	0	-1	0	-446	906	-0.97	1.97	4.92	-4.77	9.69
512	547	16974	8802	14831	8255	-2143	Und.	16510	0	1	0	-4286	10398	-0.70	1.70	34.88	-24.46	59.35
513	70943	38025	71410	49457	467	11432	0.04	22864	0.08	-0.92	934	934	10965	0.08	0.92	10.92	0.86	10.06
514	100196	21749	127747	65151	27551	43402	0.63	86804	0.78	-0.22	55102	55102	15851	0.78	0.22	58.18	45.19	13.00
515	551134	93069	622665	86319	71531	-6750	Und.	-13500	0	1	0	-13500	78281	-0.21	1.21	10.06	-2.10	12.15
516	19788	22326	22127	28803	2339	6477	0.36	4678	0.53	-0.47	4678	4678	4138	0.53	0.47	20.93	11.11	9.83
522	24657	37234	15011	44437	-9646	7203	Und.	-19292	0	-1	0	-19292	16849	-7.90	6.90	-3.95	-31.17	27.22
523	5372	23838	4813	21666	-559	-2172	Und.	-1118	0.41	0.59	1118	-4344	1613	-1.59	0.59	-9.35	-14.87	5.52
524	147	1272	7752	6344	7605	5072	0.67	12394	0.80	0.20	10144	10144	2533	0.80	0.20	893.38	714.87	178.51
531	1031	7301	662	9758	-369	2457	Und.	-738	0	-1	0	-738	2826	-0.35	1.35	25.06	-8.86	33.92
532	217	978	1431	3457	1214	2479	0.49	2428	0.66	-0.34	2428	2428	1265	0.66	0.34	309.04	203.18	105.86
533	15457	30327	12850	44176	-2607	13849	Und.	-5214	0	-1	0	-5214	16456	-0.46	1.46	24.55	-11.39	35.94
541	185901	167491	508085	224963	322184	57472	0.18	114944	0.30	0.70	114944	114944	264712	0.30	0.70	107.43	32.53	74.91
551	86898	43322	154216	49676	67318	6354	0.09	12708	0.17	0.83	12708	12708	60964	0.17	0.83	56.58	9.76	46.82
553	59010	39635	101422	58304	42412	18669	0.44	37338	0.61	0.39	37338	37338	23743	0.61	0.39	61.92	37.85	24.07
554	18928	46690	18986	58839	58	12149	0.00	116	0.01	-0.99	116	116	12091	0.01	0.99	18.60	0.18	18.43
562	15953	183134	29304	140787	13351	-42347	Und.	26702	0	1	0	-84694	55698	-2.92	1.92	-14.56	-42.54	27.98
572	1995	3545	57	2931	-1938	-614	Und.	-3876	0.48	-0.52	1228	-3876	1324	-1.52	0.52	-46.06	-69.96	23.90
582	18309	46659	10399	21636	-7910	-25023	Und.	-15820	0.48	0.52	15820	-50046	17113	-1.52	0.52	-50.69	-77.03	26.34
583	61504	167203	94077	269525	32573	102322	0.32	65146	0.48	-0.52	65146	65146	69749	0.48	0.52	58.98	28.48	30.50
591	3038	28818	758	9055	-2280	-19763	Und.	-4560	0.21	0.79	4560	-39526	17483	-1.79	0.79	-69.20	-124.08	54.88
592	95186	23009	3534	27441	-91652	4432	Und.	-38950	0	-1	0	-183304	96084	-2.10	1.10	-73.79	-155.09	81.29
598	32347	52430	234471	125144	202124	72714	0.36	185594	0.53	0.47	145428	145428	129410	0.53	0.47	324.19	171.54	152.65
Total 5	1369338	2051136	1103601	1371955	681798	268354	n.a.	484712	0.21	n.a.	471692	39700	910452	-0.50	1.09	38.42	1.61	36.82

Appendix

In this appendix, we present proofs to a number of propositions regarding the relationship between our measures of DIIT and DNT and previous measures. Our proof of each proposition is presented in two parts. In the first part, we present the conditions under which our measure is identical to the other measure. In the second part, we present the conditions under which our measure differs from the other measure. For the second part, we also quantify the bias (ie. the extent of underestimation of adjustment cost) in the other measure.

(1) GHME and DIIT

Proposition:

$$\text{GHME} \geq \text{DIIT},$$

i.e. $\{X(1) + M(1) - |X(1) - M(1)|\} - \{X(0) + M(0) - |X(0) - M(0)|\} \geq 2\ \min(\Delta X, \Delta M)$

i.e. $2\ \min(X(1), M(1)) - 2\ \min(X(0), M(0)) \geq 2\ \min(\Delta X, \Delta M)$ (A1)

Proof:

(i) The following two cases cover all possibilities where GHME = DIIT

<u>Case 1: $X(0) \geq M(0), \Delta X \geq \Delta M$</u>

L.H.S.(A1)	=	$2M(1) - 2M(0)$	=	$2\Delta M$
R.H.S.(A1)	=	$2\Delta M$		
	=	L.H.S.(A1) .		

<u>Case 2: $M(0) > X(0), \Delta M \geq \Delta X$</u>

L.H.S.(A1)	=	$2X(1) - 2X(0)$	=	$2\Delta X$
R.H.S.(A1)	=	$2\Delta X$		
	=	L.H.S.(A1) .		

(ii) The following four cases cover all possibilities where GHME > DIIT.

<u>Case 1: $X(0) > M(0), X(1) \geq M(1), \Rightarrow \Delta X < \Delta M$</u>

L.H.S.(A1)	=	$2M(1) - 2M(0)$	=	$2\Delta M$
R.H.S.(A1)	=	$2\Delta X$		
	<	L.H.S.(A1)		
Bias in GHME	=	L.H.S.(A1) - R.H.S.(A1)		
	=	$2(\Delta M - \Delta X)$.		

Examples of case 1 are SITC 513 and 514.

<u>Case 2: $X(0) > M(0), X(1) < M(1), \Delta X < \Delta M$</u>

L.H.S.(A1)	=	$2X(1) - 2M(0)$,
R.H.S.(A1)	=	$2\Delta X$,

	<	L.H.S.(A1) .
Bias in GHME	=	L.H.S.(A1) - R.H.S.(A1)
	=	2(X(0) - M(0)) .

An example of case 2 is SITC 592.

The other two cases are: M(0) > X(0), M(1) ≥ X(1), ΔM < ΔX (Case 3); and M(0) ≥ X(0), M(1) < X(1), ΔM < ΔX (Case 4). Case 3 is similar to case 1 and case 4 is similar to case 2, with the roles of X and M interchanged. Bias in GHME in case 3 is (2ΔX), and examples are SITC 512, 523, 562, 582 and 591. Bias in GHME in case 4 is (2(M(0) - X(0)), and examples are SITC 524 and 592.

(2) Brulhart's A index and SDIIT

Proposition:

$A \geq SDIIT$

i.e. $1 - \{|\Delta X - \Delta M| / (|\Delta X| + |\Delta M|)\} \geq (2 \min(\Delta X, \Delta M)) / |\Delta X + \Delta M|$ (A2)

Proof:

(i) The following two cases cover all possibilities where A = SDIIT.

Case 1: ΔX ≥ 0, ΔM ≥ 0, ΔX ≥ ΔM.

L.H.S.(A2)	=	$1 - \{(\Delta X - \Delta M) / (\Delta X + \Delta M)\}$
	=	$2\Delta M / (\Delta X + \Delta M)$,
R.H.S.(A2)	=	$2\Delta M / (\Delta X + \Delta M)$,
	=	L.H.S.(A2) .

Case 2, ΔM > ΔX > 0, is similar to case 1, with the roles of X and M interchanged.

(ii) The following four cases cover all possibilities where A > SDIIT.

Case 1: ΔX ≥ 0, ΔM < 0.

L.H.S.(A2)	=	$1 - \{(\Delta X - \Delta M) / (\Delta X - \Delta M)\}$	=	0 ,
R.H.S.(A4)	=	$2\Delta M / |\Delta X + \Delta M|$	<	0 ,
	<	R.H.S.(A2) .		
Bias in A	=	L.H.S.(A2) - R.H.S.(A2)		
	=	$-2\Delta M / |\Delta X + \Delta M|$.		

Examples of case 1 are SITC 512, 515 and 562.

Case 2, ΔM ≥ 0, ΔX < 0, is similar to case 1, with the roles of X and M interchanged. Bias in A, in this instance, is $(-2\Delta X / |\Delta X + \Delta M|)$, and examples are SITC 511, 522, 531, 533 and 592.

Case 3: $\Delta X < 0, \Delta M \leq 0, \Delta X > \Delta M.$

L.H.S.(A2)	=	$1 - \{(\Delta X - \Delta M) / (-\Delta M - \Delta X)\} =$		0 .
R.H.S.(A2)	=	$2\Delta X / \lvert\Delta X + \Delta M\rvert$	<	0 ,
	<	L.H.S.(A2) .		
Bias in A	=	L.H.S.(A2) - R.H.S.(A2)		
	=	$-2\Delta X / \lvert\Delta X + \Delta M\rvert$.		

Examples of case 3 are SITC 523, 582 and 591.

Case 4. $\Delta X < \Delta M \leq 0$, is similar to case 3, with the roles of X and M interchanged. Bias in A, in this instance, is $(-2\Delta M / \lvert\Delta X + \Delta M\rvert)$, and an example is SITC 572.

(3) Brulhart's B index and SDNT

Proposition:

$$\lvert B\rvert \leq SDNT$$

i.e. $\lvert(\Delta X - \Delta M) / (\lvert\Delta X\rvert + \lvert\Delta M\rvert)\rvert \leq \lvert\Delta X - \Delta M\rvert / \lvert\Delta X + \Delta M\rvert$ (A3)

Proof:

(i) The following two cases cover all possibilities where $\lvert B\rvert$ = SDNT.

Case 1: $\Delta X \geq 0, \Delta M \geq 0.$

L.H.S.(A3)	=	$\lvert\Delta X - \Delta M\rvert / (\Delta X + \Delta M)$,
R.H.S.(A3)	=	$\lvert\Delta X - \Delta M\rvert / (\Delta X + \Delta M)$,
	=	L.H.S.(A3) .

Case 2: $\Delta X < 0, \Delta M \leq 0.$

L.H.S.(A3)	=	$\lvert\Delta X - \Delta M\rvert / (-\Delta X - \Delta M)$,
R.H.S.(A3)	=	$\lvert\Delta X - \Delta M\rvert / (-\Delta X - \Delta M)$,
	=	L.H.S.(A3) .

(i) The following two cases cover all possibilities where $\lvert B\rvert$ < SDNT.

Case 1: $\Delta X \geq 0, \Delta M < 0.$

L.H.S.(A3)	=	$(\Delta X - \Delta M) / (\Delta X - \Delta M)$	=	1 ,
R.H.S.(A3)	=	$(\Delta X - \Delta M) / \lvert\Delta X + \Delta M\rvert$	<	1 ,
	>	L.H.S.(A3) .		
Bias in $\lvert B\rvert$	=	L.H.S.(A3) - R.H.S.(A3)		
	=	$1 - \{(\Delta X - \Delta M) / \lvert\Delta X + \Delta M\rvert\}$.		

Examples of case 1 are SITC 512, 515 and 562.

Case 2: $\Delta M \geq 0, \Delta X < 0.$

L.H.S.(A3)	=	$\lvert\Delta X - \Delta M\rvert / (\Delta M - \Delta X)$	=	1 ,
R.H.S.(A3)	=	$(\Delta M - \Delta X) / \lvert\Delta X + \Delta M\rvert$	>	1 ,
	>	L.H.S.(A3) .		

Bias in |B| = L.H.S.(A3) - R.H.S.(A3)

= $1 - \{(\Delta M - \Delta X) / |\Delta X + \Delta M|\}$.

Examples of case 2 are SITC 511, 522, 531, 533 and 592.

(4) Brulhart's C Measure and DIIT

Proposition:

$$C \geq DIIT$$

i.e. $$|\Delta X| + |\Delta M| - |\Delta X - \Delta M| \geq 2\,min\,(\Delta X, \Delta M) \quad (A4)$$

Proof:

(i) The following two cases cover all possibilities where C = DIIT.

<u>Case 1: $\Delta X \geq 0$, $\Delta M \geq 0$, $\Delta X \geq \Delta M$.</u>

L.H.S.(A4) = $\Delta X + \Delta M - (\Delta X - \Delta M)$ = $2\Delta M$,

R.H.S.(A4) = $2\Delta M$,

= L.H.S.(A4) .

<u>Case 2, $\Delta M > \Delta X > 0$</u>, is similar to case 1, with the roles of X and M interchanged.

(ii) The following four cases cover all possibilities where C > DIIT.

<u>Case 1: $\Delta X \geq 0$, $\Delta M < 0$.</u>

L.H.S.(A4) = $\Delta X - \Delta M - (\Delta X - \Delta M)$ = 0 ,

R.H.S.(A4) = $2\Delta M$ < 0 ,

< R.H.S.(A4) .

Bias in C = L.H.S.(A4) - R.H.S.(A4) = $-2\Delta M$.

Examples of case 1 are SITC 512, 515 and 562.

<u>Case 2, $\Delta M \geq 0$, $\Delta X < 0$</u>, is similar to case 1, with the roles of X and M interchanged. Bias in C, in this instance, is $(-2\Delta X)$, and examples are SITC 511, 522, 531, 533 and 592.

<u>Case 3: $\Delta X < 0$, $\Delta M < 0$, $\Delta X > \Delta M$.</u>

L.H.S.(A4) = $-\Delta X - \Delta M - (-\Delta M + \Delta X)$ = $-2\Delta X$ > 0 .

R.H.S.(A4) = $2\Delta M$ < 0 ,

< L.H.S.(A4) .

Bias in C = L.H.S.(A4) - R.H.S.(A4) = $-2(\Delta X + \Delta M)$.

Examples of case 3 are SITC 523, 582 and 591.

<u>Case 4, $\Delta X < \Delta M < 0$</u>, is similar to case 3, with the roles of X and M interchanged. Bias in C is also $(-2(\Delta X + \Delta M))$, and an example is SITC 572.

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