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STRUCTURAL DECOMPOSITION ANALYSIS OF CHANGES IN MATERIAL DEMAND IN THE U.S. ECONOMY

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by

Adam Rose and Chia-Yon Chen*

I. INTRODUCTION

The "intensity of use" concept has frequently been applied to the study of mineral and material demand. One group of researchers has examined this ratio of minerals/materials to GNP in terms of a single theme. These studies range from Malenbaum's (1978) simple correlation of intensity of use (IU) with the level of development to the sophisticated analysis of IU in relation to product life cycles by Labys and Waddell (1988). Another, larger group of researchers has analyzed mineral/material demand in terms of a "decomposition" of the IU ratio into two or more components, such as input substitution, technological change, and product mix. Over the last several years advances in this methodology have emanated from applications of growth accounting (productivity measurement), input-output analysis and econometrics. However, to date there has been no comprehensive methodology capable of a consistent estimation of the role that the many hypothesized variables might play in the utilization of materials.

Input-output based structural decomposition analysis (SDA) represents a major advance in this direction. It is defined as a method of distinguishing major shifts within an economy over time by means of comparative static changes in key sets of parameters (Rose and Miernyk, 1989). This methodology is able to overcome the major limitations of the basic, static I-O model, including the fixed coefficient requirement. In fact, recent work by the authors (Rose and Chen, 1987; 1991) has presented the case that our version of SDA is capable of yielding results comparable to those derived from 2-tier KLEM models based on flexible functional forms, yet with much less demanding data requirements (see also Rose and Casler, 1996).

The purpose of this paper is to explain the usefulness of SDA in analyzing changes in materials demand and to illustrate the workings of the methodology by analyzing the situation in the U.S. between 1972 and 1982. The results of the analysis represent work in progress. Thus far we have used 2-digit

(83) sector tables. Our goal, however, is to perform the analysis at the more meaningful 4-digit (500) sector level and to extend the time horizon to a more recent year.

II. REVIEW OF THE LITERATURE

The intensity of use concept is usually ascribed to Schurr and Netschert (1960) in the context of their study of energy in the U.S. economy. The first formal decomposition of IU is due to Tilton (1985) and Roberts (1985)[i] in the manner of splitting an identity:

$$\frac{X_i}{Y} = \sum_j^n \left[\frac{X_{ij}}{Q_j}\right] \cdot \frac{\sum Q_j}{Y}$$

where

X_i = the apparent use of material i

X_{ij} = the amount of material i used in the production of major material using industry j

Q_j = the output of material using industry j $(j = 1 \ldots n)$

Y = gross national product

Following Tilton (1985), the first term on the right-hand side has come to be known as the material composition of product (MCP) and the second term as the product composition of income (PCI). The first term is intended to capture supply-side considerations, while the second embodies demand-side effects.

Table 1 lists the methodological advances in decomposing IU. These contributions are distinguished according to studies expressly concerned with IU of minerals and materials and those in the domain of I-O structural decomposition analyses applied to materials/minerals or the closely related area of energy resources.

For example, Roberts (1985) decomposed materials-using industries according to the useful distinction of durable and non-durable goods sectors. In addition, he incorporated a crude production function and its statistical estimation into the framework in order to better analyze the MCP term (see also Roberts, 1986). Considine (1990a) has analyzed the intensity of use concept using modern duality-based methods within a partial equilibrium framework. In the process, he resolved the problem of comparability of material substitutes by the use of the divisia index (see also Considine, 1990b).

Input-output structural decomposition analysis is attributable to Leontief (1951). Although Leontief and his associates have performed major studies of mineral demand, their orientation has been forecasting, and, hence, they have utilized a dynamic I-O formulation rather than the more historically-oriented SDA (see Leontief et al., 1983). The motivation of SDA is the same as the identity splitting of direct IU methodologies. The apparent advantages of the I-O approach are that by definition the economy is disaggregated into the various materials-using sectors and that direct effects can be distinguished from indirect effects. Additional advantages will be explained in the following section. Note also that there are some minor terminological differences between the two approaches. MCP is referred to as technical coefficient change in SDA parlance, while PCI is often referred to as the (final demand) product mix effect. A (final demand) growth effect is also included, so that the results yield both intensities and levels of utilization.

Myers (1986) was the first to apply SDA directly to minerals use.[2] More recently, Devine (1988) demonstrated the insights that could be obtained via a decomposition of final demand according to its major categories (consumption, investment, inventories, imports, exports, federal defense expenditures, other federal expenditures, and state and local government). As will be explained in more detail below, Rose and Chen (1987; 1990) broadened and deepened the analysis to a 2-tier KLEM production function level, thus creating distinctions between technological change and technical (input) substitution within the general category of coefficient change. More recently, Duchin (1989) has modified the basic I-O framework to incorporate recycling, a feature that might be integrated into SDA versions of the I-O model.

Note that advances in theory and method are sometimes misconstrued as representing sophistication for its own sake. These advances listed in Table 1 serve the practical purpose of analyzing a broader set of determinants of intensity of use and in a more accurate fashion. The divisia index provides a means of adjusting for quality (of characteristics) differences between materials. Flexible functional forms allow for more realistic production functions and more meaningful analyses of substitution. Disaggregation of final demand is a major step toward analyzing behavioral differences among categories of decision-makers. As noted above, the 2-tier KLEM formulation of SDA overcomes the vagueness of coefficient change results of the rudimentary SDA approach. Moreover, it does not require the extensive data or complex specification/estimation of, say, a translog cost function.

Not surprisingly, each major methodological advance has yielded important new insights into the intensity of use of materials. Tilton (1983; 1985) found a greater role for technological change than had previous researchers, while Considine (1990a; 1990b) identified a relatively more prominent role for material input substitution in response to relative price changes. Myers (1986), using an innovative combination of I-O and econometrics, also found price changes to be an important explanatory variable for material input coefficient change. Our methodology provides a means by which to analyze these and other sources of change in greater depth.

III. THE CONCEPTUAL FRAMEWORK

The economics of production is typically couched in terms of primary factors--capital, labor, and sometimes land or other natural resources. A major departure from this tradition for over 50 years has been input-output analysis, which explicitly recognizes the role of intermediate inputs. As issues relating to energy and resources become more prominent in the 1970s, there was a shift toward complete input accounting. This approach has come to be known as "KLEM" modeling, where the acronym represents capital, labor, energy and materials (actually all non-energy intermediate inputs). It is often further subdivided into 2-tiers, the delineation of subaggregates within some of the KLEM components (e.g., coal, oil, gas and nuclear components of the energy aggregate). This formulation has typically been estimated using a flexible functional form, such as the translog (see, e.g., Hudson and Jorgenson, 1974; Hazilla and Kopp, 1984).

Overall, the neoclassical KLEM modeling approach has proven to be a powerful and versatile tool in analytical studies and forecasting models. Hudson and Jorgenson (1974), Berndt and Wood (1975) and others have used a time series of input-output data to estimate the parameters of the dual price frontier of a translog specification of the KLEM model. The resulting parameters yield elasticity measures that are invaluable in policy simulation modeling. Only recently has the approach been used for structural analysis, as in the case of Considine's (1990a) investigation of intensity of use.

We choose as our model framework input-output analysis applied in the manner of what has recently been referred to as "structural decomposition analysis." This approach dates from the work of Leontief (1951), Chenery et al. (1962), and Carter (1970), and seeks to distinguish major sources of change in the structure of the economy by means of a set of comparative static changes in key parameters of an I-O table. More recently, research in this area has reached a high level of sophistication (see, e.g., Skolka, 1989; Kanemitsu and Ohnishi, 1989).

In recent papers (see Rose and Chen, 1987; 1990), the authors have advanced this approach in two major directions. First, we expanded the framework to the level of a full two-tier KLEM model by distinguishing between 4 groups of aggregate inputs and various fuel and material subaggregates. Second, unlike the majority of I-O structural decomposition analyses, which have been specified in an ad hoc manner, the estimating equations are derived formally, thereby ensuring consistency. The authors were also able to show heuristically that the modified SDA approach is capable of yielding as much insight into structural questions as the neoclassical KLEM approach and with only slightly more restrictive assumptions. The advantage of the I-O formulation is that it makes use of more readily available data (tables for the initial and terminal year), as contrasted to the time series of tables needed for econometric estimation of KLEM parameters in aggregated models.

The basic two-tier KLEM function is expressed as:

$$Q = F\Big[K,\ L,\ E\big(E_1 \ldots E_g\big),\ M\big(M_1 \ldots M_h\big)\Big]$$

In its typical neoclassical form, this model is assumed to be positive, twice differentiable, strictly quasi-concave function. In addition, it is often assumed to be homothetically weakly separable, meaning that the optimal mix of components in each aggregate is independent of the optimal mix across aggregates.

This latter assumption makes the neoclassical production function more restrictive than usual. For example, it means that indirect (general equilibrium) changes in fuel use take place in fixed proportions, just as they would in an I-O model. At the same time, our I-O variant is modified to be less rigid than its basic counterpart. Our approach readily allows for changes in coefficients over time, due either to technological change or technical substitution.

Thus, in the typical neoclassical version of the KLEM model, material conservation in the aggregate does not alter the material mix (though changes in individual material prices bring about a substitution response within the aggregate as a separate response). The exact same results take place in our modified I-O model. In fact, the only adjustment within the context of a KLEM framework that differs between the two models corresponds to output effects associated with changes in input costs. Here the neoclassical model allows for non-linear responses in the indirect effects for the aggregates, where the I-O model does not. However, in cases where the actual production functions are characterized by constant returns to scale, our model is no more restrictive than its neoclassical counterpart.

IV. THE ESTIMATING EQUATIONS

The decomposition equations of our I-O approach are presented in Table 2. (The reader is referred to Rose and Chen, 1990 for a formal derivation). The equations reflect the comparative static computations, which differ from each other only in terms of altering one set of key I-O coefficients. However, the reader should note one initial modification of the KLEM formulation of the previous page, that of using M to distinguish "major materials" from "other materials" (general intermediate inputs), denoted by O.

The first two equations decompose changes in final demand other than exports into "mix" and "level" components. For example, in equation 2, the effect of a change in the mix of final economic activity is modeled by utilizing the 1972 material and other technical coefficients throughout, but with the 1982 mix of final demands set at 1972 levels. This means subtracting actual material use in 1972 from the material use in the U.S. economy that would have been required if the total of the 1982 mix of final demand were the same as in 1972. In the term $Y^{82(72)}$, the first superscript refers to the year coefficient values (i.e., proportions, or the mix) are set, while the superscript in parentheses refers to the year that serves as the control total (level).[3]

Equation 3 through 8 isolate productivity changes in each of the five KLEMO components, respectively. Here, the subscript symbols of the G matrix (Leontief Inverse) refer to individual elements that differ from the status of the generic input category G.[4] For technological change in capital and labor there is only a single row of coefficients in each case that is changed. In the case of energy and materials, both of which are aggregates of inputs, 1982 coefficients are used as relative proportions of these component inputs, adjusted to their overall 1972 levels.[5] Note, also that there are a pair of equations relating to technological change in materials. Equation 7 refers to the direct productivity changes operatingthrough the matrix of material input requirements, *M*. Equation 6 covers the indirect and induced (linkage) effects of technological change in materials via the total requirements (Leontief Inverse) matrix. That is, a reduction in materials use per unit of output will lead to a reduction in the demand for materials and their various direct and indirect inputs, which in turn, sets off more rounds of material production reductions.

Equations 9 through 12 refer to substitution within the bottom tier of the material and energy aggregates. In this case, 1982 coefficients of individuals components of M, O, and E, respectively, are utilized as weights for the corresponding aggregates set at 1972 levels to capture substitution effects. Again the material-related estimation is split into two components. The first refers to the pure intermaterial substitution effect, which, in an ideal market where prices reflect material utilization characteristics, should sum to zero. The second refers to the indirect and induced repercussions of this substitution. Finally, equation 13 reflects substitution within the top tier of the production function.[6]

V. APPLICATION

The decomposition equations presented in Table 2 were applied to the analysis of the change in energy use in the intermediate sectors of the U.S. economy between 1972 and 1982. This period was chosen because the endpoints correspond to benchmark years for two U.S. I-O tables and because this period coincides with one of the major periods of change in materials use in the nation's history.

A. The Empirical Model

The I-O tables in the analysis consist of a 1982 constant dollar version of the official benchmark 1972 U.S. BEA input-output table (U.S. BEA, 1979) and the update to 1982 of the BEA's 1977 I-O table (U.S. BEA, 1987). While a decomposition analysis is best performed at the finest level of detail possible, the preliminary nature of our inquiry lends itself to a more aggregated, and hence more manageable, 2-digit BEA classification consisting of 83 industries. At this level there are five major materials sectors: Plastics and synthetic materials (BEA industry 28), Rubber and miscellaneous plastics (32), Glass and glass products (35), Primary iron and steel (37), and Primary nonferrous metals manufacturing.[7] In the future, we hope to utilize 500 sector (4-digit) I-O tables, which would enable us to distinguish between individual plastics and metals, and also enable us to consider some Stone and clay products (BEA 2-digit industry 36), such as ceramics.[8]

Material production by type for intermediate use in the U.S. economy and intensity of use measures are presented in Table 3. As analysts have noted, utilization of metals has decreased during this period, while the utilization of nonmetals has generally increased.[9]

A closed I-O inverse was used for equations 3 through 13, in order to determine induced effects as well as direct and indirect ones. The employee compensation row of the tables was included in the inverse and also served as the basis for the labor input of the KLEMO formulation. The personal consumption column of the I-O table served as the spending counterpart of the income row. On the capital side, a limitation of data at this juncture of the research forced us to use a rough estimate of depreciation on a sectoral basis,[10] though the total conformed to the depreciation estimates from the National Income and Product Accounts for 1972 and 1982. The counterpart columns represented purchases of replacement investment goods from individual supplying sectors. In the absence of explicit sectoral data for this variable, we used the sectoral proportions of the Total Capital Formation columns of the 1972 and 1982 tables. This will result in biased results to the extent that the sectoral composition of plant and equipment purchases for replacement purposes differs from the sectoral composition of total investment.

B. Results

The results of our decomposition analysis of the structure of change in materials use are presented in Tables 4 and 5. We summarize them in relation to the individual sources of change in energy use below. Again, we remind the reader of several caveats we noted in the previous section.

1) The largest overall positive stimulus to material use in the U.S. economy over the course of our study period was the real change in the level of final demand of 18.2 percent. This amount, which corresponds to the real level of economic growth between 1972 and 1982, represents the change in overall material demand that would have taken place had there been no other parametric changes. The minor variation in materials use increases across sectors (17 percent to 20 percent) is due to rounding and to some problems associated with the computations we used to obtain constant dollar I-O tables.

2) Had there been only a change in the mix of final demand, materials use would have dropped overall by 7.0 percent. The results reflect a shift by consumers (along with investment and government) away from relatively more expensive, heavy and traditional items. Iron and steel was affected by this source of change by a far greater margin than any other material.

3) Technological change, or productivity improvement, in capital represents one of the more significant positive sources of change, accounting for an 8.3 percent overall increase in materials use, or a relative contribution of 84.2 percent of the total (see Table 5).[11] The increase stems from the fact that the production of the mix of capital goods became directly and indirectly more material-intensive, thus offsetting any material decreases stemming from a decrease in capital per unit of output. Note that this is the pure productivity effect; the effect of increased capital intensity is included in estimating equation (13).

4) Technological change relating to labor represents another positive source of change in material demand. This could stem from the fact that wage increases out-paced labor productivity increases, with further increases in labor-output ratios, when expressed in wage-bill terms, reflecting this. The increase in wages per unit of output translates into higher income, then higher consumption, and eventually to a higher derived demand for materials.

5) Technological change in energy has a very minor effect on material use. This is not surprising since materials are not a significant input into energy production.

6 & 7) The indirect technological change in materials is the second largest negative influence. As such it represents "material conservation" and is prominently reflected in the outcome for 4 of the 5 material sectors. The results for plastics are not surprising though they merit some further investigation. The reader may at first conclude that all sector changes should be equivalent because of the I-O model property analogous to the assumption of homothetic weak separability. However, because of differing overall and individual materials intensities across using sectors, these changes need not be a constant proportion over 1972 base-year values for the economy as a whole. Finally, note that linkage effects are very insignificant.

8) Changes in materials use stemming from technological change (TC) in intermediates (other materials) is also very small. This is due either to a small level of TC or the possibility that the material composition of intermediates does not vary much by material type. As will be discussed, the results for equation (11) indicate that the latter is not the case.

9 and 10) By definition, the overall effect of direct material substitution is zero. The important result here is the direction of the change for individual materials sectors. The substitution toward plastics, rubber and even nonferrous metals and away from iron and steel and glass is not surprising, especially in relation to relative price changes between 1972 and 1982. The linkage effect is rather insignificant, however.

11) The major negative overall influence on materials use is intermediate substitution. The size of this result is especially surprising. Pending further study, our explanation is that costs and pushes for conservation in general caused a shift toward less material intensive intermediate products. Examples would be smaller component parts for items such as automobiles and computers.

12) Interfuel substitution has a trivial effect on materials use. Again, materials are not a significant input into energy production.

13) Overall substitution of KLEMO aggregates results in a significant negative impact. Again, the non-uniform effect on individual fuel demand is consistent with the assumption of weak homothetic

separability, since it pertains only to direct effects in any given sector. Also, the mix of sectors can change significantly as a result of the second-order effects of KLEMO substitution.

Note that our analysis has been able to account for 100 percent of the change in demand for each of the major categories of materials. Of course, to a great degree this is due to the inherent nature of the identity splitting involved even in the I-O version of the intensity of use measure. Still, it lends support to the correctness of our model specification.

VI. CONCLUSION

The intensity of use of minerals and materials has been the subject of considerable study in recent years. We have offered a major advance in the domain of structural decomposition analysis for this purpose. Prior work by the authors in deriving the methodology and indicating its near equivalence to flexible functional form versions of the KLEM formulation provide a solid conceptual basis. It is hoped that the results presented today illustrate its usefulness. Still, until further refinements of the basic data can be made, we warn against interpreting the results as definitive.

ENDNOTES

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[1] Malenbaum does provide an analysis of factors underlying his "dematerialization" hypotheses, though without any formal decomposition.

[2] Note that after performing a critical review of the literature on IU, Auty (1985) concluded that an I-O approach was what was needed to analyze the influence of technological change on materials consumption.

[3] The analysis is of course subject to an index number problem relating to whether the reference point is the base year or terminal year. This problem can also arise with respect to the sequencing of equations. Sensitivity tests by the authors indicate, however, that the problem is not a serious one (see also the discussion by Skolka, 1989, pertaining to simple decomposition analyses.

[4] Still, the notation can be confusing. For example, in the left-hand term of equation 3, K^{82} means that capital is set at its 1982 level and $(LEMO)^{82(72)}$ means that the other three aggregate inputs are set at their 1982 mix but 1972 level. The right-hand term has all 4 aggregates set at their 1982 mix and 1972 levels. Thus, the two sides differ simply with respect to the level of capital usage per unit of output (technological change in capital). The simplified expression $B^{72}G^{72}\ Y^{82}\ -B^{72}G^{72}Y^{82}$ conveys the same intent, but the K^{82}empirical estimate differs slightly. The more complex expressions in Table 2 are used to insure consistency of the equation set.

[5] Due to a lack of data and time, we employed a simple aggregator operation for both materials and energy. This implies a perfect substitutability across materials characteristics and the perfect substitutability of a BTU of each fuel type. No doubt, this has introduced a bias into our analysis, but we cannot tell to what extent (cf., Tilton and Radetzki, 1990, and Considine, 1990a).

[6] We maintain that our equation set is mutually exclusive and completely exhaustive of outcomes within the KLEM production function framework. Both of these considerations are supported by the results in Section VB below, in which we account for 100 percent of the change in material demand. However, some researchers have suggested that various interaction effects need to be modeled (see, e.g., Campbell, 1986; Casler et al., 1990).

[7] In her study, Devine 1988 analyzes sectors 37 and 38 along with their corresponding mining operations (BEA 2-digit industries 4 and 5). Thus, her analysis includes some double-counting.

[8] This will be possible when the 1982 benchmark I-O table becomes available in June.

[9] Refinements planned for the near future include the calculation of apparent use (via an inventory adjustment) and the estimation of domestic vs. imported quantities, likely to be especially important for iron and steel.

[10] The estimates are based on fixed proportions of total capital-related income accruing to each sector.

[11] The numbers in Figure 5 are calculated by dividing each of the numbers in Table 4 by their respective column sums.

TABLE 1. METHODOLOGICAL ADVANCES IN DECOMPOSING CHANGES IN MATERIALS DEMAND

Intensity of Use Approach	
Tilton (1985)	material composition of product & product composition of income
Roberts (1985; 1986)	durable vs non-durable goods distinction production function formulation
Considine (1991)	flexible functional form production function; divisia index for materials
Structural Decomposition Approach	
Myers (1986)	econometric estimation of I-O coefficient change and price linkage
Rose & Chen (1987; 1991)	two-tier KLEM formulation equivalent to flexible functional forms
Devine (1988)	decomposition of final demand expenditure categories

TABLE 2. DECOMPOSITION OF CHANGE IN MATERIAL DEMAND

	Source	Estimating Equation
1.	Level of Final Demand	$M^{72} G^{72} Y^{82} - M^{72} G^{72} Y^{82(72)}$
2.	Mix of Final Demand	$M^{72} G^{72} Y^{82(72)} - M^{72} G^{72} Y^{72}$
3.	Tech. Change in Capital	$M^{72} G^{72}_{K82(LEMO)82(72)} Y^{82} - M^{72} G^{72}_{(KLEMO)82(72)} Y^{82}$
4.	Tech. Change in Labor	$M^{72}G^{72} Y^{82} - M^{72} G^{72}_{\substack{K82L82(EMO)82(72)\\ K82(LEMO)82(72)}}$
5.	Tech. Change in Energy	$M^{72} G^{72}_{K82L82E82(MO)82(72)} Y^{82} - M^{72} G^{72}_{K82L82(EMO)82(72)} Y^{82}$
6.	Linkage Tech. Change in Major Materials	$M^{72} G^{72}_{K82L82E82M82O82(72)} Y^{82} - M^{72} G^{72}_{K82L82E82(MO)82(72)} Y^{82}$
7.	Direct Tech. Change in Major Material	$M^{82} G^{82} Y^{82} - M^{82(72)} G^{82} Y^{82}$
8.	Tech. Change in Other Materials	$M^{72} G^{82} Y^{82} - M^{72} G^{72}_{K82L82E82M82O82(72)} Y^{82}$
9.	Linkage Major Material Substitution	$M^{72} G^{72}_{M82(72)} Y^{82} - M^{72} G^{72} Y^{82}$
10.	Direct Major Material Substitution	$M^{82(72)} G^{82} Y^{82} - M^{72} G^{82} Y^{82}$
11.	Other Material Substitution	$M^{72} G^{72}_{M82(72)O82(72)} Y^{82} - M^{72} G^{72}_{M82(72)} Y^{82}$
12.	Interfuel Substitution	$M^{72} G^{72}_{E82(72)M82(72)O82(72)} Y^{82} - M^{72} G^{72}_{M82(72)O82(72)}$
13.	KLEMO Substitution	$M^{72} G^{72}_{(KLEMO)82(72)} Y^{82} - M^{72} G^{72}_{M82(72)O82(72)E82(72)} Y^{82}$

Variables:

M = Material input coefficients
G = Leontief inverse
Y = Final demand
(see text for explanation of G matrix subscripts and time superscripts)

TABLE 3. MATERIAL USE IN THE U.S. ECONOMY
(in millions of 1982 dollars)

Year	(28) Plastics	(32) Rubber	(35) Glass	(37) Iron & Steel	(38) Nonferrous Metals	Total
1972						
level	22,167	35,761	11,329	101,653	56,193	227,103
intensity	.00944	.01523	.00482	.04329	.02393	.09671
1982						
level	25,682	44,727	10,681	71,386	52,330	204,806
intensity	.00915	.01593	.00380	.02542	01864	.07294
1982-1972						
level	3,514	8,965	-648	-30,267	-3,863	-22,297
intensity	-.0003	.0007	-.0010	-.0179	-.0053	-.0238

TABLE 4. PERCENTAGE CHANGE IN MATERIAL DEMAND IN THE U.S., 1972-83

		(28) Plastics	(32) Rubber	(35) Glass	(37) Iron & Steel	(38) Nonferrous Metals	Weighted Avg.
1.	Level of Final Demand	19	20	19	17	19	18.2
2.	Mix of Final Demand	-4	1	-4	-14	-1	-7.0
3.	Tech. Change in Capital	9	9	8	8	9	8.3
4.	Tech. Change in Labor	9	8	9	6	6	6.8
5.	Tech. Change in Energy	2	2	2	2	2	2.0
6.	L. Tech. Change in Materials	-1	-0	-0	-0	1	*
7.	D. Tech. Change in Materials	0	-25	-14	-13	-15	-14.4
8.	Tech. Change in Intermediates	0	1	3	2	0	1.4
9.	L. Material Substitution	8	1	-0	-2	-1	-0.3
10.	D. Material Substitution	4	29	-7	-11	1	-0.0
11.	Intermediate Substitution	-19	-16	-17	-23	-15	-19.1
12.	Interfuel Substitution	1	1	1	0	1	0.5
13.	KLEMO Substitution	-12	-6	-5	-1	-14	-6.3
	Total	16	25	-6	-30	-7	-9.8

*Less than .5 percent.

TABLE 5. RELATIVE CONTRIBUTION TO CHANGE IN MATERIAL DEMAND IN THE U.S., 1972-82

		(28) Plastics	(32) Rubber	(35) Glass	(37) Iron & Steel	(38) Nonferrous Metals	Weighted Avg.
1.	Level of Final Demand	119	78	330	57	281	185.3
2.	Mix of Final Demand	-25	2	-64	-47	-18	-71.6
3.	Tech. Change in Capital	54	36	145	26	124	84.2
4.	Tech. Change in Labor	56	34	149	20	92	69.7
5.	Tech. Change in Energy	15	10	39	6	29	20.7
6.	L. Tech. Change in Materials	--6	-1	-1	-1	13	-0.1
7.	D. Tech. Change in Materials	2	-100	-249	-45	-220	-146.6
8.	Tech. Change in Intermediates	2	6	48	7	3	14.6
9.	L. Material Substitution	51	6	-2	-8	-13	-3.0
10.	D. Material Substitution	26	115	-117	-36	15	-0.0
11.	Intermediate Substitution	-120	-66	-302	-76	-214	-194.7
12.	Interfuel Substitution	4	3	11	2	8	5.6
13.	KLEMO Substitution	-77	-23	-85	-4	-200	-64.1
	Total	100	100	-100	-100	-100	-100.0