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Abstract

A dematerialisation of the economy can provide a crucial contribution toward sustainable development. It can take place in the production sphere through technological change or in the consumption sphere through altered consumer behaviour. This paper focuses on the second case, a shift of expenditure from material consumption (e.g. manufactured products) to non-material consumption (e.g. services). Since all production requires material, an input-output model is used to account for indirect material use. The model features post-Keynesian macroeconomic foundations, which make it possible to study the effects of altered consumption patterns on total consumption, output, and income distribution. The empirical application for the case of Germany shows that a dematerialisation of consumption might be considered a win-win strategy from an ecological and economic viewpoint. However, its effects on the distribution of income and international trade may be problematic.

Keywords

Sustainable consumption, input-output model, social sustainability, income distribution

JEL Codes

C67, E12, Q01, Q43, Q57

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1 Introduction

Ecological economics was founded on the realisation that the human economy is a subsystem of the surrounding ecosystem, and that humans cannot produce matter. What we call "production" is more appropriately seen as a transformation of material inputs into material output subject to the principle of mass balance, which states that the mass of inputs is equal to the mass of outputs. Furthermore, the use of material inputs and the consumption thereof always impacts on the surrounding ecosystem and may cause significant ecosystem damage if certain thresholds are exceeded. Accordingly, the material throughput that is required to maintain a modern economy has become an important issue in research and policy. Although it is by now widely accepted that economic policy should aim at reducing the level of material throughput, there is no general agreement on how this reduction should come about and how possible conflicts with other policy goals, such as providing a growing human population with an acceptable range of consumption opportunities, should be resolved.

The relationship between material throughput, consumption expenditure and population size can be written mathematically as

$$(1) \qquad M = \left(\frac{M}{C}\right)\left(\frac{C}{H}\right)H$$

where M denotes material throughput, C denotes the level of consumption expenditure, and H denotes the number of humans.

Equation (1) clearly shows that if humans wish to reduce material throughput in order to avoid excessive ecosystem damage, they will have to reduce the material intensity of consumption (M/C), the level of consumption per capita (C/H), or the number of humans. The last option would require strict birth control, a policy which is opposed by many on ethical grounds. The option of reducing consumption per capita is advocated by an increasing number of authors, but under prevailing circumstances it does not appear to be politically feasible. Therefore, much hope is riding on the first option, a reduction in the material intensity of consumption, a *dematerialisation* of consumption. The United Nations Development Programme, for example, remains convinced that consumption growth can continue if only reforms are undertaken to limit the associated ecosystem damage (UNDP, 1998, 2008). This view receives support by Rodrigues et al. (2005), who use a neoclassical growth model to study the conditions that must be met for the economy to reach a sustainable growth path. On the other hand, there are those who question the validity of the neoclassical framework and, using different approaches, come to the conclusion that the term 'sustainable growth' is an oxymoron (Daly, 1990). Proponents of the latter view argue that changes in the material intensity of consumption are insufficient and that the growth of aggregate consumption must be stopped or reversed[1].

At any rate, it is clear that a dematerialisation – at least to some degree – of consumption would be beneficial from an ecological point of view. A crucial component of a dematerialisation strategy involves a shift from actual physical consumer goods to services (Halme et al., 2004). Practical examples include laundry services as a substitute for washing machine ownership and renting services of all kinds (DVD, books, cars etc.).

Dematerialisation is related to the problem of delinking growth from ecosystem damage, but it is not the same. Delinking refers to a special case in which consumption continues to grow at a positive rate while material throughput falls (i.e. grows at a negative rate). Dematerialisation, by contrast, refers to a situation in which the ratio M/C falls without specifying whether either growth rate is positive or negative. If material throughput continues to grow at a positive rate,

[1] This debate can be traced back to the conflict between Georgescu-Roegen and the Club of Rome (Levallois, 2010). For a discussion of the emerging "de-growth" paradigm, see Martínez-Alier et al. (2010).

one may speak of *relative dematerialisation*, and if it actually falls, one may speak of *absolute dematerialisation*. Thus, dematerialisation alone does not ensure a reduction in the level of material throughput. In fact, relative dematerialisation may actually induce an increase in total consumption which in turn raises the level of material throughput. This relationship has become known as the *rebound effect* (Madlener and Alcott, 2009, Sorrell and Dimitropoulos, 2008).

The rebound effect is essentially a microeconomic phenomenon. However, from a macroeconomic perspective there is an additional reason for believing that a (relative) dematerialisation of consumption may affect the level of consumption. Dematerialisation as discussed above implies a shift in the structure of consumption expenditures away from manufactured products toward (largely) immaterial services. Thus, the output of the service sector will increase at the expense of the manufacturing sector. These sectors differ considerably in terms of input structures and in the way in which value added is divided between workers (who earn wages) and capital owners (who receive profits, dividends and interest payments). The income of the public sector may also be affected, because some industries/products are taxed/subsidised more heavily than others. Thus, the shift in consumption patterns may lead to a redistribution of income. According to Keynesian macroeconomic theory, the distribution of income in turn affects the level of consumption, because the propensity to consume differs between workers and capitalists (or, as a matter of fact, between all sorts of social groups). Hence, here is another way in which a shift from material consumption toward immaterial consumption affects the level of consumption. In extreme cases, the level of consumption may increase so much that overall material throughput rises – a perverse result. The primary goal of this paper is to investigate that possibility.

To this end, a multisectoral macroeconomic model of the German economy (MMG) was constructed. The model is essentially an extended input-output model based on the post-Keynesian macroeconomic framework. This modelling approach has a number of advantages over other approaches, most notably its ability to study structural change within consumption and production. Moreover, the post-Keynesian framework is compatible with ecological economics because it is based on similar theories on consumer behaviour and production (Gowdy, 1991, Kronenberg, 2010). MMG also makes it possible to study some side effects of consumption dematerialisation, such as the impact on income distribution and on the trade balance, which are important for the economic and social dimensions of sustainable development (SD).

In order to provide a quantitative meaning of the dematerialisation of consumption, this study follows the approach of Jackson and Marks (1999), who make a distinction between material and nonmaterial consumption and split the consumption vector of UK households accordingly[2]. It is assumed that households shift a certain percentage of their total consumption expenditure from material consumption to immaterial consumption. The results of this hypothetical situation are compared to the actual data from the national accounts for 2005.

In the following, section 2 describes the model's theoretical foundation and motivates the use of the post-Keynesian macroeconomic framework. Section 3 explains the empirical implementation of the model, and section 4 presents the model results. Finally, section 5 provides some concluding remarks and suggestions for further research.

2 Theoretical Background

It has been argued elsewhere that ecological economics, when addressing macroeconomics problems, should apply the post-Keynesian modelling approach in order to maintain theoretical consistency (Gowdy, 1991, Kronenberg, 2010)[3]. Post-Keynesian economics has a variety of features

[2] Actually, the provision of services inevitably requires some material use, so the distinction between material and immaterial consumption should not be taken too literally.

[3] Post-Keynesian economics is a school of thought which is characterised by a healthy degree of heterogeneity. This heterogeneity manifests itself in debates on the spelling ('post-Keynesian' versus 'post Keynesian') as well as the

that make it especially well suited for applications in ecological economics: First, it has always put great emphasis on social issues such as income distribution and unemployment, which feature prominently in the social dimension of sustainable development. Second, it has always recognised the implications of fundamental uncertainty about the future. Third, it has placed production rather than exchange at the centre of interest. Fourth, it readily accepts the frequent occurrence of market failures. These four features are further discussed in the following.

2.1 Emphasis on income distribution and unemployment

Post-Keynesian economics prides itself in having descended directly from the economics of Keynes himself. Since Keynes was highly interested in explaining the existence of unemployment and finding a cure to it, it follows quite logically that the direct heirs to Keynes would be interested in unemployment as well.

Post-Keynesian economists follow Keynes in rejecting Say's assertion. This allows them to explain why there may be an excess supply of labour even if prices are fully flexible. The widespread belief that the Keynesian explanation of unemployment relies on some sort of wage or price rigidity is a myth. In the words of Roy Harrod: "Some commentators have suggested that Keynes' system depends on wages being inflexible downwards, as indeed they usually are these days. This shows a complete lack of intellectual grasp of his system. His theory of equilibrium with unemployment in no wise depends on wages being inflexible downwards" (Harrod, 1939, p. 65). In the Keynesian system, the level of employment is ultimately determined by the level of aggregate demand, and even with full wage and price flexibility, the level of aggregate demand may never be high enough to ensure equality between labour demand and labour supply. Thus, unemployment is neither a paradoxical puzzle nor the result of market failure; it is simply a common outcome of the economic process.

Since the level of aggregate demand plays such a crucial role, post-Keynesian economists are naturally interested in the determinants of aggregate demand. They realised from the very beginning that the level of aggregate demand depends on the distribution of income due to variations in the propensity to consume (PTC) between individuals, households, social groups or classes. Generally, if income is redistributed from a social group with a low PTC to another group with a high PTC, aggregate consumption expenditure increases. This constitutes an increase in aggregate demand, which in turn raises the demand for labour, raises employment, raises income, and raises aggregate demand further. The existence of such multiplier effects is a central feature of Keynesian economics in general and post-Keynesian economics in particular.

There are, of course, alternative theoretical frameworks which deal with unemployment and income distribution at the macroeconomic level. However, post-Keynesian economics is unique in its ability to study the interrelationships between income distribution, unemployment, and the level of output. Rather than developing one model to explain unemployment, one model to explain income distribution and yet another model to explain the level and growth of output, post-Keynesian economics offers the possibility of an integrated assessment of all these variables in one single, plausible, and more or less realistic theoretical framework.

2.2 Fundamental uncertainty about the future

Post-Keynesian economists make a sharp distinction between *uncertainty* and *risk*. The latter refers to events whose outcome cannot be known in advance but can be reasonably estimated using statistical methods. An example of such an event is the roll of a die. Although the actual outcome

'boundaries' of the term. In the present paper, the term 'post-Keynesian' is used in a rather broad sense, encompassing the work of 'fundamentalists' like Paul Davidson as well as the 'Kaleckian' and 'Sraffian' contributions inspired by what Luigi Pasinetti has called the 'Cambridge school of Keynesian economics' (Pasinetti, 2005).

cannot be predicted, it can be reasonably estimated because the distribution of the potential results is precisely known – it is a uniform distribution containing the elements 1, 2, 3, 4, 5, and 6. Hence, we actually know a lot about the outcome of the event. We know that the result will be a full number between 1 and 6, and that each of these outcomes is equally likely. This knowledge allows us to compute the odds of a certain outcome and the expected value of bets and wagers. Risk can be assessed, and expected values can be calculated. The law of large numbers then allows us to derive successful strategies for playing a repeated game subject to risk.

Uncertainty, by contrast, is said to exist when the outcome of an event cannot be estimated by statistical means because there is no way of getting any useful information on the distribution of random variables. In cases of true uncertainty, we are not able to specify either the range of possible outcomes or their likelihood. Hence, statistical methods are of little help, and it is impossible to devise winning strategies based on the expected values of uncertain outcomes.

Post-Keynesian economists argue that fundamental uncertainty about the future is the reason why money is different from all other goods in the economy. Money provides liquidity, and people want to hold liquid means of payment as an insurance against events which cannot be reasonably predicted. In this sense, money plays a special role which makes it fundamentally different from all other goods. It is not only a 'medium of exchange' which a barter economy implements to bring transactions costs down; it is a store of value and an insurance against uncertain future events. Thus, fundamental uncertainty is the principle foundation of the post-Keynesian theory of money.

Fundamental uncertainty also plays a crucial role in the SD debate. SD is about the welfare of future generations. Thus, the 'future' which we have to consider is decades, centuries, even millennia away. All serious participants in the SD debate admit that the behaviour of complex systems such as the economy or the ecosphere cannot be reasonably predicted over such long time spans. Therefore, a macroeconomic theory which acknowledges the existence of fundamental uncertainty about the future is the proper framework in which to discuss the macroeconomic impacts including social repercussions of environmental and climate policy.

2.3 Production at the centre of interest

Post-Keynesian theory places production rather than exchange at the centre of its analysis. This is especially true for its Sraffian stream, as can be seen by the title of Sraffa's influential *Production of Commodities by Means of Commodities* (Sraffa, 1960). This book was widely interpreted as a sort of 'update' or 'resurrection' of the Ricardian theory of production. Inspired by Sraffa's ideas, many economists have subsequently developed a theory of production which forms, in a way, a bridge between the classical theory of Ricardo and the macroeconomic revolution initiated by Keynes and his followers (Kurz and Salvadori, 1995, Pasinetti, 1977, Schefold, 1989). This approach has also become known as the classical-Keynesian approach.

The Sraffian approach, having its origins in Ricardo's writings on production, rejects the theory of marginal productivity. Not all post-Keynesians share this view, pointing out that Keynes himself frequently argued on the basis of marginal productivity. However, they also acknowledge the special role of production in comparison to exchange. In their view production is special because it takes time, so the goods whose production starts today will earn an uncertain amount of revenue in the future. This implies that the equalisation of marginal profit and marginal cost, which theoretically maximises profit, is usually not possible in reality. Because of this, producers often follow rules of thumb (e.g. mark-up pricing).

Thus, there is some disagreement between post-Keynesians on which theory of production is to be used (classical or marginal productivity). However, both sides of the argument come to similar conclusions concerning the implications on pricing and distribution. In both views, the price of a good is generally not equal to the marginal cost of production. This implies that the prices of primary inputs such as capital and labour are generally not equal to their marginal productivities. Although environmental issues do not feature prominently in the post-Keynesian literature, some post-Keynesians have made an effort to study the role of environmental resources as a primary input factor. The implications are quite clear: If market prices do not reflect marginal cost, and primary input prices do not reflect marginal productivities, there is no reason to assume that market forces will ever determine the 'correct' price of environmental resources. Consequently, post-Keynesians tend to have little faith in 'market-based' environmental policy measures.

The theory of pricing and distribution is highly relevant from a SD point of view because social equity is an important feature of SD. Moreover, in the post-Keynesian view the distribution of income is not only an *outcome* of the economic process; it is a central *determinant* of the level and the composition of aggregate demand. Through its effect on demand, the distribution of income ultimately affects the type and amount of goods which are consumed and produced as well as the accompanying emissions. Therefore, the distribution of income is not only an indicator relating to social aspects of SD; it also has important implications for the environmental sphere of SD. Through its well-developed theory of production, distribution and consumption, post-Keynesian economics can provide a substantial contribution to SD.

2.4 Acceptance of frequent market failures

Achieving SD is made difficult through the existence of a wide variety of market failures. In a world with perfectly functioning markets, the economy reaches a Pareto-optimal state without the intervention of government. That state may not conform to the ideals of SD, because Pareto optimality does not guarantee social equity. However, it is clear that in a world without market failures SD is much easier to achieve than in reality. Failures in the market for exhaustible resources, for example, tend to increase the rate of resource consumption (Kronenberg, 2008).

Post-Keynesian economics acknowledges the fact that market failures occur frequently in reality. Its theory of pricing, for example, is based on the observation that producers usually do not apply marginal cost pricing because a) it is in reality not possible to compute marginal cost and b) many producers possess some kind of market power, at least within a market niche. By incorporating frequent market failures into its theoretical foundation, post-Keynesian economics put itself into a good position to study SD-related problems, which are often caused by the existence of market failures, using relatively realistic models.

3 Model structure and implementation

3.1 The semi-open input-output model

MMG is basically an extended input-output model. Many readers will be familiar with the static open input-output model due to its numerous applications in *Ecological Economics*. Since input-output analysis was developed by Wassily Leontief in the mid 20th century[4], it has come a long way. The current state of the art is summarised in Miller and Blair (2009). In the early days, input-output models were characterised by their treatment of final demand. Models which treated final demand (consumption by households) as endogenous were called 'closed'. Conversely, models which treated final demand as exogenous were called 'open'. The latter type was frequently applied to identify the amount of natural resources 'embodied' in final goods (Butnar and Llop, 2007, Duarte et al., 2002, Roca and Serrano, 2007, Wiedmann et al., 2006). For this kind of analysis, the open input-output model is the proper framework.

In the wake of the Keynesian revolution, however, economists became interested in the relationship between autonomous demand (comprised of government expenditure, investment, and ex-

[4] Antecedents of Leontief's work have been surveyed by Kurz and Salvadori (2000).

ports) and induced demand (final consumption expenditure by households). The solution to this problem was to build semi-open input-output models in which household consumption is modelled, in accordance with Keynesian macroeconomic theory, as a function of current household income. If this relationship is assumed to be linear, it can be read directly from an input-output table. Alternatively, it may be specified in a flexible way using econometric techniques. These developments have given rise to the development of extended input-output models or econometric input-output models. Such models are quite popular among post-Keynesian economists because their structure fits nicely with the Sraffian theory of production. When they are enriched with data from the environmental-economic satellite accounts, they can be used to study a variety of SD-related questions. Dejuán et al. (2008), for example, use an extended input-output model to forecast the energy demand of the Spanish economy.

The core of MMG is essentially an input-output model with a disaggregated income multiplier. Effective demand, as post-Keynesian theory suggests, is divided into autonomous demand and induced demand. It is assumed that the investment expenditure by businesses can be treated as autonomous demand. Induced demand consists of consumption expenditure (final consumption) and the demand for intermediate goods. The goods markets are in equilibrium when the following condition is fulfilled:

$$\mathbf{x} = \mathbf{Cx} + \mathbf{Ax} + \mathbf{f} \qquad (2)$$

Equation (2) states that the total output of goods **x** (i.e. supply) must be equal to the demand for goods, which consists of autonomous demand **f** (comprised of consumption expenditure by government, investment, and exports), induced consumption and intermediate consumption. **A** is a matrix of technical input-output coefficients reflecting the production technology. Element $A_{i,j}$ tells us how many units of input *i* are required to produce one unit of output *j*. **C** is a matrix of income-induced consumption. Element $C_{i,j}$ tells us how much demand for good *i* will be induced when the production of good *j* rises by one unit.

The elements of **A** were computed from the input-output table provided by the Federal Statistical Office of Germany (Destatis, 2008b). Henceforth, it is assumed that **A** is exogenous and constant. This assumption is consistent with the post-Keynesian theory of production as well the ecological economists' view on production (Kronenberg, 2010). In the short run, it is realistic because most firms cannot instantly change their production recipe. In the long run, one could allow for changes in **A** because firms may adjust their production recipe in response to altered prices[5]. Therefore, the results presented in the following should be interpreted as short-run effects.

The elements of **C** can be computed from a social accounting matrix, if such is available. It is defined as:

$$\mathbf{C} = \mathbf{P}\hat{\mathbf{c}}\mathbf{Y} \qquad (3)$$

Where **P** is a matrix describing the consumption patterns of different social groups, **c** is a vector containing the propensities to consume, $\hat{\mathbf{c}}$ is the diagonalised form of that vector, and **Y** is a matrix describing the distribution of income between the social groups. In the following, these matrices are assumed to be constant.

According to post-Keynesian theory, autonomous demand is exogenous, at least in the short term. As firms produce output to fulfil the requirements of autonomous demand, they produce a surplus, which is distributed to workers and firm owners in the form of wages and profits. Workers and firm owners spend part of that income, inducing further demand, to which firms react by

[5] At all times, changes in **A** must be compatible with the laws of nature.

producing additional output. This process continues until the goods markets are cleared, i.e. condition (2) is fulfilled.

The level of output (of each good) which is consistent with a given level of autonomous demand (for each good) can be determined by re-arranging (2) and substituting (3) for **C**. The result is

$$(4) \qquad \mathbf{x} = (\mathbf{I} - \mathbf{A} - \mathbf{C})^{-1}\mathbf{f} = (\mathbf{I} - \mathbf{A} - \mathbf{P\hat{c}Y})^{-1}\mathbf{f}$$

where **I** denotes the identity matrix.

Fur the purposes of sustainability analysis, the basic model was extended in two ways: Firstly, the public sector was explicitly modelled in order to reflect the effects of macroeconomics changes on public revenue and expenditure, an issue of increasing importance in the public debate on fiscal sustainability and consolidation. Secondly, an environmental impact module was introduced in order to capture three types of environmental impacts: energy use, (abiotic) material use and carbon dioxide emissions. For each of these impact types, impact factors were constructed using data from the environmental-economic accounts (EEA) produced by the Federal Statistical Office. Total energy use was then modelled as

$$(5) \qquad \mathbf{E} = \mathbf{e_p x} + \mathbf{e_c c},$$

where **E** denotes total energy use, $\mathbf{e_p}$ denotes the impact factors of production, and $\mathbf{e_c}$ denotes the impact factors of consumption. Total material use and total carbon dioxide emissions were modelled in a similar fashion[6].

3.2 Empirical implementation

The input-output table of MMG follows the commodity-by-industry concept. That is, each row of the Northwest quadrant refers to a commodity while each column refers to an industry. The classification of commodities is based on CPA 2002. Each industry is understood as a homogenous branch producing only one type of commodity (joint production is thereby ruled out). Thus, the resulting IOT is of the 'symmetric' variety, with column *j* referring to the production of the commodity to which row *j* refers. This concept is also used in the input-output tables published by the statistical offices of the EU member states and Eurostat. Table 1 shows the input-output table for the German economy of 2005 according to the MMG layout. Although MMG uses the full-scale official input-output table with 71 commodities and industries, Table 1 has been aggregated to show the two types of commodities and industries that are at the centre of this paper's interest – goods and services.

[6] Actually, the direct material use of households was not included in the model due to lack of data. However, it amounts to less than four percent of total material use according to Destatis, so this limitation can be tolerated.

Table 1: Input-output table for Germany, 2005

Input-ouput table Germany, 2005 Mill. EUR	Homogeneous branches			Final use					Total use
	Production of goods	Production of services	Total intermediate use	Final consumption expenditure by households	Final consumption expenditure by government	Gross capital formation	Exports	Total final use	
Goods	915,936	152,199	1,068,135	348,056	14,335	304,987	759,653	1,427,031	2,495,166
Services	343,021	707,120	1,050,141	818,183	402,685	51,613	137,397	1,409,878	2,460,019
Total intermediate use / final use at basic prices	1,258,957	859,319	2,118,276	1,166,239	417,020	356,600	897,050	2,836,909	4,955,185
Net taxes on products	14,587	42,792	57,379	130,001	4,490	26,760	-430	160,821	218,200
Total intermediate use / final use at purchaser prices	1,273,544	902,111	2,175,655	1,296,240	421,510	383,360	896,620	2,997,730	5,173,385
Compensation of employees	370,215	760,785	1,131,000						
Net taxes on production	1,824	18,836	20,660						
Consumption of fixed capital	82,453	253,127	335,580						
Net operating surplus	106,331	432,829	539,160						
Value added	560,823	1,465,577	2,026,400						
Output	1,834,367	2,367,688	4,202,055						
Imports of similar products	660,799	92,331	753,130						
Total supply of products	2,495,166	2,460,019	4,955,185						

Source: Destatis (2008b), author's calculations

The Northeast quadrant of Table 1 describes the final use of commodities. MMG distinguishes four final use categories: final consumption expenditure by households (including non-profit institutions serving households), final consumption expenditure by government, gross capital formation, and exports. In Table 1, the last two columns also report total final use and total use of commodities.

Normally, all monetary magnitudes are valued at basic prices (b.p.). Table 1 also shows the relationship between the valuation at basic prices and purchaser prices (p.p.). In the third row, total intermediate consumption and total final use are reported in terms of basic prices. The fourth row reports the amount of net taxes on the commodities concerned. Adding rows 3 and 4 yields the respective magnitudes valued at purchaser prices.

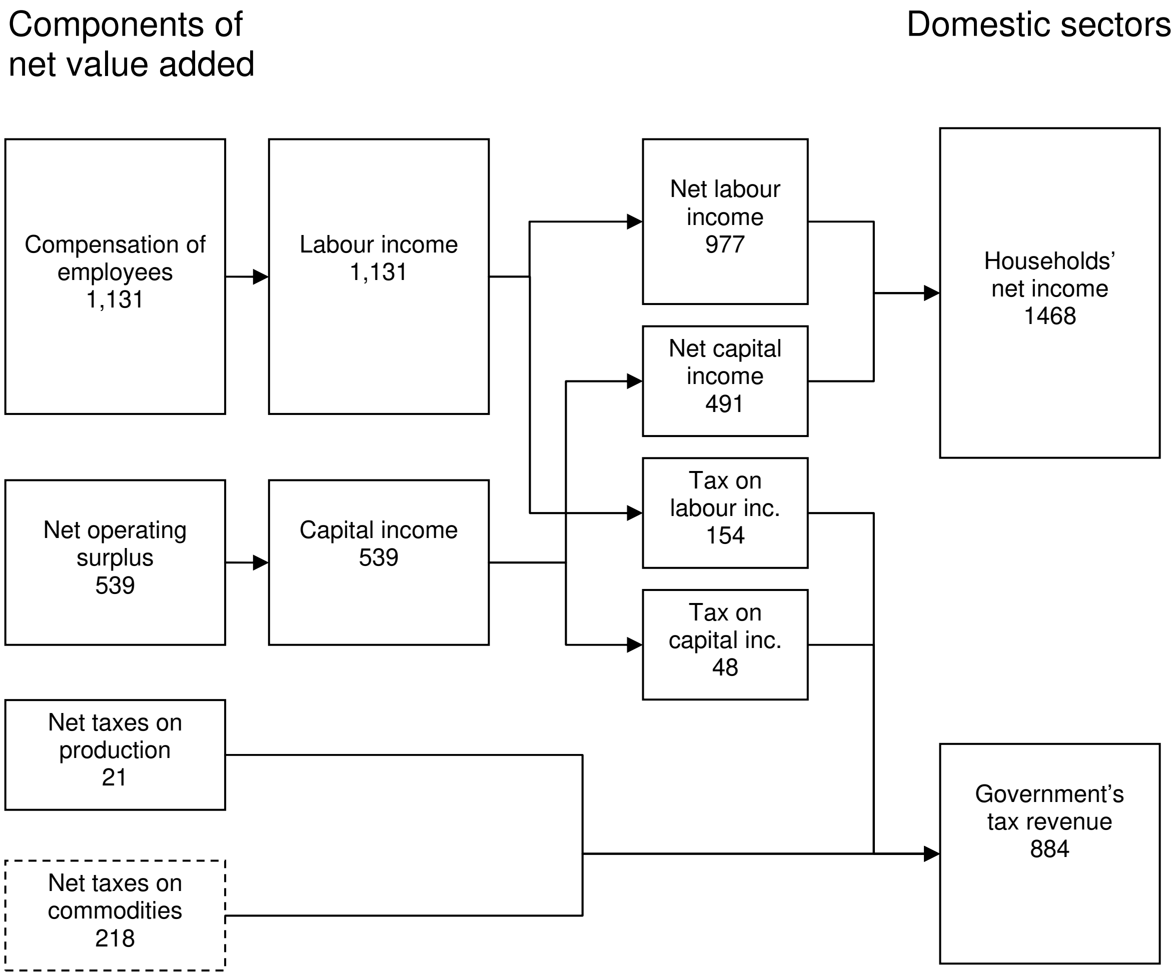
The Southwest quadrant describes the generation and distribution of primary income by dividing total value added among four value added components: compensation of employees (gross wages plus SSC paid by employers), net taxes on production, consumption of fixed capital, and net operating surplus. In the second-to-last row, imports of similar goods are reported. Note that in the standard ESA 95 tables, imported commodities are reported as 'imports of similar goods' in the column referring to the domestic industry producing the same (or similar) commodities. Furthermore, they are recorded as deliveries from that industry to the industry (or final use category) which was actually responsible for importing the commodities. Thus, imported commodities appear twice in the input-output table.

Although the input-output table (Table 1) contains a lot of useful information, it does not contain all the information necessary to provide a full account of the flows of income and expenditure in an economy. Therefore, MMG adopts a number of additional accounts to capture those transactions. The first social account continues basically where the input-output table leaves us – with primary income. It is therefore called the primary income distribution table. It shows how the three types of primary income (compensation of employees, net taxes on production, and net operating surplus) are distributed between sectors. MMG distinguishes three sectors: households, government, and the rest of the world (ROW). Firms are not modelled as a distinct sector. By assumption, they transfer their entire profit (net operating surplus) to households in the form of capital income. Similarly, the social security system is not explicitly modelled. In reality, a significant share of gross wages is redistributed through the social security system. At the end of the day, however, social security contributions are finally transferred back to households. Therefore, in order to keep the model structure simple, it is assumed that the entire compensation of employees is transferred directly to the household sector in the form of labour income without taking a detour through social security.

The government generates revenue by raising taxes. MMG recognises four types of taxes: net taxes on commodities, net taxes on production, taxes on labour income, and taxes on capital income. Net taxes on commodities are reported in a special row of the input-output table (Table 1). Net taxes on production form one component of value added. The remaining taxes are levied on labour income and primary income.

Figure 1 provides a graphical representation of the distribution of primary income. At the left side of the figure, the three components of net value added (compensation of employees, net operating surplus, net taxes on production) are shown. Net taxes on commodities are also shown (with a dashed line) because they form another part of the government's tax revenue. Compensation of employees and net operating surplus are converted into labour and capital income. Both types of primary income are then subjected to taxation. After taxes have been paid, net labour income and net capital income are received by households. Thus, the household sector's income is equal to the sum of net labour income and net capital income.

Figure 1: Distribution of primary income in MMG terms



Source: author's illustration

In order to capture distributional effects and socio-demographic changes, MMG breaks down the household sector into two groups called 'workers' and 'rentiers'. By assumption, workers receive the entire net labour income while rentiers receive the entire net capital income. This identification of social groups by their main source of income is, of course, motivated by the post-Keynesian theoretical background discussed above.

Table 2: MMG social groups account

	Workers	Rentiers	Total
Net labour income	977,184	0	977,184
Net capital income	0	490,636	490,636
Total net income	**977,184**	**490,636**	**1,467,820**
Consumption of goods	262,386	85,670	348,056
Consumption of services	616,796	201,387	818,183
Total consumption expenditure at b.p.	879,182	287,056	1,166,239
Net commodity taxes	98,002	31,999	130,001
Total consumption expenditure at p.p.	**977,184**	**319,056**	**1,296,240**
Saving	**0**	**171,580**	**171,580**

Source: Destatis (2008b), author's calculations

Table 2 shows MMG's social groups account, representing the income and spending of the two social groups. As in Table 1, the model's 71 commodity groups are aggregated to two broad groups in order to save space. The distribution of primary factor income in Table 2 is based on the aforementioned assumption that workers receive the entire net labour income while rentiers receive the entire net capital income. Under this assumption, total net income for each group can easily be computed. The numbers for consumption were derived under two simple assumptions: First, it was assumed that the saving rate of workers is equal to zero. With total net income of workers 'known', total consumption expenditure by workers (at p.p.) is then also 'known'. And since total consumption expenditure by households is known from the official input-output table, the level of consumption expenditure by rentiers can be easily deduced. The amount of saving by rentiers was then calculated by subtracting consumption expenditure from net income. A second assumption was made in order to derive the composition of each group's consumption expenditure. It was assumed that the structure of consumption expenditure is the same for both groups, and hence equal to the overall structure of consumption expenditure which can be computed from the official input-output table. Based on these simplifying assumptions, it was possible to complete Table 2 and implement the model[7].

[7] Future work will allow MMG to capture differences in consumption patterns between social groups. So far this has not happened because the scientific use files of the EVS 2008 household survey are not yet available.

Table 3: Environmental impact of production

	Goods	Services	Total
Output			
Level (MEUR)	1,834,367	2,367,688	4,202,055
Share (%)	43.7	56.3	100.0
Energy use			
Level (TJ)	16,889,751	2,430,492	19,320,243
Share (%)	87.4	12.6	100.0
Intensity (TJ/MEUR)	9.207	1.027	4.598
Material use			
Level (kt)	1,110,884	68,269	1,179,153
Share (%)	94.2	5.8	100.0
Intensity (kt/MEUR)	0.606	0.029	0.281
CO_2 emissions			
Level (kt)	558,005	100,558	658,563
Share (%)	84.7	15.3	100.0
Intensity (kt/MEUR)	0.304	0.042	0.157

Source: Destatis (2008b, 2009), author's calculations

Table 3 shows industrial production and the associated environmental impact in terms of energy use, material use and CO_2 emissions. The numbers clearly show how a shift from goods to services would contribute to dematerialisation. The share of goods in total output is only 43.7%, yet the production of goods accounts for 87.4% of energy use, 94.2% of material use, and 84.7% of CO_2 emissions associated with total production. The difference between goods and services is most striking with respect to material use – the material intensity of goods production amounts to 0.606 kt/MEUR whereas the material intensity of service production amounts to only 0.029 kt/MEUR. Thus, services are not completely immaterial, but they consist of considerably less material (per output) than goods[8].

Table 4: Environmental impact of consumption

	Wood	Coal	Natural gas	Refined petroleum products	Electricity, steam and hot water	Other goods	Services	Total
Consumption								
Level (MEUR)	676	379	5,115	23,665	21,466	296,755	781,933	1,129,989
Share (%)	0.1	0.0	0.5	2.1	1.9	26.3	69.2	100.0
Energy use								
Level (TJ)	194,046	32,404	987,750	1,970,093	651,138	0	0	3,835,432
Share (%)	5.1	0.8	25.8	51.4	17.0	0.0	0.0	100.0
Intensity (TJ/MEUR)	287.1	47.9	1461.2	2914.3	963.2	0.0	0.0	5673.7
CO2 emissions								
Level (kt)	0	3,351	59,920	140,046	0	0	0	203,317
Share (%)	0.0	1.6	29.5	68.9	0.0	0.0	0.0	100.0
Intensity (kt/MEUR)	0.0	662.4	11843.5	27680.9	0.0	0.0	0.0	40186.8

Source: Destatis (2008a, 2008b, 2009), author's calculations

Environmental impacts are not only caused by production, they also accrue during consumption of goods. Table 4 shows the amounts of energy use and CO2 emissions that are allocated to the

[8] The material intensity of service production is highest in sewage and waste disposal (0.391 kt/MEUR) and air transport (0.308 kt/MEUR). For all other services, it amounts to less than 0.1 kt/MEUR.

consumption activities of households[9]. The numbers show that the consumption of services does not cause any energy use or CO2 emissions *directly* (for indirect impacts, see Table 3). The same is true for most goods. The major part of households' direct energy consumption is associated with the consumption of refined petroleum products (51.4%) and natural gas (25.8%). These two products also account for nearly all of households' direct CO2 emissions (68.9% and 29.5%, respectively). The consumption of electricity, steam and hot water is associated with some energy use (17.1%) but not with CO2 emissions, because emissions are generated only during the production of these goods. Also, the consumption of wood is not associated with direct CO2 emissions due to accounting conventions (wood being considered a renewable resource). Since the consumption of services does not cause any direct environmental impact, it is clear that a shift from goods to services would substantially improve the environmental balance of the household sector.

The data sources outlined above were used to implement MMG in GAMS. The results of the modelling exercise are presented in the following section.

4 Results

When all parameters are set equal to the actual values from the official statistics, MMG precisely reproduces the official statistics (input-output tables etc.) for the year 2005. This situation will henceforth be called the 'base scenario'. In order to investigate the possible effects of dematerialising consumption, an 'alternative scenario' was constructed, which differs from the base run in the allocation of consumption expenditure between goods and services (Table 5). In the following, the results of the alternative scenario will be compared to the base scenario.

Table 5: Consumption patterns in both scenarios

Expenditure share of…	Base scenario	Alternative scenario
Goods	0.30	0.24
Services	0.70	0.76

Source: author's calculations

Table 6 shows the differences between the two scenarios in terms of macroeconomic aggregates. The most striking observation is the difference in final consumption expenditure by households, which is almost 2 % higher in the alternative scenario. Thus, the shift in the *composition* of consumption expenditures is indeed associated with a significant change in the *level* of the same. The other components of final demand, as mentioned above, are the same in both scenarios. Hence, total final use is only 0.75% higher in the alternative scenario. Interestingly, intermediate consumption is actually lower in the alternative scenario, and therefore total use is only marginally higher (0.25%).

The higher use of commodities must of course be met by a higher supply of commodities. Therefore, total supply is also 0.25% higher in the alternative scenario. However, the share of domestically produced commodities in total supply is obviously higher – domestic output is 0.83% higher while imports are 2.99% lower. These observations suggest that a dematerialisation of consumption raises domestic output while lowering imports – a reasonable result, as services are still largely non-tradable.

[9] Households' material use is negligible (cf. footnote 6)

Table 6: Macroeconomic aggregates in both scenarios

	base run (MEUR)	alternative (MEUR)	deviation (MEUR)	deviation (%)
Use of commodities				
Final consumption expenditure by households	1,159,802	1,181,110	21,308	1.84
Other final use	1,670,670	1,670,670	0	0.00
Total final use	2,830,472	2,851,780	21,308	0.75
Intermediate consumption	2,113,874	2,104,697	-9,178	-0.43
Total use	4,944,346	4,956,477	12,131	0.25
Supply of commodities				
Domestic output	4,192,487	4,227,092	34,605	0.83
Imports	751,859	729,384	-22,475	-2.99
Total supply	4,944,346	4,956,477	12,131	0.25
Components of gross value added				
Compensation of employees	1,128,656	1,143,705	15,048	1.33
Net taxes on production	20,591	22,189	1,599	7.76
Consumption of fixed capital	334,627	342,644	8,017	2.40
Net operating surplus	537,500	555,680	18,179	3.38
Gross value added	2,021,374	2,064,217	42,843	2.12

Source: author's calculations

The bottom rows of Table 6 show how the higher level of domestic output is accompanied by an increase in income. Gross value added is 2.12% higher, which means that there is more income to be distributed. However, the additional income is distributed quite unevenly between the components of value added. Compensation of employees (gross wages plus social security contributions) is only 1.33% higher, whereas net operating surplus (i.e. profits) is 3.38% higher. This suggests that a dematerialisation of consumption affects the distribution of income between workers and capitalists, in favour of the latter.

Table 7: Sectoral accounts in both scenarios

	base (MEUR)	alternative (MEUR)	deviation (MEUR)	deviation (%)
Households				
Labour income	1,128,656	1,143,705	15,048	1.3
Capital income	537,500	555,680	18,179	3.4
Total gross income	1,666,157	1,699,384	33,228	2.0
Taxes on labour income	153,497	155,544	2,047	1.3
Taxes on capital income	48,375	50,011	1,636	3.4
Total income tax payments	201,872	205,555	3,683	1.8
Net labour income	975,159	988,161	13,002	1.3
Net capital income	489,126	505,669	16,543	3.4
Total net income	1,464,285	1,493,830	29,545	2.0
Final consumption expenditure at p.p.	1,293,233	1,316,993	23,760	1.8
Net saving	171,052	176,837	5,785	3.4
Government				
Net taxes on products	221,490	224,881	3,391	1.5
Net taxes on production	20,591	22,189	1,599	7.8
Taxes in labour income	153,497	155,544	2,047	1.3
Taxes on capital income	48,375	50,011	1,636	3.4
Total tax revenue	443,952	452,625	8,672	2.0
Final consumption expenditure at p.p.	421,510	421,510	0	0.0
Net saving	22,442	31,115	8,672	38.6
Rest of the world				
Exports	896,620	896,620	0	0.0
Imports	751,859	729,384	-22,475	-3.0
Net exports	144,761	167,236	22,475	15.5

Source: author's calculations

Table 7 provides a more detailed view of the income distribution and the other aspects of the sectoral accounts. In the alternative scenario, the total income of the household sector (both before and after income taxes) is 2.0% higher. Final consumption expenditure by households, however, is only 1.8% higher, so net saving is significantly higher (3.4%) than in the base scenario. The reason for this is that capital-owning households have a higher saving rate.

The government's consumption expenditure is equal in both scenarios. Its revenue, however, is considerably higher in the alternative scenario, which results in a massively higher net saving (+38.6%)[10]. The trade surplus is also significantly larger, reaching a value of 167,236 million EUR compared to 144,761 million EUR in the base run.

[10] The positive value for net saving does not mean that the government is actually running a surplus; it only means that current revenue is higher than current *consumption* expenditure. Other types of expenditure (spending on investment goods, debt service) can move the government's budget into deficit.

Table 8: Structural characteristics of goods and service production

	Production of goods	Production of services	Total production
Input-output coefficients (%)			
Goods	46.9	5.2	6.2
Services	19.0	29.9	15.3
Intermediate consumption at b.p.	68.4	36.3	71.7
Net taxes on products	0.8	1.8	1.0
Intermediate consumption at p.p.	69.2	38.1	72.7
Value added	30.8	61.9	27.3
Distribution of value added (%)			
Compensation of employees	67.6	51.9	44.1
Net taxes on production	0.4	1.3	-0.7
Consumption of fixed capital	13.8	17.3	26.3
Net operating surplus	18.1	29.5	30.2
Source of supply (%)			
Domestic production	74.7	96.2	61.9
Imports	25.3	3.8	38.1

Source: author's calculations based on Table 1

These findings can be explained by structural differences between the goods and service industries. Table 8 shows the structural characteristics of goods and service production – input-output coefficients, the distribution of value added, and the share of domestic production and imported products in total supply. Compensation of employees accounts for 67.6% of value added in the goods industry but only 51.9% in the service industry. Conversely, net operating surplus amounts to 18.1% and 29.5%, respectively. Thus, in the service industry a larger share of value added is received, at the end of the day, by capital owners. This explains why a dematerialisation of consumption causes income to shift (relatively speaking) from workers to capital owners. Table 8 can also explain the observed differences in imports. The share of imported goods (25.3%) is much higher than the share of imported services (3.8%). Hence, a shift of consumption expenditure from goods to services amounts to substituting domestic production for imports.

Table 9: Environmental impact in both scenarios

	Goods	Services	Total
Base scenario			
Consumption expenditure (MEUR)	346,135	813,667	1,159,802
Output by industry (MEUR)	1,831,698	2,360,789	4,192,487
Energy use (TJ)			
by consumers	3,814,262	0	3,814,262
by producers	16,848,952	2,423,718	19,272,669
total	20,663,214	2,423,718	23,086,932
Material use (kt)			
by producers	1,109,214	68,144	1,177,358
CO2 emissions (kt)			
by consumers	202,195	0	202,195
by producers	556,662	100,275	656,937
total	758,857	100,275	859,132
Alternative scenario			
Consumption expenditure (MEUR)	281,995	899,115	1,181,110
Output by industry (MEUR)	1,768,105	2,458,988	4,227,092
Energy use (TJ)			
by consumers	3,107,471	0	3,107,471
by producers	15,911,212	2,517,562	18,428,774
total	19,018,683	2,517,562	21,536,245
Material use (kt)			
by producers	1,075,142	69,916	1,145,058
CO2 emissions (kt)			
by consumers	164,728	0	164,728
by producers	526,440	104,023	630,463
total	691,168	104,023	795,191
Deviation (%)			
Consumption expenditure	-18.5	10.5	1.8
Output by industry	-3.5	4.2	0.8
Energy use			
by consumers	-18.5		-18.5
by producers	-5.6	3.9	-4.4
total	-8.0	3.9	-6.7
Material use			
by producers	-3.1	2.6	-2.7
CO2 emissions			
by consumers	-18.5		-18.5
by producers	-5.4	3.7	-4.0
total	-8.9	3.7	-7.4

Source: author's calculations

Finally, Table 9 reports the environmental impact of consumption and production in both scenarios both in absolute numbers (first two panels) and in terms of the percentage difference. In the alternative scenario, the consumption of goods is lower (-18.5%) while the consumption of services is higher (+10.5%) than in the base run. For output, the difference is smaller but still noticeable. Total consumption expenditure and output, as mentioned above, are slightly higher in the alternative scenario. What this means for energy use, material use and CO2 emissions can be seen in the rows below.

Most importantly, the increase in overall consumption and production is not strong enough to overcome the dematerialisation effect. That is, total environmental impact, measured by the three indicators used in this paper, is certainly lower than with the base run parameters. Thus, a dematerialisation of consumption clearly contributes to reducing environmental damage. Moreover, it also induces a dematerialisation of production in the sense that total production is increased (by 0.8%) while the associated material use is reduced (by 2.7%). Also, the production-related energy use and CO2 emissions are reduced, so the energy intensity and CO2 intensity of production are reduced as well. These findings show how a shift in consumption can lead to significant changes in the production sector as well.

5 Conclusion

The model results presented above generally yield the impression that a dematerialisation of consumption would generate various beneficial effects, raising total income while and simultaneously reducing the environmental impacts of consumption and production. In this respect, it can be considered a win-win strategy. However, there are certain aspects which may be problematic from a social or economic point of view.

On a national level, there are distributional consequences – the share of capital income in total income may increase at the expense of labour income. This observation is all the more troubling because Germany has seen the income share of capital increase substantially over the last few years, a development which has gone hand in hand with increasing poverty among worker households (the 'working poor'). A dematerialisation of consumption may exacerbate this trend and should perhaps be countered by means of deliberate redistribution measures.

From an international perspective, an increase in Germany's trade surplus, which is likely to occur as a result of consumption dematerialisation, would also be problematic. Germany has been running substantial trade surpluses for many years, and these are partly responsible for the current financial turmoil in the European Union, because Germany is accumulating foreign assets while (most of) its trading partners are accumulating debt. If the trading partners' debt becomes excessive, they may be forced to default (as Greece nearly did in 2010).

These two potential problems are indirectly related – both the decreasing income share of labour and the increase in exports are caused by a policy of stringent wage moderation, which has increased German competitiveness vis-à-vis its trading partners in the Eurozone massively because the common currency makes the adjustment via currency exchange rates impossible. Therefore, it might be sensible to accompany a policy of consumption dematerialisation with deliberate wage increases.

These considerations lead us to the question how a consumption dematerialisation of the extent discussed in this paper can come about. The earlier literature on dematerialisation expressed the hope that the growth of income per capita will automatically lead to dematerialisation, as material needs of consumers are already fulfilled and additional income is spent on non-material items of consumption. This line of reasoning led to the 'consumption-based' environmental Kuznets curve hypothesis (Canas et al., 2003, Rothman, 1998). So far, environmental Kuznets curves have been documented for a number of pollutants, but in case of crucial issues such as CO2 emissions and material use or the ecological footprint as an indicator of aggregate environmental impact, the evidence seems to be – at best – mixed (Caviglia-Harris et al., 2009, Galeotti et al., 2006). Therefore, one should not rely on income effects to break the link between GDP and environmental impact. Dematerialisation might come about due to other developments in the household sector, e.g. demographic change (Kronenberg, 2009). It is likely, however, that significant changes in consumer attitudes and social norms will be required for large-scale dematerialisation to occur. The model presented in this paper cannot address the question how or why consumers decide to consume less material-intensive products, but it can be used to assess the effects of dematerialisation, which a deliberate dematerialisation policy should take into account.

To sum up, this paper has shed some light on the macroeconomic effects of consumption dematerialisation in the sense of a substitution of services for goods. The question of how such a consumption shift can be brought about is left open for future research. If policymakers want to implement a consumption dematerialisation deliberately, they should take into account the possible effects on the income distribution and the trade balance, as discussed above, and if necessary implement additional policies to cushion these effects. Under these conditions, consumption dematerialisation is likely to be a win-win strategy in economic and ecological terms.

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