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For several years now, there has been a group of international researchers working on issues related to the flow of materials through their respective industrial economies and out from their economies into the environment—with one purpose—to create macro indicators of material flows. The goal of this work has also required the creation of the physical accounts of the economies of each of these countries, providing comparative data so we can see how countries differ. These researchers also want to be able to look at where policy interventions work to reduce the flow of materials out into the environment.

The first publication of this consortium was called *Resource Flows*. It looked at the total amount of materials required to run these economies. The current publication of this group, that just came out a couple of months ago, is called the *Weight of Nations*. It looks at all the materials that we put out into the environment.

Every material we pull out of the environment either ends up as durable goods or infrastructure or it comes out of the economy as waste. It was our goal to try and account for all of these things. In the United States, we looked at a total of 450 different materials. We looked at many industrial minerals, metals—of course all the fossil fuels, construction materials, the movement of earth (which is not a commodity per se but is a big material flow), non-renewable organics (especially synthetic organic chemicals which turned out to be a very important flow), and, of course, biomass—agricultural, and human and forestry.

The part of the material cycle that we were concerned with is not what goes on within the economy but rather what goes into the economy and then flows out of the economy. We are talking about things that we extract, things that we import, things that we export, and wastes that we put out into the environment.

But there are other flows that are attached to those activities, and these are what we call “hidden flows.” These are flows that are not priced and that are not captured in normal monetary statistics -- such as overburden from mining, soil erosion, dredging, and the removal of earth in construction and building. All material flows have some environmental impact whether it is local and micro or global and macro. This is especially true for these hidden flows.

We have tried to create indicators of these flows that allow us to compare countries. One of the major indicators is total material requirement (TMR) that we created about 3 years ago. The methodology that we created in this international consortium was the result of a lot of political negotiation among us. We needed to set boundaries and create definitions, and we came up with ones that were not only satisfactory for all the research institutions involved, but also have been adopted by other research institutions around the world. As a result, we are now able to get comparative data that allows us to compare how countries in different stages of development use materials.

In the study, *Weight of Nations*, we looked at total domestic output from economic activity to the environment. This includes the total processed output, that is, the stuff that comes out of the economy, as well as hidden flows that do not directly enter the economy in the first place. We anticipate that these indicators will be adopted widely. And, in fact, in Europe, Eurostat (the European Unions central statistical agency) has requested the total material requirements of all member governments and will soon request data on direct processed output or waste. It is likely that the Organisation for Economic Cooperation and Development (OECD) will request the same information from their member governments, of which the United States is one.

At this macro level, we are talking about the absolute size of these flows. The sheer amount of the stuff is certainly correlated to the impact of economic activity on the planet. But these macro level indicators also allow us to look at the composition of the flows, to compare the use of the materials between countries, the waste of materials, and the links that exist among material flows, the monetary economy, population.

While we have used materials flow analysis and materials flow accounting to understand the physical economy at the macro level of a country, these methods can easily be extended to other administrative levels, such as a state or county, or can be applied to geographically defined areas such as watersheds, or economically defined sectors such as transportation or mining.

The point is to try and account for all the material flows that are generated by the economic system, that enter that system, and that leave that system. One object of the exercise is to identify those waste flows that could be converted to resources and those points of policy leverage that might make the system more efficient.

Policy could make waste generation (outflows) flow more efficient in both an economic and an environmental sense.

Here is a comparison of five countries—the U.S., the Netherlands, Japan, Germany, and Austria. The DPO (Domestic Processed Output) can be considered waste, but it also includes stuff that we put out in the environment through the use of a product – fertilizers and pesticides, for instance. The rest of DPO is what we think of traditionally as waste. This compares the amount of waste from country to country. The U.S. is the largest producer of waste.

It is also the largest producer of these five countries on a per-capita basis. In terms of hidden flows, the United States generates the most on a per-capita basis. We are a big country and extract a most of the materials we require from our own resources, while the other four countries, the Netherlands for example, primarily import materials and do not import into their own environments those hidden flows or their consequences. This is important to remember for later when we talk about "problem shifting"—the shifting of an environmental problem from here to there by importing materials rather than cleaning up your own act.

Now, the size of the flows *per se* are not direct measures of environmental impact, but they are good measures of how things change over time. But we can characterize flows in ways that allow us to analyze them and look at potential consequences.

Here is the composition of the total U.S. domestic output. Hidden flows—coal mining, earth moving, soil erosion, dredge materials—really dominate the amount of stuff that we are putting out into the environment from our economic activities. The other big piece, of course, is CO_2, followed by NO_2 and SO_2.

Here is another picture of the same thing from a per-capita point of view. Each person in the United States accounts for the emission of 21.6 tons of carbon dioxide into the atmosphere each year and is responsible for 22 tons of materials from coal mining, including the generation of overburden and waste. Hidden flows have both physical and aesthetic impacts, but they also have effects on environmental chemistry and hydrology. It is important to keep in mind that hidden flows are not necessarily benign.

We characterized each flow associated with the United States economy by mode of release—where they go, their physical and chemical qualities, and their velocity through the economy. Other characteristics could be added to this database. You could add

price, carcinogenicity, or anything else you wanted to base on a particular analytical need.

Most of the DPO of the United States goes to the air. If there has been a domestic problem shift here, it has been from land disposal to air disposal. And, in fact, this air area here has increased not just because of the increase in CO_2, SO_2, and NO_2 emissions, but also because we have changed the mode of deposition from land and water to air.

Here is a quick peek at the potentially hazardous outflow we have seen from the United States economy from 1975 to 1996. It keeps rising. Fuel-related contaminants actually represent about 200 different materials, ranging from fly ash to methane and oil spills.

Here we can see how the flow of lead from the economy to the environment has changed over time.

Here is a more interesting one—it is the flow of arsenic in the U.S. economy. What has come to dominate arsenic use in the United States is pressure treated wood. Because it is so durable it lasts 15 to 30 years or longer. Regardless of environmental regulations, it is often chipped and put in municipal wastestreams, and even burned. Burning is of particular interest because of its correlation with catastrophes. When Hurricane Andrew hit Florida, where a lot of the treated wood is used, the scale of demolition resulted in the concentration of waste and its incineration in the open, resulting in the emission of large amounts of arsenic to the atmosphere.

moving ahead....

Here we have what is to me the most interesting result, since it is something we do not deal with well—medical and chemical waste disposal. Now this means not just hazardous waste, but also waste flows from end users. These flows include tossing pills into your wastebasket, flushing them down the toilet, or excreting biologically active substances into the wastewater stream. This is something we are not saying is good or bad (it is probably bad), but we are saying that it is definitely something that we should keep an eye on. And because of the material flow accounting system, we can actually estimate the magnitude of these flows.

One of the interesting revelations of this accounting is that not only do we excrete things from the economy, but we also build up stocks. These stocks will ultimately become waste or become raw materials for reuse. These stocks are very large indeed. On a

global basis, for example, the amount of copper embodied in existing infrastructure is 50 times that of global annual primary production. These are huge resources that can be reused and produce less environmental impact for their reprocessing compared to raw material extraction.

One thing that folks like Avery Lovings want to do is to reduce our dependence on materials. They want to increase the economic efficiency of these materials. Here you can see a comparison among these five countries and see how well we are doing. We all have improved over time. The U.S. is still the least efficient, but if you look at the U.S. experience, you can see that, over time, waste per GDP has declined. In other words, our use of materials has improved (in relation to our monetary economy, even though the total waste has gone up). Total waste has gone up 30 percent during this 21-year period, but we have become more efficient.

The same cannot be said for population. As you can see here, waste generated per person has remained stable over time. Population has increased, but so too has total waste. So as a result, on a per capita basis, we have not improved at all over the past 21 years. We have changed the mix of waste, but we have not changed the total amount that we put out per capita.

Finally, what are the policy messages here? There are a number of material flows that are not currently measured or considered in environmental policy. All economies continue to grow and use more and more materials, even though we are getting more efficient in the use of that materials. There are many hazardous flows that are upstream and downstream of actual manufacturers. There are probably too many flows to regulate each individually. The decoupling between material outputs and the GDP (Gross Domestic Product) is happening, but not as fast as believed by people who think that information technology will decrease our material use. It is essential to look at the entire material cycle.

In summary, this study tried to develop macro-level indicators of the physical economy as a guide to understanding potential environmental effects. And, by tracking these indicators over time, we can see how these flows might change in response to policy intervention. Looking at particular material flows, we can see how they change over time, how their use changes over time, and points or areas where some intervention needs to be done.

This is a source of information for those of us who want to look at industrial economies in ecological terms—who look at the industrial

metabolism of the economies and try to make that industrial ecology as exclusive as possible. Without this basic information on what materials are being used, how they flow through the economy, and how they leave the economy, we cannot begin to rationally manage—to close the loop of industrial ecology—so that we have a more self-sustained economic system without unreasonable inputs from the environment or outputs that overwhelm the assimilative capacity of the earth.

Thank you.