Chapter 7

A Theory of Economic Systems, Part 2:

The Production System as a Whole

In the previous chapter, two important aspects of technological change were discussed: first, change in the technologies of one or more categories of production reverberate to other categories of production; and second, the change to a fully reproductive production technology allows for exponential growth. Great Powers that are more successful in encouraging and harnessing the beneficial effects of these technological changes will rise relative to Great Powers that are less successful.

The present chapter will further explore the sources of technological change and their effects on the performance of Great Powers. The importance of reproduction and production machinery will be highlighted, and the benefits that emerge from the interaction of all production system functions taken as a whole will be discussed.

This chapter will also lay the groundwork for rigorous modeling of the economy. The concepts which are discussed in this chapter can be used to construct a sophisticated computer simulation of the production system, although such a simulation is beyond the scope of this study. The capability to create a simulation is important for validating and refuting hypotheses that arise from my theory of economic systems.

The Structure of the Production System

The two dimensions of the ordering principles of the structure of the production system can be combined into a two-dimensional diagram, to be called a *production matrix*:

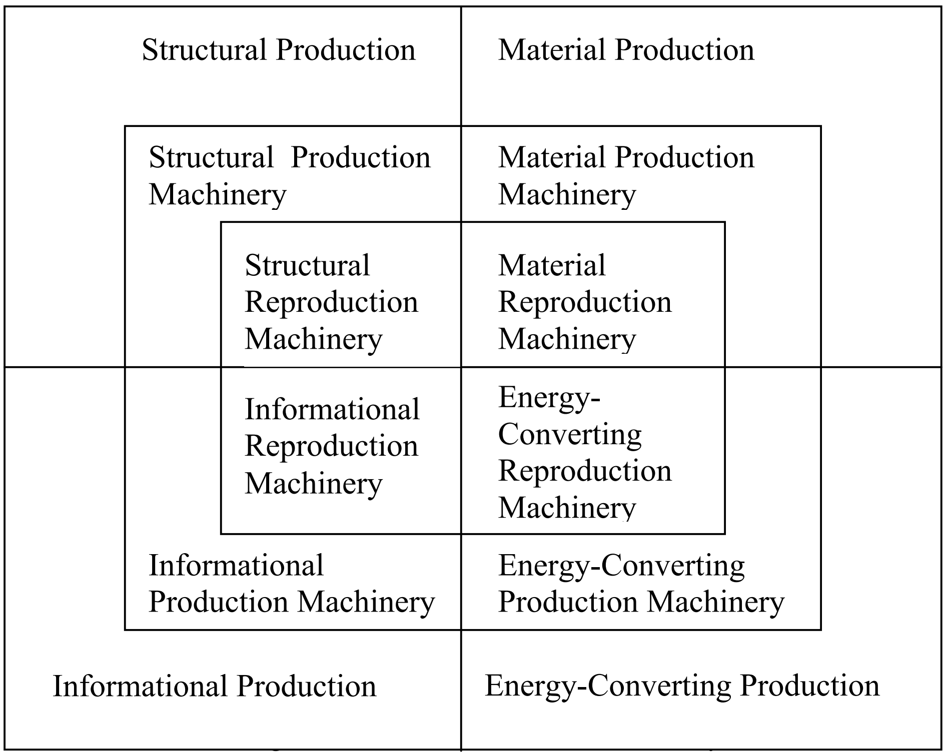

Fig. 28. Structure of the production system.

Each stage of production is composed of four categories of production.

There are twelve functional sectors of the production subsystem of the economic system. These functional sectors are the *elements* of the production system; they are arranged in a structure which is characterized by two ordering principles, categories and stages of production. These sectors will be referred to as *production system niches*, or simply *niches*.

The production matrix is an attempt to disaggregate the economy while retaining comprehensibility. In a similar way, Nathan Rosenberg has stressed the necessity of disaggregating technology:

> "Not only do technologies change over time, there are, in fact numerous technologies that coexist in a society at any moment. This heterogeneity renders distinctly suspect all attempts to speak about technology and its consequences in highly aggregated ways. It is not possible to come to grips with the complexities of technology, its interrelations with other components of the social system, and its social and economic consequences, without a willingness to move from highly aggregated to highly disaggregated modes of thinking. One must move from the general to the specific, from 'Technology' to 'technologies'. One must even be prepared to 'dirty one's hands' in acquiring a familiarity with the relevant details of the technology itself" (Rosenberg 1976, 2).

By dividing the production subsystem of the economy into twelve niches, I have attempted to strike the proper balance between aggregation and disaggregation. It should be possible to construct a useful explanation of the working of the economy, while retaining comprehensibility.

The functional sector can be called a niche in the sense used in ecological theory. The term "niche" has been difficult to define rigorously. As one biology text puts it, "an organism's niche is its ecological role – how it 'fits into' an ecosystem" (Campbell, Reece and Campbell 1999, 1115). More generally, Webster's dictionary defines an ecological niche as "the position or function of an organism in a community of plants and animals" (Webster 1989, 964). In the same way, a production system niche is the position or function of certain production technologies in the structure of the production system.

I have stressed the role of machinery in the discussion of the production system. However, there are two other factors of production which must be fit into a conception of a niche. The discussion of these factors includes a discussion of the interactions among the elements of the system. These extra factors, physical structures and intermediate goods, along with machinery, are the inputs and outputs which make up the interactions among the elements of the production system.

The first extra factor is the category of physical structures (national income accounts refer to these as structures, but for clarity I will refer to them as physical structures). Buildings, transportation infrastructure such as roads, electrical and communications networks and water and sewer systems, among others, fall under this term. Production machinery must have physical structures in order to function. For instance, machinery must be housed in a factory building. Trucks require roads, and electrical use usually requires an electric grid. Generally, when economists refer to "fixed capital", they are referring to "plant and equipment", which means machinery and physical structures.

Machinery is the active part of fixed capital, while physical structures are the passive part. That is, physical structures *enable* machinery to be agents of production, just as structures within a system enable or constrain actions by agents. Since most of the technological change which has led to the economic growth of the last two hundred years has been the result of change in the technology of machinery, this study will focus on machinery, not physical structures. But each niche still contains physical structures which are necessary for production. Like machinery, physical structures can be classified according to the category of production in which they participate. Thus, roads are part of the process of transportation, which I have classified as energy-converting production. A building creates position in space, therefore buildings are classified as part of the structural aspect of production.

According to the model adopted here, physical structures are only created in the final production stage. The machinery niches use some of the output of the final production stage in the form of physical structures. The machinery niches, in turn, move machinery in the following manner: first, the reproduction machinery stage generates reproduction machinery to be used in both the reproduction and production machinery stages; then, the production machinery niches move only production machinery to the final production niches. Unlike the machinery stages, the final production stage generates physical structures for all production system niches.

The second additional factor of production is the category of intermediate goods, or what economists call “circulating capital”. These are the goods, such as steel, chemicals, electricity, metal and plastic parts, natural resources, and myriad other items, which are used by machinery to generate output. Each niche, in the machinery and final production stages, contains a set of intermediate goods which are used by that stage to generate goods. However, intermediate goods do not move between stages, in my model.

The final production niches output everything that humans use to live. Humans use machinery in all four categories of production, among which are the following: first, tools and utensils for structural production; second, stoves and ovens for material production; third, the energy-conversion of refrigerators, lights, air conditioners and transportation machinery in the form of automobiles; fourth, computers, telephones, televisions and stereos as information production. Economists refer to these types of goods as consumer durable goods.

Humans also use physical structures, in the form of the infrastructure that final production niches also use, again in the four categories; buildings and furniture for structural production; water and sewage systems for material production; roads, railways, airports and the electrical grid for energy-converting production; and telephone and internet infrastructure for informational production.

People use intermediate goods, which economists usually refer to as nondurable goods, as well as services. The nondurable goods and services can also be categorized: first, housing services such as real estate or hotels, can be seen as structural; second, food in general is part of the material production of the human being; third, cars, transportation services, utilities such as gas and electric power, and household goods such as light bulbs can be considered as energy-conversion production; and fourth, the telephone services, printed and broadcast media can be classified as informational production.

This human use of goods and services thus is similar to the categories of production within the production matrix. Human life can be thought of as a sphere of production. People use machines, structures, and intermediate goods, just as the production system niches use the same factors. Thus, the realm of the use of goods and services by people can be labeled *human production*.

Data for human production can be obtained from the U.S. national income accounts in the form of personal consumption expenditure (PCE) data, which measures the expenditure of consumers by category. This table is an example of what I will call the *expenditure view* of the economy. The following table presents a rough guide to the 1994 figures for the U.S., which I have categorized into structural, material, energy-conversion, and informational expenditures:

Table 4. US Expenditures in Categories of Production

Structural Production	%	Material Production	%	Energy Conv Production	%	Informational Production	%
Housing	15	Food & Tobacco	16	Transportation	11	Recreation	8
Hospitals	8	Drugs	2	Gas & Electric	3	Education	2
Household Operations	5	Clothing & Shoes	6			Religious & welfare	3
		Personal Care	1			Doctors, Dentists & other services	7
		Cleaning	1			Telephone	2
		Water	1			Jewelry & Watches	1
Total %	28		27		14	Total	23

This table was constructed using the U.S. Statistical Abstract 1997, table no. 702 (Bureau of Economic Analysis 1997, 454). The total was 4,925 billion dollars for PCE, and the total of the four categories is 92% of PCE. The remaining 8% of PCE consists of financial and legal expenses. These constitute parts of the distributional system and the state.

The following diagram illustrates the factors of production which emanate from each stage of production:

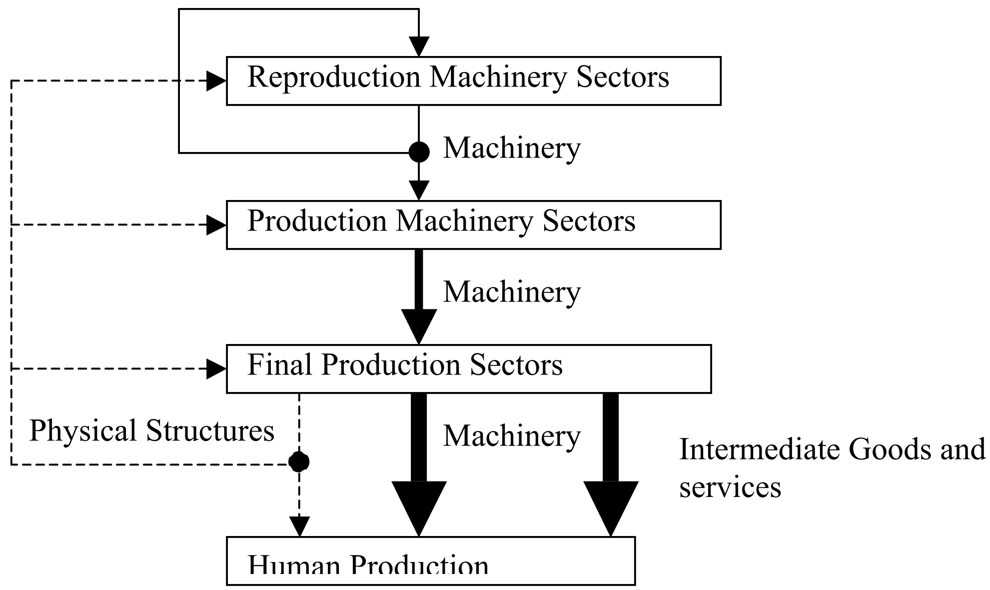

Fig. 29. The stages and capital factors of production.

The thin arrows represent reproduction machinery, the medium width arrow represents production machinery, the dashed arrows represent physical structures, and the very large arrows represent consumer durables and nondurables.

All parts of the production system have now been accounted for. There are machinery niches, which contain physical structures and intermediate goods as well as machinery. The final production niches contain the production of all physical structures, as well as the production of machinery and intermediate goods for human use.

In the diagram on the following page, I have divided the production of machinery, physical structures, and intermediate goods for humans among the twelve production system niches proposed in the preceding diagram of the production matrix, using the names of industries as specified in the United States national income accounts (using Standard Industrial Classification Manual 1987):

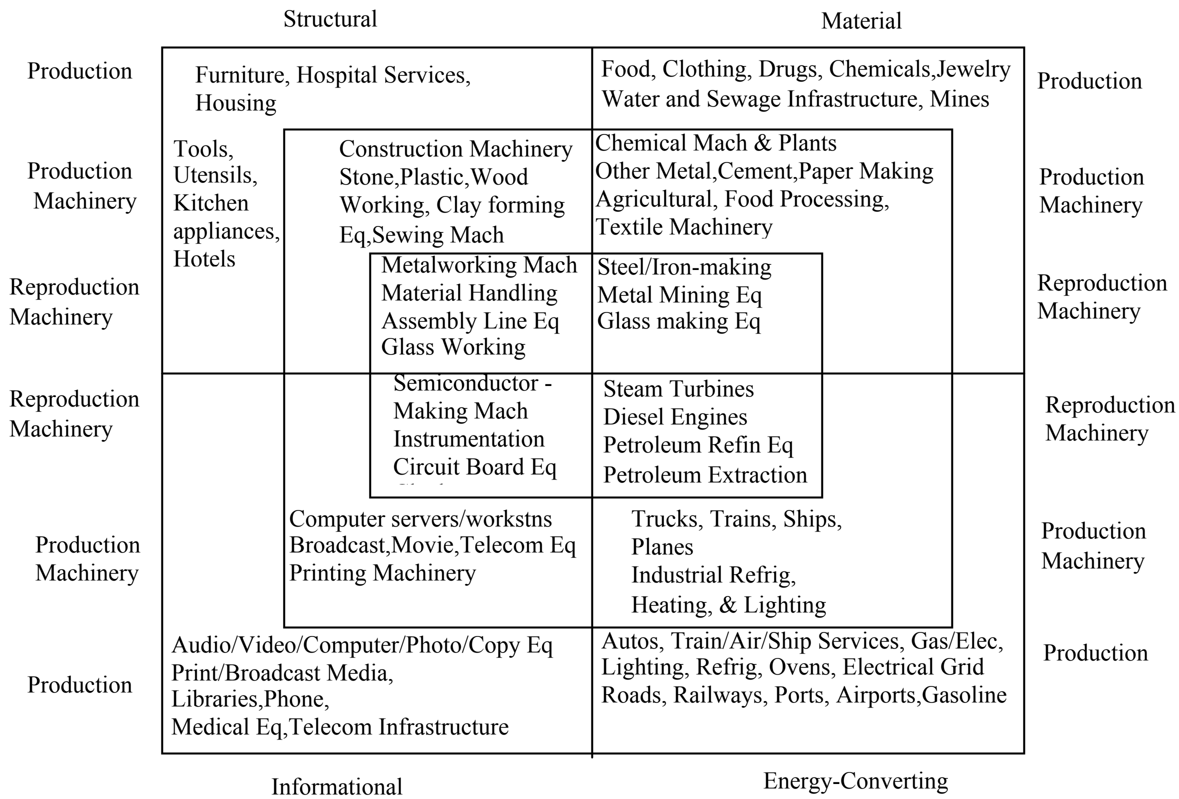

Fig. 30. Detailed structure of production system.

The labels on the outside of the large box indicate the categories and stages of production. A full specification of the lists of industries associated with each production system niche is included as Appendix 1 of this chapter.

These production system niches are themselves composed of a number of industries, or groups of industries. An industry, in theory, is composed of a number of firms. A homogenous group of firms within one industry is the domain of neoclassical economic theories. Neoclassical economists conceive of an economic system as a market composed of identical firms, within one industry. This study is focused on production system niches, however, not firms.

The following is a diagram of the hierarchy of domains as proposed in this study:

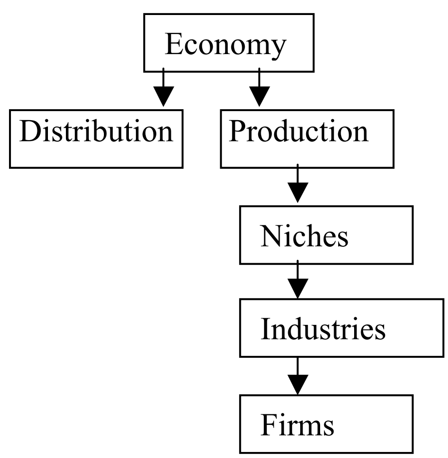

Fig. 31. Hierarchy of economic system.

In order to understand the working of the economic system it is best to focus on the level of the niches. It is necessary to be aware of particular industries, because in the national accounting systems, data are categorized according to these industries. The level of the firm, while useful for understanding the determination of prices and other phenomena, is not as important when exploring the national processes of production.

The ordering principles of the production system have now been specified. The elements are ordered according to two dimensions, categories of production and stages of production. The resulting twelve elements, called production system niches, are arranged into a structure as described above, according to their functional differentiation.

The Distribution of Capabilities within the Production System

A structure of a system is composed of ordering principles, a possible functional differentiation, a distribution of capabilities, and a possible distribution of causal capability. The ordering principles and functional differentiation have been specified. Since each niche can be represented as having a money value, there is also a distribution of capabilities which must be examined. There are three ways to describe this distribution empirically: an expenditure view, a capital asset view, and a value-added view.

The expenditure view has been used, in table 4, to describe personal consumption expenditures (PCE). In national accounting, expenditure in an economy is divided into a number of categories. The standard division includes the following: 1) personal consumption expenditures, which as the name implies covers the spending of people for their own use; 2) fixed private investment, which includes additions to the reproduction and production machinery niches, as well as physical structures; 3) government spending, which includes wages to employees but also includes investment in physical structures; and 4) net imports, that is, the trade balance.

The production matrix can be presented by showing the distribution of capabilities in terms of expenditure. The distribution of expenditure in the various niches gives an indication of the demand in that niche, that is, it shows the ability of the niche to call forth spending. The machinery niches have a very small ability to bring forth spending in comparison to the final production niches themselves, because the machinery niches are very small in comparison to the rest of the economy.

The second kind of measure of capability is called *value-added*. In national accounting systems, value-added is used as a measure of the money value that is added at a particular point in the process of production. This figure is calculated by subtracting the price of the material inputs from the price received for the outputs. For instance, in the steel industry, a particular amount of money is spent on iron, other materials, energy, and machinery. The value-added is the revenue of the steel industry minus these inputs. Generally, the value-added equals the income received by the various people who participate in the production. The value-added is therefore synonymous with profit plus wages, plus occasional other charges, such as rent.

The value-added approach is useful for explaining the detailed interactions of the various industries in an economy. In particular, a system of *input-output tables* has been constructed by the United States and other governments, which shows the inputs which each industry uses, as well as the destination of the outputs of each industry (Leontief 1986). The standard input-output table, however, only includes flows of intermediate goods in its most detailed sections. The expenditure view can also be represented in a standard input-output table, but is separated from the detailed flows of intermediate goods. The twelve niches of my production matrix can be modeled in terms of value-added input (Lawson and Teske 1994), not including expenditure:

Table 5. Intermediate Goods Input-Output Table of the U.S., 1987, in billions

	Struct Final Prod	Struct Mach Prod	Mat Final Prod	Mat Mach Prod	Energy Final Prod	Energy Mach Prod	Info Final Prod	Info Mach Prod	Total
Struct Prod	294.6	13.5	109.3	2.5	103.5	28.0	118.2	10.5	680.0
Mat Prod	194.4	9.9	438.3	1.7	41.1	22.0	68.1	6.2	781.6
EnergyProd	80.5	6.5	87.0	1.6	317.5	41.3	63.0	19.2	616.5
Info Prod	62.5	1.3	23.0	.3	23.3	6.2	187.8	18.2	322.6
Total	632.1	31.1	657.6	6.1	485.4	97.6	437.1	54.1	2,401.1

Note: Struct stands for Structural, Mat for Material, Energy for Energy-Converting, Info for Informational, Mach for Machinery, and Prod for Production

As the U.S. Bureau of Economic Analysis advises, “for the distribution of industries *producing* a commodity, read the *column* for that commodity. For the distribution of commodities *produced* by an industry, read the *row* for that industry” (Lawson and Teske 1994, 106, emphasis added). In order to find the inputs for an industry, we look at the column; in order to ascertain which industries used a particular kind of commodity, we look at the row.

For example, machine tools have been categorized in the table as structural machinery production. Structural machinery production industries used over 13 billion dollars of goods from the material production niche, the greatest part consisting of steel and other iron products. Another example is the final material production industries, which according to this table used over 438 billion dollars worth of products from the material production industries. For example, the steel industry uses some of its own products, as well as products from other material production, such as chromium.

This table only uses industries which I have categorized as involving production, excluding distribution and state systems. Much greater detail for the production system niches is possible using the 1987 U.S. Input-Output accounts (Lawson and Teske 1994).

This input-output table constitutes the *interactions* of the elements of the production system. It does not reveal the structure, which I have described in terms of the categories and stages of production, because interactions occur at the elemental level of a system, not at the structural level.

The advantages of the value-added approach are that 1) the internal functioning of the production system can be studied, and 2) the proper relative money value of each industry can be ascertained. In the expenditure view, on the other hand, the steel industry disappears, except for the plant and equipment that is invested in it, because all final products that use steel come from industries other than the steel industry. The steel is subsumed in the production of automobiles, for instance. By using a value-added view, we can see that the value of the product of the automobile industry is only partly added by the automobile industry, and that most of the value of the cars has come from various other industries, such as steel, that are never seen in the expenditure view.

Like the expenditure view, the value-added view also shows that the machinery niches are relatively small. In the table above, the machinery industries are always smaller than their associated final production industries. The value-added view shows the ability of an industry or niche to *generate* output, and thus it is the more important than the expenditure view, because the role of the production system is to generate goods and services. Reproduction and production machines *directly* generate relatively little value.

The machinery production niches, however, *indirectly* generate almost *all* output. The third view of capabilities, in terms of capital assets, gives a better measure of this phenomenon. In this view, we see the means of production of each niche, both in terms of structures and in terms machinery (for discussion, see Katz and Herman 1997). This is the value, appropriately depreciated by the U.S. Department of Commerce, of the assets used during production. The previous table showed the value of the goods and services that is generated by the assets shown in the following table.

The following table shows the main assets used in each niche, in millions of dollars (from Bureau of Economic Analysis 1998):

Table 6. Capital Assets Input-Output Table for the U.S. (in millions)

1987 Machinery and Physical Structures	Structural Production	Material Production	Energy Production	Information Production	Total
Structural Reprod Mach	78,328	41,077	35,526	22,039	176,970
Structural Prod Mach	93,423	59,372	94,067	27,118	273,980
Structural Phys Structure	203,104	181,833	91,683	644,820	1,121,440
Material Reprod Mach	0	10,077	17,289	0	27,366
Material Prod Mach	5,268	191,337	1,425	963	198,993
Material Phys Structure	1,078	611,937	29,844	10,159	653,018
Energy Reprod Mach	160	2,022	45,503	1,684	49,369
Energy Prod Mach	20,138	68,405	246,034	27,450	362,027
Energy Phys Structure	19,267	36,540	1,607,741	37,814	1,701,362
Information Reprod Mach	2,635	2,190	21,842	13,524	40,191
Information Prod Mach	6,635	29,228	33,331	235,205	304,399
Information Phys Struct	0	0	0	163,518	163,518
Total	430,036	1,234,018	2,224,285	1,184,294	5,072,633

Thus, to determine how much material production machinery is used for structural production, for instance, one would look at the row labeled “material prod mach”, and move to the column labeled “structural production”, to find the figure of 5,268 million dollars. While the standard, intermediate goods input-output table shows the *interactions* of the elements of a production system, this table shows the *capabilities* of the elements, and therefore indicates the distribution of capabilities in terms of productive power.

The capital assets input-output table, Table 6, should be combined with the intermediate goods input-output table, Table 5. Each stage of production should have its own table for fixed capital, which interacts with its own table for intermediate goods. Thus, each stage will have a capital input-output table which interacts with its own intermediate goods input-output table. For example, the reproduction machinery stage will have its reproduction machinery assets, which use its own intermediate goods to produce reproduction machinery, both for itself and for the next stage, the production machinery stage. The production machinery stage will have its own assets, made up of reproduction machinery, which uses its own intermediate goods. The output of this stage, production machinery, will be used in the final stage, final production. The final production stage will have its own capital assets, made up of production machinery, as well as its own intermediate goods. Finally, the final goods for human consumption will emanate from the final production stage. Figure 32, comprising the next page, shows this combination schematically.

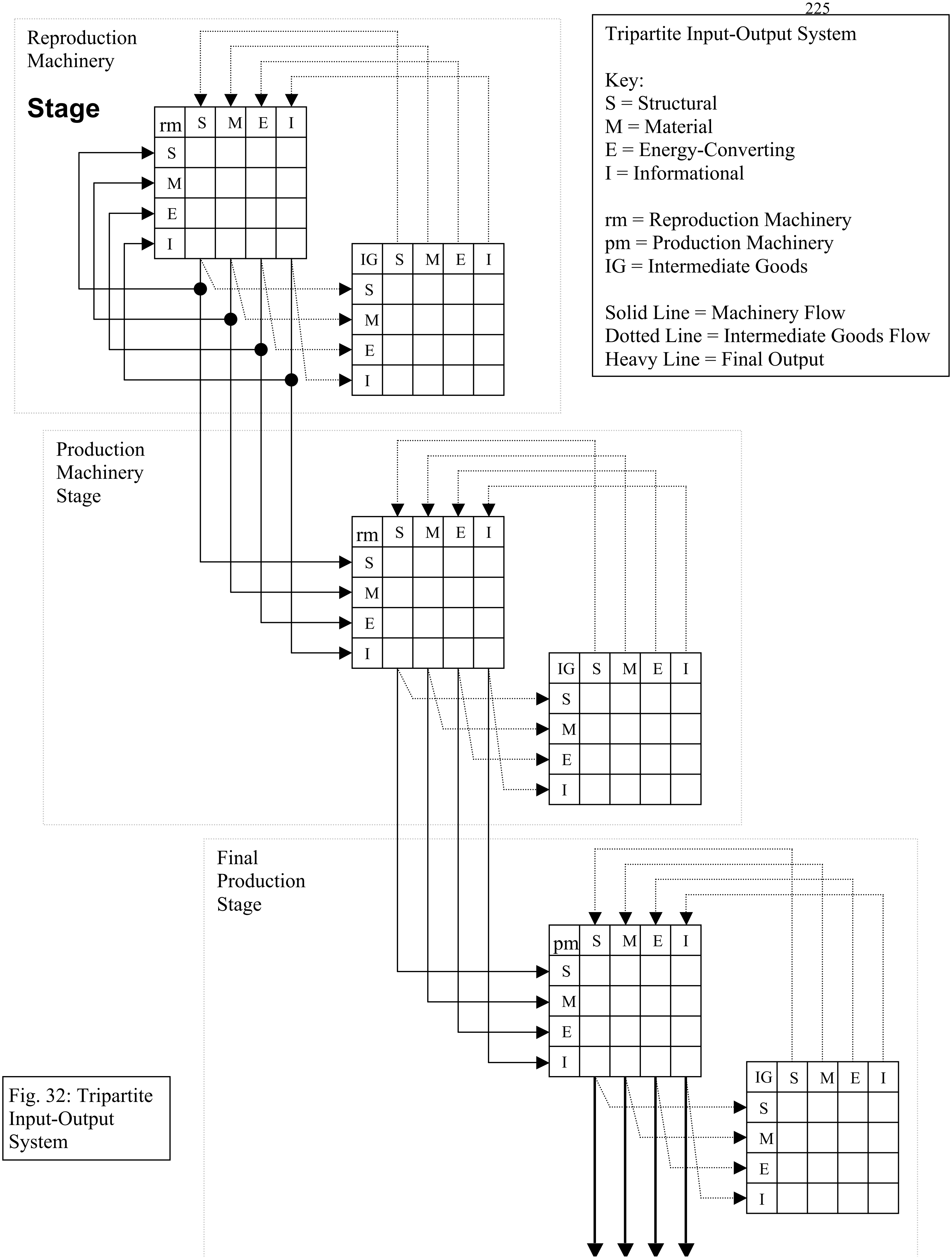

Fig. 32: Tripartite Input-Output System

In the reproduction machinery stage, we have a capital assets table which shows, in its rows, the machinery (and physical structures) which are used by each of the industries in the columns. The intermediate goods table, similarly, shows the commodities in the rows, distributed to the industries that use the commodities, in the columns. This intermediate goods table works the same as Table 5. However, unlike the standard input-output table, the commodities used by each industry move to the capital assets input-output table, because all production requires machinery (and structures). The commodities therefore come out of the top of the intermediate goods table, into the top of the capital assets table.

The output of the reproduction capital assets table – which is the output of the particular niche -- comes out of the bottom of the capital assets table. The output will either be in the form of more intermediate goods, in which case they move to the intermediate goods table, or the output will consist of machinery. Machinery either moves back to the reproduction machinery capital assets table (since this is a reproductive stage), or the machinery moves to the production machinery stage.

This movement of machinery out of a capital assets table and into another one is referred to as machinery *investment*. These investments, or *capital flows* as they are termed in the national income accounts, are also measured by government agencies (see, for example, [Bonds and Aylor 1998], for investment data).

The production machinery stage works in much the same way as the reproduction machinery stage. The difference is that in the production machinery stage the machinery output moves only to the final production stage, not back to the originating stage, as in the reproduction machinery stage.

The final production stage is similar to the other stages. Output can move to the intermediate goods table, or output moves out of the production system altogether, to the human production sphere. For simplicity, I am not showing that the structures generated in the final production stage are fed back to all three stages.

The advantage of this tripartite input-output table is that it can be used to create computer simulations of the production system. Neoclassical economists use analytic mathematical methods in order to model the economy. These methods are useful when the phenomena to be modeled are aggregated. When the phenomena are disaggregated, as they are in this study, then the interactions of the various elements, iterated through time, should be observed. Computer simulation is designed for just such tasks. Thus, a computer simulation using a tripartite input-output model is useful as a tool for validating or refuting hypotheses that are proposed to account for the behavior of production and economic systems.

Thus, depending on which phenomena one wishes to investigate and the methods used to investigate the phenomena, different views of the distribution of capabilities of a production system are warranted. The tripartite input-output model will be most useful for exploring the actual workings of the economy, as it combines the value-added and capital-assets views. The production matrix is useful as an overview of functional differentiation, and to model expenditure.

Since the production system is generative, the functional differentiation of the structure of the production system is more important than is the distribution of capabilities for explaining the growth, stagnation, or decline of the production system. The distribution of capabilities is useful for understanding the interactions of the different functions and production system niches, for tracking changes, and for testing hypotheses. However, the arrangement of the functions is the central focus of concern.

The same prioritization between function and capability occurs in much of biology. The internal workings of a cell, organism, or ecosystem must be based on a solid understanding of the physical weight, appearance, and other measurable characteristic of the various biological elements. But the focus of study is how these various elements interact to create the living cell, organism, or ecosystem. Computers are needed to simulate the simultaneous functioning of many elements in biological systems, because of the complexity that results from functional differentiation (for an ecological example, see [Ford 1999]). A similar need arises in order to simulate a production system.

In order to focus on the workings of the production system, one would use the various measures of expenditure, value-added, and capital-assets to illuminate that functioning. In terms of the distribution of capabilities, the distribution of expenditure, value-added, and capital-assets shows that the machinery niches have lesser capabilities in terms of the ability to call forth spending or to project power on the basis of assets than the niches which they make possible, the final production niches. Therefore, the machinery niches are always vulnerable in an industrial system. As will be asserted in the next chapters, the machinery niches have fewer resources with which to control their fate than do other parts of the production system and system of political economy as a whole. However, the machinery niches have a large capability to affect the growth of the production system.

Systems sometimes include a distribution of causal capability among their elements, and this distribution of causal capability may be very different from the distribution of capabilities. Because of their position in the structure of the production system, the machinery production niches are more important in causing change than the final production niches. When one or more of the reproduction machinery technologies change, the capabilities of the production machinery sectors also change, and therefore the possibilities and productivities in the production sectors will also change. A change in a final production niche will only affect the affected production niche. Any changes in the final production niche will only be possible because of preceding changes in the production technologies used to generate that production.

Therefore, *there is an ordering of the capability to cause technological change within the production system which reflects the sequence of stages of production, from reproduction machinery as the most powerful source of technological change, to production machinery as less powerful, and to the final production stage as least powerful*; this is the third hypothesis about economic systems. Technological power can be defined as the capability of a part of the economic system to propagate, directly and indirectly, greater ability to generate value-added throughout a particular economic system, in a particular period of time.

However, since "the benefits of innovation were difficult to identify comprehensively because such benefits were frequently captured by industries other than the one in which the innovation was originally made " as Rosenberg (1982, 77) pointed out in terms of the past two centuries, the machinery industries have not, historically, received as income from other parts of the economic system the income that the machinery niches have made possible for the rest of the economy. There is therefore a potential that machinery niches will receive less than ideal economic support for their activities.

Recently, some economists have become interested in general purpose technologies, or GPTs, "characterized by the potential for pervasive use in a wide range of sectors and by their technological dynamism. As a GPT evolves and advances it spreads throughout the economy, bringing about and fostering generalized productivity gains…Advances in GPT technology lead to new opportunities for applications. Such positive feedbacks can reinforce rapid progress and economic growth. The problem is that these complementary innovative activities are widely dispersed throughout the economy, making it very difficult to coordinate and provide adequate innovation incentives to the GPT and application sectors" (Bresnahan and Trajtenberg 1995, 84-85). In other words, some parts of the economy have a greater impact on the economy as a whole than other parts, but it may become difficult to steer investment back into these critical niches.

The concept of GPTs does not seem to include technologies that are used only in production, such as machine tools, but only technologies, such as electricity and semiconductors, that are used in *all* parts of the economy: "Most types of machinery have such a limited variety of uses that they do not come close to qualifying as GPTs…We rule out machine tools because their range of use is restricted to manufacturing…From the point of view of the economy as a whole, they do not quite fulfill our criteria of widespread use" (Lipsey, Bekar, and Carlaw 1998, 47). Thus, the concept of GPTs will not be used in this study.

Other scholars have also argued that production machinery is critical for economic growth, although they do not support their statements. For example, Chudnovsky and Nagao (1983, xi) state "All advances in productivity are connected with the volume and efficiency of the tools, instruments and machinery with which mankind carries on its productive activities". They later claim that "capital goods production has thus been the dynamic agent in accelerating the technological transformation of society" (xii). Boucher (1981, 101) states that "it is the writer's belief that the most pervasive influence on productivity advance is the improvement in design of the tools of production". For Fransman, "The machine sector lies at the heart of the processes involved in the generation and diffusion of technical change" (Fransman 1986, xi). The main theoretical basis for this claim seems to be the Feld'man model, which was discussed in the previous chapter.

In an important economic article, J. Bradford De Long and Lawrence H. Summers (Secretary of the Treasury in the last Clinton years) tried to show the importance of production machinery using statistical techniques. They came to the conclusion that there is "a clear, strong and robust statistical relationship between national rates of machinery and equipment investment and productivity growth. Equipment investment has far more explanatory power for national rates of productivity growth than other components of investment, and outperforms many other variables included in cross-country equations accounting for growth" (De Long and Summers 1991, 446).

De Long and Summers also suggest that "the private return to equipment investment is below the social return, and that the social return to equipment investment is very high" (De Long and Summers 1991, 482). In other words, the machinery niches do not receive as income that which they contribute to the rest of the economy. According to De Long and Summers, in fact, "The social rate of return to investment is 30 percent per year, or higher" (De Long and Summers 1991, 485), even though the rates of return for the machinery industries are far below 30 percent.

There is an inherent contradiction between the causal capability of machinery industries and their relative capabilities as measured by expenditure or revenue generation, and because of this discrepancy, industrial economies are in constant danger of suboptimal technological change; this is the fourth hypothesis about economic systems. The machinery industries may be underfunded, while the richer and larger niches will command the attention of the financial and state systems.

Structure, Rise, and Decline

Because of the distance of the machinery niches from the larger centers of economic power, as an industrial economy declines, its competence will deteriorate from the center out. That is, competence in reproduction machineries will be the first to decline, followed by competence in production machinery, until finally all productive capabilities are depleted. By contrast, a country that is rising will first increase its abilities in the final production niches, then it will upgrade its competence in production machinery, and finally a rising country will become a world leader in reproduction technologies.

Thus, *nations rise economically by moving up the stages of production in terms of competence, from production to production machinery to reproduction machinery. Nations decline by moving down those same stages of production, first losing competence* *in reproduction machinery, then in production machinery, and lastly in final production*. This is the fifth hypothesis about economic systems.

This sequence of rise or decline of a production system is linked to the size of the economic system. The economic system must be large enough to support a full complement of machinery industries. As Rosenberg has put it, "An economy may be sufficiently large to make possible all the economies of specialization available to the producers of consumer goods without being nearly large enough to generate optimum conditions for the producers of capital goods" (Rosenberg 1976, 143). In order for a particular class of machinery to be produced, the machinery industry must be a minimum size. Unless the industry reaches this minimum size, sufficient economies of scale may not be possible, or the skill base may not be available to support the industry. This minimum size can only be achieved if the niches which the machinery producer is supplying are also at a minimum size; there is no market for textile machinery if there is no textile industry. The minimum size of the final production niches that enables most or all of the production machinery sectors to persist can be referred to as the *minimum market size* of the production machinery niches. The minimum size of the production machinery niches that enables most or all of the reproduction machinery niches to survive will be referred to as the minimum market size of the reproduction machinery niches. This concept of minimum market size will be important in the chapter 10, in which it will be hypothesized that a Great Power must have a minimum market size for production and reproduction machinery industries.

As the final production niches decline, they reach a level *below* the minimum market size for the production machinery niches, at which point many of the production machinery industries disappear or start a process of severe decline. Since the reproduction machinery industries, such as the machine tool industry, are sensitive to the decline of *production* machinery industries, production machinery industries may persist, but the decreasing production machinery niches may decline to below the minimum market size for the reproduction machinery industries. Therefore, one would expect that initially reproduction machinery industries would decline and collapse, followed by production machinery industries, until finally production industries would decline in a situation of general economic decline. A reverse process would occur in a sequence of rise: first, final production would develop; second, production machinery industries would be established as a result of the growth of the final production industries; and third, reproduction machinery industries would become fully functional as a result of the growth of the production machinery industries to a minimum market size.

The most important benefit of economic "common markets" is that they provide minimum market sizes for all niches of a production system. I will refer to these as *global regional production systems*. This advantage of size was the case for the United States throughout most of its history, and has been one of the consequences of the European Union.

When all production system niches are present within an economic system, then that production system may be said to be *complete*. *A complete production system is greater than the sum of its parts; both the stages and categories of production participate in a mutually self-reinforcing, positive feedback process of production and technological change. There is a negative feedback process within a complete production system* *because there must be a balanced pattern of growth among all niches.* This is the sixth hypothesis about economic systems.

To anticipate an argument from Chapter 10, most types of production and reproduction machinery must reside within the national economy in order for the national economic system to reap the greatest benefits from those industries. This is a consequence of the above hypothesis. The addition of a new niche or set of niches to an economy has greater effects than simply the addition of the value-added of those industries; in other words, my argument directly contradicts the doctrine of comparative advantage, which concludes that nations should focus on those few industries which are their best. In the long-run, because of the complementarities of the various niches, overall competence in production increases at a greater rate than if only a few niches, no matter how well developed, exist within an economy.

A corollary of this argument is that trade *within* a global regional production system is the most important type of trade, not trade *among* global regional production systems. Intra-regional trade is necessary in order to produce the output of a complete production system. Inter-regional trade has two consequences.

First, discrepancies in productivity of industries between countries will be overcome if trade occurs. This is the perspective of comparative advantage and the benefits of exchange in general, as elaborated by neoclassical economists.

Second, the interchange of designs will be advanced by interregional trade. For all of recorded history, peoples have expanded their technological stock of knowledge and designs by trading (see Pacey 1990 and Pacey 1992). This process continues today, and is the global equivalent to a process which will be touched on in the next chapter, the importance of the interchange of ideas in processes of innovation. From the perspective of this study, the interchange of ideas is the most important function of trade.

The ability to export to other countries is important if two questions are answered affirmatively: first, “Are a significant proportion of the exports going to a global regional production system of which the national production system is a part?”, in other words, the trade is intra-regional; and second, “Is the income received for these exports being used to develop other parts of the national production system, viewed as part of a wider global regional production system?” In other words, the resources received in exchange for the exports is used to develop the home industries, not simply as income for consumption or for foreign investment that will never return to the exporting country.

Developing countries and nonGreat Powers never develop machinery industries, which are referred to by Rosenberg in the following as capital goods industries:

> Many of the major innovations in Western technology have emerged in the capital goods sector of the economy. But underdeveloped countries with little or no organized domestic capital goods sector have not had the opportunity to make capital-saving innovations because they have not had the capital goods industry necessary for them. Under these circumstances, such countries have typically imported their capital goods from abroad, thus this has meant that they have not developed the technological base of skills, knowledge, facilities, and organization upon which further technical progress so largely depends. (Rosenberg 1976, 147)

Thus, economic systems need certain human assets in order to develop a full complement of production system niches. In order to understand the importance of “skills, knowledge, facilities, and organization”, I turn in the next chapter to a discussion of what will be called capital systems. Once capital systems are explained, the distribution subsystem will be discussed in conjunction with the production subsystem, thus presenting a framework for understanding the economic system as a whole.

Chapter Appendix: Industries in Functional Sectors

Numbers in parentheses refer to categories from the Standard Industrial Classification 1987 of the United States

Structural Reproduction Machinery: Machine tools (3541, 3542) , Material handling (Conveyers 3535, Hoists 3536,Industrial Trucks 3537), Rolling Mill Machinery (3547), Welding Equipment (3548), Handtools (3546), Assembly Machinery (3549), Glass-working (35598 15, 35598 19)

Material Reproduction Machinery: Steel-making machinery, Mining machinery (3532), Glass making-machinery

Energy-Converting Reproduction Machinery: Turbines (3511) and Diesel Engines (35191, 35193), petroleum refining (3559801)

Informational Reproduction Machinery: Semiconductor-making Machinery (35595), Circuit-Board Equipment (35596), Process Control Instruments (3823), Analytical Instruments (3826), Lab Apparatus (3821)

Structural Production Machinery: Stone and ceramic working (3559813, 3559817, 3559822), plastic-forming (35593) , wood-working (3553) , construction machinery (3531) , sewing machines (3559888, 3559889, 3559890), clay-forming (3559827), concrete-forming (3559831, 3559835)

Material Production Machinery: chemical manufacturing (35591), textile (3552), food products (3556), paper (3554), oil and gas field machinery (3553), farm machinery (3523), cotton-ginning (3559853), cement-making (3559839), glass-making (3559843)

Energy-Converting Production Machinery: industrial heating and cooling and lighting, trucks and buses (3713, 3715), freight train (3743), cargo plane (37215), cargo ship (37313)

Informational Production Machinery: servers, telecomm equip (3661), broadcast equipment (3663), business computers, business software, printing trades machinery (3555), motion picture equipment(38613), still photography (38611), photocopy (38612), clocks (38732)

Structural Final Production: Housing, Commercial Buildings, Factory, Furniture (25), Clothing (Apparel 225 and 23), footwear leather and leather products (31)

Material Final Production: Cleaning and toilet preparations (284), Paints (285), drugs (283), food and kindred products (20), tobacco products (21), water systems, gasoline systems (gasoline 29991)

Energy-Converting Final Production: cars, buses, passenger trains and planes, heaters, cooking (3631), air conditioners, Freezers/refrigerators (3632), household wares (3634), laundry (3633), vacuum cleaners (3635), lighting (3645, 3646), roads, electrical systems, ports, airports, elevators (3534), car repair machinery (35597), commercial laundry equipment (3582), refrigeration and cooling (3585), service industry (3589), electrical grid, roads, airports, ports, canals

Informational Final Production: Computers, telecomm, audio & video (3651), print, medical equipment(3841, 3842,3843, 3844, 3845) , telecomm system, watches (38731), ophthalmic (3851)