Connectionist Economics - An Outline. Introductory Section: Chapters 1 to 4
H. Georg Schulze

To cite this version:

HAL Id: hal-01492977
https://hal.archives-ouvertes.fr/hal-01492977v2
Submitted on 24 Jun 2017 (v2), last revised 29 Dec 2017 (v3)

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Connectionist Economics

An Outline

Introductory Section: Chapters 1 to 4

Georg Schulze
Introduction
Introduction

Summary

Artificial neural networks or connectionist models play a key conceptual role in this theory. I provide a short description of the rationale behind the linkage of artificial neural networks and economics and why the linkage has this specific structure. It is followed by an overview of the organization of the work and the various topics covered in each of the chapters. After that I give a more detailed discussion of the objectives I had in mind and conclude with what I see as some of the key structural difficulties that remain. I cover artificial neural networks in a brief tutorial that constitutes the appendix to this chapter.
Introduction

In simple form, the Anima Motrix model (Schulze 1995; Schulze and Mariano 2003; Schulze 2004a) claims that the physiological integrity of a person is maintained by homeostatic mechanisms. When these mechanisms by themselves are insufficient to maintain physiological integrity, the hedonic states of pain and pleasure are generated to recruit behaviors to aid them. Recruited behaviors, then, are auxiliary means to maintain physiological homeostasis and can be modified by learning. Thus, at the most basic or primitive level, every adult engages in autarky - various behaviors to provide for his/her own requirements.

An economy arises when internal decoupling occurs between requirements and provisioning and a looser external coupling arises such that one person contributes towards the satisfaction of another’s requirements in exchange for a similar consideration. When these exchanges occur within set parameters (be they formal or informal) an economic system emerges. The term “an economy” is thus used here in its most general sense, namely any social system where exchange interactions occur between members of the social system. “Economic system” is a narrowing of this definition to account for the parameters governing these exchange interactions: whether they be free, limited, proscribed, or coerced; what the medium of exchange is; what the temporal characteristics of exchange are; and so on.

The basic thesis advanced in this work is that an economic system can be modeled as an assemblage of interacting artificial neural networks (ANNs). Specifically, it is an attempt to use ANNs to develop a universal model that can adequately represent the details of micro- and macroeconomics in the same framework. This would then provide the basis of explanatory, interpretative, and predictive considerations of economic phenomena. Macro- and microeconomics are to be described by this general model by taking the appropriate perspective; converting between these views should be easy and intuitive given the model, and changing the perspective should not affect the underlying structure, function, or assumptions of the model. Thus, what I’m proposing here is not financial engineering – the use of ANNs as (function) estimators of financial time series (e.g. Levine 2000: 369) – but something more fundamental and encompassing that may eventually inform or influence economic thinking at large.

Why use ANNs? ANNs consist of a number of independent computational units, called nodes, that are often arranged in layers, and that are in communication with one another through connections. ANNs are particularly interesting. First, one can describe the operation of the very same ANN at a local (e.g. Tsoi and Back 1997: 186) or global level (e.g. Tsoi and Back 1997: 193) and the quantitative descriptions at these different levels are fully commensurate. Second, ANNs combine inputs, transform these combined inputs and produce desired outputs in ways that are suggestive of economic production processes. Third, they are adaptive systems that can be constructed to respond to changing input conditions and output expectations and in this respect too are suggestive of an economic system. Fourth, visual representations of ANNs are common (e.g. Lippmann 1987; Hush and Horne 1993) and I believe that visual representations of economic systems that are tightly coupled to their quantitative representations will be highly valuable: any change to the visual model will have an immediate quantitative effect. Finally, ANNs are quite flexible from a design point of view and there are many types of ANNs (e.g. Harvey 1994: 3; Lippmann 1987: 5; Hush and Horne 1993: 8, 9; Tsoi and Back 1997: 207). They offer thus plenty of scope for visual and quantitative economic modeling.

The best known type of ANN is perhaps the perceptron (e.g. Harvey 1994: 86; Levine 2000: 18) and the three-layer (i.e. one hidden-layer) perceptron is used as a point of departure. Because the core economic system is here represented by two counterpoised three-layer perceptrons, it is reasonable to consider collapsing them into one structure with feedforward (money) and feedback (goods and services) connections such that an (modified) adaptive resonance theory network (e.g. Harvey 1994: 64; Levine 2000: 226) can be used as a model. I have not pursued this possibility, but confined my thinking to perceptrons.
A short description of how perceptron ANNs function is provided in the Appendix to this chapter. The reader already familiar with ANNs may wish to skip the Appendix and proceed to Chapter 2. In the remainder of this section, I present the key ingredients of the model and a brief description of each.

**General overview**

Demand- and supply-side networks. Two ANNs form the foundation of the connectionist theory of economics (CTE). These two networks are in resonance with each other in various ways, but pertinently so regarding their outputs. The first, in a broad sense of causality and importance, is the demand-side network (DSN) that represents the demand-side of an economic system. The second is the supply-side network (SSN). The second has resources as inputs and an array of products as outputs. The supply-side is more intuitively represented as an ANN and is described first (Chapter 2). The demand-side, described thereafter, has as inputs physiological, psychological, and sociological requirements arising from individuals - these combine to produce an array of demands as outputs (Chapter 3).

The inputs of both networks are transformed into product-related outputs (i.e. product demand and product supply, respectively) by economic transformation units (ETUs). At the most simple level, the demand-side ETU is conceptually an individual market analysis enterprise (and functionally a retailer) while the supply-side ETU is conceptually an individual market supplying enterprise (and functionally a manufacturer). Thus, linking back to Veblen, the DSN is more related to the humanistic processes of ‘sufficient reason’ and the SSN more to the scientific ones of ‘sufficient cause’ (Seckler 1975: 8).

A balanced system requires a matching of supply outputs with demand outputs as set out in Chapter 4. Although the demand-side output is conceptually key in terms of shaping the supply-side output, mutual interactions do occur at a secondary level. The primary determinants of individual demand (physiological, psychological) and secondary determinants of demand (psychological, sociological) and their susceptibility to modification by the supply-side are addressed in depth in Chapter 5. This is followed by an examination of the factors that affect the number of enterprises (Chapter 6) and the array of products demanded and supplied (Chapter 7). The issues covered in the latter three chapters arise as a consequence of the need to create a quantitative model.

Local descriptions. The computations performed at every node in a network are dependent on that node’s transfer function. Transfer functions govern the relationship between inputs and outputs at a local level and they can be used to model the specifics of demand and supply at a more detailed level. This is done in Chapter 8 where the production function is furthermore shown to be the economic counterpart of the transfer function.

Global descriptions. On a more global level the partitioning of demand input nodes to reflect social strata, the number of nodes per layer, as well as the connections that are established between them, is considered in Chapter 9. Parallel systems such as the public sector are described in Chapter 10. Chapter 11 deals with source/sink considerations such as the population (i.e., households) and the environment and their roles in the generation of circular flows of money on one hand and circular flows of goods and services on the other. In simple form, goods flow from the supply side input to the supply side output and then continue ‘backward’ from the demand side output to the demand side input – demands, thus money, flow in the opposite direction. As I explain in Chapter 12, money is the formalized and standardized (and often tangible) tokens used to represent demands. Therefore money is in counterflow with goods and services. Consequently, every network connection is seen to sustain two types of flows: money and goods and services. Here an interesting symmetry emerges because the product supply network (i.e. SSN) can now be seen as a (money) demand network, and likewise, the product demand network (i.e. DSN) can be seen as a (money) supply network. Again, I consider product demand to be primal and it should exist before trade can exist. In fact, as mentioned above, where demand can be supplied sufficiently and efficiently at its origin (i.e. self-supplied), trade will not emerge.
Interacting networks. The interactions that occur between output-coupled networks generate oscillations. Because the output of one network is the target of the other (and vice versa), a change in the output of one network induces both networks to compensate for the discrepancy, but in opposite directions. This can easily lead to over- or undershooting of the equilibrium level and it is considered to be one of the causes of economic cycles (Chapter 13). The actions of powerful fiscal and monetary agents may inadvertently synchronize and amplify such oscillations. Furthermore, credit can be expanded far more rapidly than production can be ramped up, making temporary mismatches in demand and supply, and the resulting oscillations, all but unavoidable. As a result, systemic credit expansion is particularly disruptive, especially when inadvertently coordinated by policies.

Interacting systems. International trade also arises from interactions, but from those that occur between systems (Chapter 14). Where extensive trade occurs between two similar systems, a single system with two currencies is approximated. Ultimately, environments determine the types of economic systems in existence and the types of economic systems constrain the extent to which they can interact or merge. This conclusion derives from the idea that some behaviors, thus by extension some cultures, are sustainable in some environments but not others - keeping in mind that technological advances may blur some of these constraints.

Finally, in Chapter 15, I discuss some implications of the connectionist theory of economics for topics that I think others may find of interest (price stability and full employment) and that I find of interest (taxation). Specifically, I consider (supernormal) profit, inflation, and economic growth to be closely related. Profit is a signal of a relatively localized supply-demand imbalance and serves to adjust supply and demand over a limited number of connections. This I deem self-correcting if the local profits are applied to fund the changes needed to adjust supply and demand where the imbalance arises. An increase, not justified by productivity and education, in the monetary base or in credit allows demands to expand system-wide generating, at first, profit signals along multiple connections and along with it economic growth and higher employment. However, these are false profits because the ‘profits’ expected by some are now eroded due to the ‘profits’ accruing to others. In order to pay for commitments made, turnover or prices have to be increased. At some point, increasing production capacity becomes too cumbersome, slow, and uncertain, and increasing prices remains the only alternative.

Regarding taxation, I think that it should be used as a monetary instrument, specifically, income and other taxes (not user fees) should be abolished and a transaction tax, applied to all monetary transactions, instituted. Not a penny should be able to change hands or accounts without exciting a tax. Interest rates could be said to accomplish something similar, but is it effective? A transaction tax would provide greater monetary control of the economy, since along with the money supply, its velocity can be managed better. This arises from adjusting the ‘friction’ in all monetary conduits by way of the tax. An economy that is stable, all the more so when noticed to be stable due to good stewardship, will encourage agents to participate constructively.

This outline is concluded with Chapter 16 where I show the results of some simple simulations and discuss their implications along with suggestions on how to move to more advanced simulations.

A closer look at the objectives

My ultimate aim is to create a sufficiently robust and functionally meaningful general model of any economic system to permit quantitative modeling in toto or in part. Cameron and Neal (2003: 3) claim that “…scholars and scientists have not yet produced a theory of economic development that is operationally useful and generally applicable.” In my view, this applies to economics in general, and this view has been reinforced by the global economic distress that emerged around 2007.

One might wonder why I chose such a big bite. The answer is that I think I can make more progress in creating a coherent and articulated framework by taking an overarching view rather than starting with
smaller bites and generating micro-theories that ultimately turn out to be disjointed, mutually incompatible, and collectively uninformative. By taking an overarching view, the different parts can be made first to relate closely and functionally to one another and second to develop in detail themselves. Thus the whole can be allowed to grow organically – arborizations that hopefully develop from a solid root system. In this vein, I have attempted to indicate points of intersection between the framework developed here and the various subdisciplines of economics.

A second aim, and the one more readily attainable perhaps, is to provide a conceptual framework of sufficient cogency to guide formal thinking about economics. The trivial often becomes more profound when systematically examined. The reader may perhaps recognize herein the observation by the protagonist in The curious incident of the dog in the nighttime that something was interesting because it was being thought about, not because it was new (Haddon 2003). Formal definition would contribute to clarity, and greatly so, if the formal definitions are mutually compatible, globally coherent, and internally consistent. This will be more difficult to achieve in a piecemeal approach, therefore again my preference for the larger framework.

Clarity of concepts in turn will promote insight. Having defined “price” for example as the ratio of demand for a given product along a specific connection to the flow of that product along the same connection, it becomes easier to explain the relative levels of prices and how they are determined. Thus the statics and dynamics of requirements and how they translate into demands and the statics and dynamics of resources and how they translate into goods and services need to be considered – tractable because the concepts ‘requirements’ and ‘resources’ also have been defined and elaborated on. Furthermore, since the aggregate size of monetary flows through a given node can be used to define the size of a firm, and since the aggregate size of monetary flows through that node depends on the connections it has to other nodes, its transfer functions, and the relative pressure of supplies and demands pertaining to its inputs and outputs, respectively, the spread of firm sizes in an economic system can be assessed. An understanding of the hierarchical nature of requirements and the relative elasticities of these requirements also provides insight into consumption since ‘needs’ (i.e. physiologically determined requirements) are inelastic and varies little from person to person. However, status desires are elastic, and capital accumulation may reflect these. Thus, capital could be accumulated to gain status, but will not necessarily lead to an increase in per capita consumption of inelastic ‘needs’ that are already satisfied.

Some problems, however, may have to be addressed indirectly. Capital accumulation is often seen as being in tension with labor wages because high wages impede capital accumulation while high levels of capital accumulation may drive up labor costs (Levine 2005: 13-14). From my current perspective, however, capital accumulation should not be seen as a major objective – instead capital accumulation is viewed as the accumulation of reserves and these do not arise in a system in equilibrium, but in one experiencing stress. For example, along a connection where demand stress occurs, prices are likely to increase resulting in (supernormal) profit, this profit provides the reserves needed for production expansion and it should occur in the general absence of concomitant wage increases. Save for natural disasters and perhaps unique conditions of population growth, economies where system-wide stresses occur are not managed well. Even so, for some, this may still leave unresolved the issue of relative if not “fair” wages. Thus one could model a number of identical economic systems but each with a different level of wages and seek to determine which is the most robust under different internal and external perturbations and which provides the most consistent and efficient long-term matching of supply and demand. I make here the underlying assumption that the long-term survival of the population is paramount.

In general, therefore, this modeling could shed light on some of the central issues of economics such as the allocation, distribution, and utilization of resources (Ison 2000: 2). I hope then, that with the aid of a coherent model a response to Kalecki can emerge: that theoretical laws can be derived that are verifiable and that for empirical laws can be found explanations.
Some remaining difficulties

Yes, there are remaining difficulties. Most of them can be fixed if the model has “good bones”. But if the bones themselves are a problem, it is a different matter. Here are some of the bothersome bones that come to mind. The first, enterprises on the demand side are thought of as being, in practice, retailers. Conceptually, they are thought of as enterprises that utilize combinations of requirements to create or formalize demands for specific products. It is rarely the consumer that produces detailed specifications for running shoes, but someone close to her and with an understanding of her needs and wishes, that does this. The manufacturer produces according to the product’s specifications, but does not generally consider himself to be in the business of product design. Thus “retailers” conceive of a product that they anticipate their customers would want and these are the products that the demand-side network has as outputs. These, of course, are also the products that the supply-side network aims to provide. At first I considered the demand-side’s hidden nodes to be individuals that fashion conceptually, from the amorphous sea of requirements that arise from a population, the individual products that they wished for consumption. This, however, did not seem to work very well or fit comfortably with my views of how things may be in reality. It prompted me to adopt the current embodiment, though it too, may yet reveal problems.

Furthermore, the approach that I adopted created the second cause for concern. If these enterprises were like retailers, then they would need access to at least some resources such as land, labor, and capital. But this casts them in the light of supply-side units. Perhaps they are somewhat hybrid in nature, with qualities of both demand-side and supply-side enterprises, but with the former dominating. In reality therefore, demand-side and supply-side networks are not as neatly separated as I have portrayed them throughout this work. They most definitely have hard wired connections between them, but perhaps not as many nor as extensively as within a given network. Thus the networks are coupled by virtue of taking each other’s outputs as targets or goals for their own outputs and joined with some direct connections between some nodes of one network and some nodes of the other. Taken together, there appears to be some scope for conceptual reorganization here. It is also true that the demarcation between demand-side and supply-side networks may be convenient rather than realistic, but the present demarcation nevertheless should serve sufficiently the exposition of the theory. In the final analysis, only time will tell how serious these difficulties may be and how many others emerge.

Another problem arises due to the circularity inherent in the model and the need to use it to simulate an economic system. Monetary flows in the system are largely circular and the model shows that the flows of goods and services must be too, even though transformed. In addition, there is the public economy and other national economies. I have not attempted to model this complexity although I believe it can be done because the components of the overall structure, and how they articulate, have been outlined.

Also, the performance of some network components such as some nodes will depend in part on the people that administer them. They, in turn, have needs, wants, and aspirations. I have not attempted formally to account for this nestedness of requirements within other components of the system. Whether these requirements are best seen as attributes inherent to network components or as contributions to aggregate demand, will require more thought.

Finally, this theory is built from the ground up. It lacks the sheen of many years of refinement, experience, and accumulated topical knowledge. Readers, especially economists, may find the work naïve and unpolished. This is so: there will be misconceptions and concepts crudely expressed. However, if the foundations are sound, both cosmetic changes and further developments are readily accommodated.
The Supply-side Network
The Supply-side Network

Summary

The most basic model of the supply-side of the economy is provided here by a three-layered network. The input nodes represent land, labor, and capital. Hidden nodes represent economic enterprises such as manufacturers. Manufacturers convert the inputs into products which are subsequently delivered to distributors. The output nodes of the network represent these distributors and they supply the products received from the manufacturers to the market. Therefore, the network has as inputs quantities of land, labor, and capital and as outputs quantities of specific products. Goods, first as resources and after conversion as products, flow from input nodes to output nodes. Money flows in the opposite direction. The network’s operation is illustrated with a simple example and different possible network representations, for instance, in terms of fractional utilization or prices, are described.
Introduction

The supply side of the economy is far easier to understand, and intuitively far more plausible to represent as a network, than the demand side is. The demand side requires the creation of more extensive underpinnings in order to represent as a network. Nevertheless, once the reader has grasped the basic idea, the conceptual transitions to the demand side will be facilitated. The supply-side network is therefore the logical candidate to discuss first.

The formal structure of the supply-side network

The basic structure of a supply-side connectionist model is shown in Figure 2.1. This model takes as inputs the economic resources of land and labor and these are represented by the input nodes. An economic transformation unit or enterprise, represented by the hidden node which employs a transfer function \( f \), converts these resources into a product that is delivered to a supplier. The supplier is represented by the output node using the transfer function \( g \). The supplier distributes the product to the market and this product is represented by the network output. The network connection weights indicate the volume fractions of goods that are distributed from one node to the next along the connection between them. Furthermore, note that the product is subscripted with “supply” to distinguish it from the similar product demanded by the demand side - products supplied and products demanded are not taken to be identical, but are taken to be matched to a degree that is good enough. Intuitively, one might think of better matches as producing better flows through the system. Here, “good enough” is taken to mean that the match is sufficient to permit economic exchanges to occur.

![Figure 2.1](image_url)

A simple supply-side economic network is shown in this figure. The network takes as inputs the economic resources of land and labor (input nodes). An economic manufacturing enterprise (hidden node with transfer function \( f \)) converts these resources into a product that is supplied to market via a distributor (output node with transfer function \( g \)). The network connections indicate the fractions of these goods used by (or distributed to) the next layer. In this example, there are two nodes in the input layer, and one each in the hidden and output layers.

Figure 2.1 is intended to lay the foundations for some of the basic concepts involved. Clearly, the network of Figure 2.1 is highly simplified and basic model. Although, land, labor, and capital are the standard resources of economic systems, this example network takes as input only the two resources of land and labor. However, capital is easily accommodated in a manner analogous to accommodating additional enterprises and additional products (see below), i.e. by adding an input node to account for it. More products,
more enterprises, more resources, or all of them, can be accommodated as shown in Figure 2.2. In passing, note that panel (a) in Figure 2.2 represents a basic monopoly while panel (b) implies competition.

**The flow of resources, goods and services**

I shall term the flow from input to output nodes in a network ‘main flow’ and the flow from output to input nodes ‘counterflow’. The related terminology for multilayer perceptions is “feedforward”, pertaining to the flow of information from input layer to output layer through the perceptron, and “backpropagation”, pertaining to the adjustment of weights from the output layer back to the input layer to effect error reduction (e.g. Jain et al. 1996: 37). In the SSN, resources and, after their conversion, goods and services are the main flows of the network. The inputs to the SSN indicate the total quantity of each resource available. It is acknowledged that arriving at such a quantity for each of the resources in question is not a simple issue, and I address these at a later stage (see Chapter 5). For present purposes though, I make the assumptions that the total quantities of resources are known and that the total quantities of resources are fixed. Input nodes in neural nets normally function as buffers to store the network’s inputs. These can then be distributed in unadulterated form to the hidden layer nodes where the key nonlinear computations are performed. Therefore the input layer nodes have linear transfer functions so as not to distort the input data and their transfer functions are not indicated in the figures. It is conceivable though, that in applying the connectionist model to economics, one may consider transfer functions for input nodes that are, to varying degrees, nonlinear. This could represent, for example, processes such as resource extraction or access to labor.

The hidden node in Figure 2.1 is an ETU and constitutes a single manufacturing enterprise producing the single product available to the market. The transfer function, $f$, specifies the manner in which it converts resources into products. Thus, the transfer or activation function of connectionist models maps onto the production function of economic enterprises (see Chapter 8). In general, this function is nonlinear and different for each enterprise, but the transfer functions for a given industry may be a related family of functions that reflect the production technologies utilized by that industry. If a single enterprise produces more than one product, it is possible that a separate production function is required for each product (i.e. many-variable factor relationships pertain). In terms of the standard ANN though, such complexity of transfer functions is uncommon; instead, it is customary for a single node to use a single transfer function and often the same transfer function is used by all nodes in a layer.

The output node represents a supplier or distributor that provides the product to market. Although I indicate in the figures that output nodes have (nonlinear) transfer functions, in practice these may just be linear or approximately linear and can be omitted. In other words, the distributor or supplier may also perform mainly a ‘buffering’ or warehousing function. The output from the output layer node constitutes the network’s output and it represents the quantity of product available to the market. Ideally the network’s outputs will be in agreement with the total quantity of corresponding products demanded by the DSN.

Training the network proceeds based on the quantities involved. Since the input and desired output quantities are normally known, the connection weights are systematically adjusted until the desired output is obtained from a given input. In essence, training is a multidimensional optimization procedure; more on training can be found in the literature (Baldi 1995; Hush and Horne 1993: 12-16; Jain et al., 1996: 34-39; Lippmann 1987: 17) and in later chapters (Chapters 6 and 9). When training is complete, the network weights indicate the fraction of the output capacity of a given node used by the downstream node connected to it. A network where the weights indicate fractional use is shown in Figure 2.3; the other panels in the figure show alternative network representations. For example, if 80 acres of land ($R_1$) are available, then a weight ($v_{11}$) of 0.34 indicates that 27.2 acres of land are used by the “Manufacturer” node; the subscripts designate the connection between input node 1 and hidden node 1 in Figure 2.3(a). Likewise, if labor for 15 workdays per year ($R_2$) is available, then a weight ($v_{21}$) of 0.67 between input node 2 and hidden node 1 in Figure 2.3(a) indicates that labor amounting to 10 workdays per year is used.
In more abstract form, Figure 2.3(a) can be seen the following way. A specific manufacturer (enterprise \(j\)) uses a certain fraction of the available amount of a given resource (\(R_i\)) to generate a product. The fraction of resource \(i\) used by enterprise \(j\) is given by the weight \(v_{ij}\) of the connection between \(R_i\) and enterprise \(j\) and the amount of resource used is \(q_{ij}\). The total quantity of resources consumed by enterprise \(j\) is the sum of all the individual resources consumed by enterprise \(j\), hence \(Q_j\) is the sum of all its inputs \(q_{ij}\):

\[ Q_j = \sum_j q_{ij} = \sum_j R_i v_{ij} \quad \text{Eq. 2.1} \]

(The reader troubled by the aggregation implied by Eq. 2.1 may wish to suspend disbelief for the time being, aggregation of disparate entities is addressed more explicitly in Chapters 4 and 8.)

A transfer function, of the form \(f(x) = x^2 + 1\) instead of the more commonly used sigmoidal function (e.g. Eq. A1), is used for illustrative purposes due to its simplicity. It describes how enterprise \(j\) (manufacturer) converts \(R_1\) (land) and \(R_2\) (labor) into bushels of wheat, thus its production function. The reader may well notice the (unintended) resemblance to a quadratic production function (e.g. Beattie and Taylor 1985: 66). More specifically, let \(P_j\) represent the total amount of product generated by enterprise \(j\), then

\[ P_j = \sum_k p_{jk} = (Q_j)^2 + 1 \quad \text{Eq. 2.2} \]

The total amount of product \(P_j\) produced by enterprise \(j\) consists of individual products. Individual product \(p_{jk}\) is the amount of product \(k\) produced by enterprise \(j\). Thus, if only one product is supplied (\(k = 1\)) and only one resource is consumed (\(i = 1\), we have a one product, one-variable production relationship. \(P_j\) is identical to the total physical product (TPP) of production economics (Beattie and Taylor 1985: 9).

The supply \(s_{jk}\) is the amount of product \(k\) produced by enterprise \(j\) that reaches the distributor; it contributes to the total amount of product \(k\) available on the market. For example, and with reference to Figure 2.2 (bottom panel), \(s_{XXK}\) is the amount of Product K supplied by Manufacturer X and \(s_{YXK}\) is the amount of Product K supplied by Manufacturer Y to the distributor represented by the node labeled “1” in the output layer. The total amount of Product K available to the distributor is thus their sum; if more enterprises exist that supply this product, the total amount of Product K is the sum of all the amounts of Product K supplied by individual firms.

In analogy with the fractional utilization of resources by producers, one could see the amounts of product that a distributor receives as the “fractional utilization” of enterprise outputs by distributors. For example, the amount of Product K received by the distributor of that product can be viewed as the fractional utilization of the amount of Product K produced by Manufacturer X plus the fractional utilization of the amount of Product K produced by Manufacturer Y. Since the connection weight \(w_{jk}\) from enterprise \(j\) to product \(k\) represents the fractional utilization of the output from enterprise \(j\), we have

\[ s_{jk} = P_j w_{jk} \quad \text{Eq. 2.3} \]

The outputs from the distributor nodes (i.e. from the output nodes in Figure 2.2) then represent the products that reach the market. For present expository needs, market is defined as existing at the output of the SSN and thus at the interface between the demand- and supply-side networks. The concept will be expanded in Chapter 4. Assuming linear transfer functions for the distributors

\[ Supply_k = \sum_j s_{jk} = \sum_j P_j w_{jk} \quad \text{Eq. 2.4} \]
The basic supply-side economic network shown in Figure 2.1 can be expanded to show, from top to bottom: a network with a single enterprise producing two different products; a network with two enterprises producing a single product; a network with two enterprises producing several products; and a network incorporating multiple resources, enterprises, and products. Some labels are simplified or omitted in the lower panels to enhance readability.
Normally, it is considered that an enterprise produces an array of products; to indicate the production of just one, connection weights to other products are maintained, but fixed to be zero. For example, if in Figure 2.2 (bottom panel) Manufacturer X does not produce Product M, the connection from hidden node 1 to output node 3 is zero and kept at zero during training. As an aside, it is interesting to note that if this connection weight is free to vary, it may indicate whether Manufacturer X should (but not whether it could) produce Product M to improve economic stability, i.e. to facilitate matching supply and demand. For the network as a whole

\[
\text{Supply}_k = \sum_j w_{jk} \left( \sum_i R_{ij} v_{ij} \right)^2 + 1
\]  
Eq. 2.5

Continuing with the example of Figure 2.3, the transfer function (Eq. 2.2) indicates that \((27.2 + 10)^2 + 1 = 1384.84\) bushels of wheat are produced annually. A weight \((w_{1j})\) of 0.8 between hidden node 1 and output node 1 indicates that 80% of this capacity, about 1107 bushels, moves to the distributor which supplies this amount to the market. If the 20% of wheat not used is also not spoiled, it accumulates at the producer node as reserves and can function as capital (see Chapter 12).

Note, in this example, that weights smaller than unity indicate an underutilization of capacity and weights greater than unity indicate an overutilization of capacity (more in Chapter 8). Because neither overutilization nor underutilization of capacity can be sustained in the long run, all the (fractional utilization) weights in a network emanating from a given node in an equilibrium economic system must sum close to unity on average. Also note that negative weights on the output side of a node could be taken to mean that a node consumes, rather than produces, a given product. This may be worthy of investigation in the future. For now I intend not to consider negative weights, but to signify consumption by a separate connection. For instance, if Manufacturer X consumes Product M, a connection from Manufacturer Y to Manufacturer X is established assuming Manufacturer Y produces Product M and Manufacturer X does not. To facilitate the identification of the product consumed by Manufacturer X, this connection can be conceived as being one leg from a bifurcation of the connection between Manufacturer Y and Distributor F along which Product M is delivered.

**Money flows**

In a SSN, money flows from output to input nodes as shown in Figure 2.3(c). Thus, money flow is a counterflow - opposite in direction to the main flow of goods and services. This makes clear that a SSN is a money demand network. For every network connection, a money flow can be established from the total quantity of goods and the unit costs of those goods along the connection in question. The quantity of goods is the total quantity available multiplied by the network weight (i.e. fraction utilized). The money flow along a given connection is then arrived at by the product of the quantity of goods transferred along that connection and the unit price of those goods along the same connection. For example, \(R_{ij}\) is the money flow over the connection between resource \(i\) and enterprise \(j\). Note that the underlined variables denote unit prices (or unit costs). In terms of the example used above, if land is rented at \(R_{\text{Land}} = $100/\text{acre} \text{year}\) and the area used is \(q_{\text{Land}} = 27.2\) acres, then the money flow over the connection between ‘Land’ and ‘Manufacturer’ in Figure 2.3(c) is $2720/\text{year}. ‘Price’ will be defined more rigorously at a later stage (Chapter 4), but for the present explanatory needs I assume prices to be known.

Given that “upstream” (i.e. with regard to goods flow) prices are costs and reflect expenditures while “downstream” prices reflect incomes, I can now calculate the production costs involved in supplying the product to market. With an annual rent per acre of $100, the cost for land is 27.2 acres x $100/acre year = $2720/\text{year} and with a daily wage of $80, the cost for labor is 10 days/year x $80/day = $800/\text{year}. Hence producing 1384.84 bushels of wheat per year would cost $3520/\text{year} in resources. However, production costs
do not simply reflect the input costs - in much the same way that a bushel of wheat is not arrived at by the simple mixing of labor and soil. Let, in the example here, a production cost of $1/bushel be in effect. Then, at capacity, the total product would cost $3520/year in resources plus $1384.84 in production, that is, $4904.84/year. Unit production costs can then be calculated to be approximately $4905/1385 = $3.54/bushel. If there is no supernormal profit and all of the wheat is cleared at market, then about $4905/year is earned. However, only 80% of the wheat is moved to market; thus, the gross income is about $3919/year. Further refinements are clearly possible, but for now suspended.

For illustrative purposes, I now also formalize a basic cost transfer function:

$$C_j = \left( \sum_i R_i a_{ij} + K_j P_j \right) / P_j$$

Eq. 2.6

where $C_j$ is the goods unit cost of production for enterprise $j$, $R_i$ is the unit cost of resource $i$, and $K_j$ is the goods unit cost of manufacturing for enterprise $j$ (i.e. not associated with resource costs); all other symbols remain as defined before. Industry-specific transfer functions may very well have different forms; the current embodiment is simply to aid in exposition. Note though that it is expressed in terms of the amount of product delivered, i.e. a production cost. Note also that the price realized by one ‘producer’ is the cost to the immediate downstream ‘consumer’ as alluded to above. Therefore, one can possibly dispense with a formal representation of the cost transfer function and use the flow of money across a given node instead to estimate empirical relationships between money inputs and outputs, unless the cost transfer function is of direct interest.

**Aggregate quantities**

As shown in Figure 2.2, a SSN may consist of several enterprises supplying a variety of products. The aggregate supply of a product (ASP) is now defined as the quantity available at the output node for that given product (e.g. the output quantity for product “K” in the bottom panel of Figure 2.2). It is an aggregate of all the like products supplied by the different enterprises in the system. The gross product supply (GPS) is defined as the aggregate of all products, that is, the ‘sum’ over all the output nodes of the SSN. The GPS cannot be represented by a single number, except in common units such as the unit of mass (e.g. gram) or equivalents of energy.

However, because one gram of integrated circuits is rather quite different from one gram of toothpicks, it would be better to represent it in terms of a mass-energy unit that reflects all embedded costs. Until such views are fully developed, however, the GPS is best represented as a bar graph, simplified perhaps to show product categories instead of individual products. Regarding counterflows, the gross money demand (GMD) is the sum of all product money demands (PMDs) and these, in turn, are arrived at by the multiplication of ASPs with the unit prices of that product. The GMD is clearly a single number expressed in monetary units.

**Network representations**

There are four distinct ways in which the same network can be represented; these are shown in Figure 2.3. These representations do not affect the network structure or its function, but merely make explicit different aspects of the economic system being modeled. The four network representations are:

(i) fractional utilization (i.e. the network weights as calculated with the training procedure);
(ii) quantity of goods;
(iii) quantity of money; and
(iv) unit prices of goods.
The four representations of a simple supply-side economic network: a) connections between nodes represent utilization; b) connections represent goods flows; c) connections represent money flows; and d) connections represent unit prices. The arrows are in keeping with the convention of connectionist models originally meant to indicate a flow of information from input to output layers – in the case of money flows and prices, the direction reverses as illustrated.
It is also possible to incorporate all of these aspects in the same network representation, but at the risk of sacrificing clarity. All the network presentations in Figure 2.3 are based on the preceding example where 80 acres of land and 15 workdays are available and utilization of these resources results in the production of 1385 bushels of wheat per year of which 1107 are taken by the distributor (and presumably reach the market).

From the foregoing, it is also evident that these representations are interrelated, but it seems that at least two components are relatively independent: the supply of resources and the supply of requirements (see Chapter 3). Requirements are here represented by money (i.e. tokens of demand). It may be convenient therefore to use quantity of goods and quantity of money as the basic modes of representation. Whichever representation is preferred is likely to depend on the discipline involved and the task at hand; for example, the representation showing money flows may be of most interest from a financial point of view. However, representation (i) is used in the computational literature and the one adopted as standard here.

**Discussion and conclusions**

I have given here a representation of the supply-side of an economic system in terms of a neural network or connectionist model. This model has resources as input nodes, enterprises as hidden nodes, and distributors as output nodes. The network outputs, that is, the outputs from the output nodes, represent the products available to the market. The transfer functions of the nodes map onto the production functions of economic concerns. Furthermore, aggregate measures appear broadly analogous to those of macroeconomics. Consequently, my first conclusion is that, at both local and global levels, there is a natural and easy transfer of connectionist concepts to economics. In later chapters I will continue to map concepts from connectionist models onto economics, and where such transfer is not possible, attempt to develop the economic models independently.

The second conclusion I come to is that the SSN is a money demand network. This is inferred from the fact that money flows in opposition to goods and services. The implication is that when money (or other reusable tokens of demand) is not available, the system slows or halts. Slowing or halting must be basically a quantization effect, and not dependent on the number of tokens in the system *per se*. In other words, if there are too few tokens in the system to permit the acquisition of individual products at practical quantities, slowing will start to take effect. Prior to that, simple price deflation will appear.

The last conclusion is that the flow volumes of goods and services across the SSN must be preserved. When more goods enter the system than leave it, the excesses accumulate somewhere and can be thought of as reserves, and by extension, capital. These excesses thus contribute to the resource node 'Capital' in Figure 2.2 (d). Thus the principles of physics are seen to affect economics as they should. Applying the principle of conservation also to monetary flows, one conjectures that money entering the network, but not leaving it, must accumulate somewhere as either internal reserves (at the node) or are deposited as external reserves giving rise to financial capital.
The Demand-side Network
The Demand-side Network

Summary

The origins of economic demand are formed by a set of ‘requirements’ - needs, wants, and aspirations – derived from human motivational attributes. Analogous to the way in which the supply-side network is modeled with resources as inputs, the demand-side is now modeled using requirements as inputs. In the demand-side network, hidden nodes perform the task of devising and designing products that are expected to meet the postulated requirements. Therefore, they convert requirements into products deemed desirable (and to some extent deliverable by the supply side). By way of conceptual simplification, retailers are here taken to perform this role. Their products are product specifications and orders for those products that are provided to the output nodes that represent purchasers or wholesalers. In turn, purchasers or wholesalers canvas or put out tenders or solicit submissions for these products from the market—the demand for specific products thus represents the demand-side model’s output. The model shows how requirements, originating as physiological, psychological, and sociological variables, become transmuted into demands for more refined and concrete entities, i.e. demands for specific products. An example is used to illustrate the network’s operation and a description of various network representations is given. Like the supply-side network, this model also has counterflows. In the demand-side network, demand flow is the main flow, going from input to output nodes, while goods flow is the counterflow. When the demand-side network flows are compared to those of the supply-side network, the flows of demands and those of money appear to be coincident. This comparison suggests that money flows are indices of human demands.
Introduction

In the previous chapter the supply side of an economic system was modeled in terms of a connectionist model. Because the supply side was relatively easily and intuitively modeled in connectionist terms, the reader may have found such a model at least plausible. In this chapter, the concept is extended to the demand side. Thus, I proceed from the assumption that the demand-side model may be similar to the supply-side one when formulating network inputs and outputs. Consequently, the demand-side network emerges largely as a mirror image of the supply-side network. Although this may not be accurate in its fine structure, as will become explicit in later chapters, I consider it conceptually sufficient for present purposes.

Unfortunately, unlike the supply side, the demand side is not as well characterized in terms of inputs and outputs. This is especially true regarding inputs; therefore some initial attention will be devoted to outlining them.

The formal structure of the demand-side network

It could be argued that any economic system arises by virtue of a set of reciprocal actions that individuals engage in. These actions spring from drives or urges that individuals experience and the drives result from hedonic states that themselves arise from physiological, psychological, and social factors modified by learning. Hedonic states are additive, giving rise to a net drive state (Schulze 1995: 275; Schulze and Mariano 2003: 11-4; Schulze, 2004a: 53). Although the overall drive state is different from person to person, and within a person over the course of a lifespan, it is useful to classify drives according to their natures and hence get an inkling of the objects that may be suitable to modify these drive states. In an economic context, the origins of these drive states are termed ‘requirements’, the drive states themselves are closely related to the concept of ‘utility’, and they become manifest as demands. The classification used here partitions requirements into ‘needs’, ‘wants’, and ‘aspirations’, ranked by elasticity, and they are described in more detail next.

Needs are hard requirements and have an inelastic quality. Needs refer to physiological survival-related variables and the impact they have on behavior. The hard nature of needs means that they do not accommodate shortages or excesses easily: once essential levels are met, increased consumption is unlikely – it is in fact undesirable. For example, although we absolutely need to ingest a certain amount of water regularly, excessive consumption is unlikely and could be fatal due to water intoxication. Thus, violation of their boundaries causes death. There is no wide variation between individuals based on need. Absolute levels are important in satisfying needs. The relationship between these survival-related needs and how they govern behavior has been extensively developed in earlier work (Schulze 1995; Schulze and Mariano 2003; Schulze 2004a).

Wants are ‘softer’ and more elastic requirements. Wants refer to physiological and psychological procreation-related variables and their impact on behavior. Both shortages and/or excesses can be accommodated. If wants are unmet, death will generally not result but distress may. In my view wants are closely related to sex and procreation but may become manifest through secondary or more distal variables such as status (e.g. Wong 2000: 38-42). Not having a pool and hence not consuming water under the ‘wants’ rubric is not fatal, but may limit a male’s ability to attract mates; conversely, having a larger pool and a larger still pool, hence consuming ‘excessive’ amounts of water, may increase the number and quality of mates attracted. Wide variations can exist between individuals regarding wants. The levels at which wants are met, relative to other individuals, become significant determinants of satisfaction. This has important economic consequences because wants can be manipulated to increase consumption in ways that needs cannot be.

Aspirations are the softest and most elastic of requirement categories. It refers to psychological and sociological variables that only have diffuse and mostly longer-term effects on survival and procreation. Under ‘aspirations’ would be considered issues such as health care, education, justice, governance structures, and so on. These are clearly important issues, but lack the immediacy of needs and wants. Building a
communal pool for recreation, instruction, and competition represents water demand under the ‘aspirations’ rubric: its absence is not disastrous and its upper limits are unbounded. Variations between individuals may be extremely wide and reflect levels of imagination, intelligence, and education.

Figure 3.1 shows a very simple demand-side network. The inputs are ‘Requirements’ – needs, wants, and aspirations (the latter is not shown in the figure); for now they are limited to one type of each for clarity. Like land, labor, and capital, the standard resources of economic supply systems, needs, wants, and aspirations are the standard requirements of economic demand systems.

![Figure 3.1](image_url)

A simple demand-side economic network is presented in this figure. The network takes as inputs the economic requirements of needs, wants, and aspirations; only the former two are shown. Requirements are analogous to the standard inputs of economic resources – land, labor, and capital – to the supply-side network. Retail enterprises (hidden nodes with transfer functions ‘f’) use combinations of the levels of these requirements to estimate the types and quantities of products that are projected to be in demand and procure them from wholesalers (output nodes with transfer functions ‘g’).

The network output reflects demand by wholesalers or purchasing entities.

By way of illustration of the DSN, I shall consider only needs and wants here, noting as above, that it is easy in principle to extend the model to include aspirations by adding an input node to represent them (see Figure 3.2). The input layer represents the requirements arising from individuals. The inputs indicate the total number of requirement units (e.g. units of ‘Needs’ etc.) present on the same basis as for resources, for example “per national economy year”. The reader may realize that quantification of these requirements could be very difficult and that they are not as easily quantifiable as resources. The descriptions of needs, wants, and aspirations relate them to physiological, psychological, and sociological factors that seem less discrete and, moreover, seem most intuitively expressed on a per person basis. Nevertheless, like resources, requirements may have to be seen as collective, i.e. expressed on the same per-unit basis as resources. This would facilitate the matching of the DSN outputs with those of the SSN and make the representation of goods and money flows within and between networks consistent. A more detailed analysis and quantification of inputs (i.e. requirements) are left for a later chapter (Chapter 5), but for present purposes I assume that the total levels of requirements are known, fixed, and that like requirements can be aggregated across a population.

The layer of hidden nodes represents marketing analysis enterprises that estimate the number and type of products that the levels of requirements from all individuals are expected to translate into. Conceptually, the market analysis firm could be seen to utilize a combination of requirements to create virtual product types
and their respective quantities – these virtual products then represent the products eventually demanded of
the market. The market analysis enterprise is therefore rather analogous to a manufacturing enterprise;
however, instead of utilizing different economic resources to generate products supplied to the market, it is
an ETU that utilizes different requirements to design products sought on the market. Although marketing
analysis enterprises may be hard to identify in a formal sense, I assume here that they do exist as discrete
concerns and that retailers are closely related or perform similar functions. Therefore retailers are taken to be
these concerns in Figure 3.1. This at least, may enable me to delineate the structure and symmetry of the
DSN, to contrast it with the SSN, and to show what an ideal system may look and function like.

The transfer functions specify the manner in which inputs to a node are converted into outputs from
that node. For example, the transfer function governs how needs, wants, and aspirations at the hidden node
combine into a given product sought by the retailer – i.e. the proper (main flow-related) production function
of the retailer.

Output nodes represent agents that ‘supply’ demands from retailers to the supply-side network. For
the sake of exposition, the output node is here taken to resemble a wholesale concern. The outputs of output
nodes constitute the network’s output. As output the network produces the total quantity of product
demanded of the market. Since the ultimate aim is to match supply and demand, the output of the SSN needs
to be matched with that of the DSN. The DSN output provides therefore a target for the SSN output, and does
so in two respects: it specifies in a general sense the types of products demanded and the quantities of each.
Given that in this case only one product is demanded, the quantity of product demanded constitutes the full
market demand for this product. It is, as before, very easy to extend the basic network of Figure 3.1 to
accommodate either more products demanded, or to incorporate conceptually more requirements, or both as
shown in Figure 3.2.

The flow of requirements and money

For the SSN it has been established that money flows occur over every network connection and that
they are in counterflow to those of goods. In the DSN, in contrast, the main flows are demand flows while
goods and services are counterflows. Demands arise from requirements and, after transmutation, become
product designs and then products sought on the market.

Getting down to numbers, let, for example and with reference to Figure 3.2, a given person,
Individual X, experience a net general yearly drive state of 6,000 “drive units”. Let one third of these be
classifiable as needs, one third as wants, and one third as aspirations. Let likewise Individual Y experience a
net yearly drive state of 4,000 “drive units” and let one half represent needs and one half wants. Then,
assuming the aggregation of like requirements, both contribute drive states of 2,000 “drive units” per year to
needs. Taken together, these numbers lead to needs at 4,000, wants at 4,000, and aspirations at a level of
2,000 units per year.

The enterprises Retailer M and Retailer N use requirements to design types of products deemed
demanded by consumers and to estimate their quantities. These products exist in a virtual form in DSN main
flows, i.e. as product design concepts and product specifications, and as real products in DSN counterflows.
In order to maintain consistency, the DSN that matches the trained SSN discussed above uses fractional
incorporation as weights. For example, Retailer M uses 0.75 (i.e. 75 %) of all needs, 0.2 of wants and 0.1 of
aspirations, to generate 5,657 overall products (see below) consisting of two types, Product K and Product L.
Retailer N uses 0.25 of all needs, 0.8 of wants and 0.9 of aspirations to generate the same two products,
Product K and Product L, as well as an additional one, Product M at a level of 8,486 products per year in
total. Even though these are virtual products, the two enterprises, between them, should not use more
requirements than exist. For example, they both should not use 0.75 of needs since 0.75 + 0.75 = 1.5 or 50 %
more needs than exist. The reason is simply that an overall ‘overincorporation’ would generate a degree of
fictitious demand that would lead to inefficiencies in the system. A transfer function of the form
\( f(x) = \sqrt{2x^2 + x} \) is invoked for illustrative uses to describe how enterprises convert requirements into estimated products and their levels of demand. However, the proper functional relationships need to be determined empirically. Input and output nodes are here assumed to have linear transfer functions. Note also that, for the sake of simplicity, I have assumed that one composite drive unit (i.e. a drive unit based on any requisite combination of needs, wants, and aspirations) translates into one unit of product. In reality, different functional relationships will exist that need to be established for each product separately.

Let now 90% of product generated by Retailer M be delivered to Wholesaler D as Product K and 10% be delivered to Wholesaler E as Product L. Likewise, for Retailer N, 20% of the total product is Product K and delivered to Wholesaler D, 40% is Product L and delivered to Wholesaler E, and 40% is Product M and delivered to Wholesaler F. Then the annual demand arising for Product K would be 0.9 \( \times \) 5,657 + 0.2 \( \times \) 8,486 or 6,789 units of Product K. For Product M this would be 0.0 \( \times \) 5,657 + 0.4 \( \times \) 8,486 = 3,394 units.

More formally, like resources in the SSN, every requirement is fractionally “incorporated” or fractionally “consumed” by a given enterprise and the sum of such fractional utilizations transformed into a total overall demand level \( L \) for every enterprise. That is, requirement \( i \) \( (R_i) \) is fractionally utilized \( (v_{ij}) \) by enterprise \( j \) at a level \( l_{ij} \). \( L_j \) then follows as the sum of all these different levels at which requirements are used by that enterprise, that is

\[
L_j = \sum_i l_{ij} = \sum_i R_i v_{ij}
\]

Eq. 3.1

Note that in the DSN \( R_i \) and \( v_{ij} \) refer to requirements and requirement fractional incorporation but that the same symbols in the SSN refer to resources and resource fractional utilization, respectively.
Assuming for simplicity that both enterprises have the same transfer function, then with reference to Figure 3.2, \( f_M(x) = f_N(x) \). The quantity of an individual product \( k \) estimated to be in demand by enterprise \( j \) is \( h_{jk} \). The sum \( H_j \) is the sum of all the levels of the various products designed by enterprise \( j \), thus

\[
H_j = \sum_k h_{jk} = \sqrt{2L_j^2 + L_j}
\]

Eq. 3.2

The fraction \( w_{jk} \) of \( H_j \) represents the demand \( d_{jk} \) for product \( k \) as estimated by enterprise \( j \) and experienced by or transmitted to the wholesaler for that product

\[
d_{jk} = H_j w_{jk}
\]

Eq. 3.3

The total market demand for product \( k \) is the sum of all the estimates of product \( k \) by all enterprises delivered to the wholesaler for that product and hence sought by the wholesaler on the market, that is

\[
Demand_k = \sum_j d_{jk}
\]

Eq. 3.4

For the network

\[
Demand_k = \sum_j w_{jk}\left(\sqrt{2\left(\sum_i R_i y_{ij}\right)^2 + \sum_i R_i y_{ij}}\right)
\]

Eq. 3.5

Applying this function now to the example reveals that for Retailer M:

\[
L_M = \sum_{\text{items}} l_{iM} = (0.75 \times 4,000) + (0.2 \times 4,000) + (0.1 \times 2,000) = 4,000; \quad \text{and}
\]

\[
H_M = \sqrt{2x(L_M)^2 + (L_M)} = \sqrt{2 \times (4,000)^2 + (4,000)} = 5,657. \quad \text{Thus the demand for Product K experienced by Wholesaler D from Retailer M is}
\]

\[
d_{MK} = 0.9 \times 5,657 = 5091 \quad \text{units.}
\]

Retailer N estimates \( d_{NK} = 0.2 \times 8,486 \) and hence the total demand for Product K experienced by Wholesaler D and relayed to the market is

\[
Demand_k = \sum_{\text{items}} d_{jk} = (0.9 \times 5,657) + (0.2 \times 8,486) = 6,789 \quad \text{units per year.}
\]

Again, the reader troubled by the aggregation of disparate entities is reminded that these issues are addressed in later chapters. At present, the models operate on information in strict analogy with computational neural networks.

It is worth emphasizing at this point that not only is the annual level of Product K estimated by the DSN, the very existence of a product like Product K is also predicted. Put differently, it is predicted that there would be demand for a product like ‘K’ and that this demand would exist at the level of 6,789 units per year. Some reflection may suggest that Retailer M predicts that demand exists for a product ‘K’ at a level of 5,091 units per year while Retailer N predicts that demand exists for a product ‘K’ at a level of 1,697 units per year. Since ‘K’ and ‘K’ are very similar (but likely branded separately), they are consolidated into ‘Product K’ without loss of generality.

Regarding money flows, assuming that the monies available per unit of requirement are known and fixed, the total funds available per product type can be calculated. The quantity of demands along a given connection is the total level of demands present at the originating node multiplied by the network weight (i.e. multiplied by the fraction ‘incorporated’). The money volume is then arrived at by the product of the connection level of demands and connection unit funds available for those demands.
For example, if individuals are willing and able to expend $10 per unit of needs, $4 per unit of wants, and $1 per unit of aspirations, the funds available for distribution across all products are $10 x 4,000 (needs), $4 x 4,000 (wants) and $1 x 2,000 (aspirations) for a total of $58,000 per year. Note that this example is meant to illustrate the concepts involved; it is not meant to imply that establishing the funding amounts allocated to requirements is trivial or easy. Further, Retailer M now estimates that 75 % of funds available for needs (0.75 x $40,000), 20 % of funds available for wants (0.2 x $16,000), and 10 % of funds available for aspirations (0.10 x $2,000) will constitute a demand of $33,400 for products of all types. Of this amount, 90 %, or $30,060, would be available for Product K. Likewise Retailer N estimates that 25 % of funds available for needs (0.25 x $40,000), 80 % of funds available for wants (0.8 x $16,000), and 90 % of funds available for aspirations (0.9 x $2,000) will constitute a demand of $24,600 for products of all types. Of the latter amount 20 %, or $4,920, is available for Product K giving a total level of funds available of $34,980. Since the total demand for Product K is known, the funds available for the acquisition of Product K are $5.15 per item.

The flow of goods and services

Goods and services are the counterflows of the DSN. Assuming an economy in equilibrium, the number and type of products demanded are more-or-less met by the number and type of products supplied. The (real) products supplied to wholesalers are then delivered to retailers and these to consumers. Consumption of goods and services must therefore ultimately meet or satisfy the requirements of consumers. As for main flows above, counterflow volumes can be calculated and these should match, given the condition of equilibrium, the main flow volumes across the same connections.

Aggregate quantities

As shown in Figure 3.2, a demand-side connectionist model may consist of several enterprises projecting a variety of product demands. The aggregate demand of a product (ADP) can now be defined as the level present at the output node for that given product (e.g. the output level for “ProductK demand” in Figure 3.2). It is an aggregate of all the like products projected to be in demand by the different demand enterprises in the system. The gross product demand (GPD) is defined as the aggregate demand of all products, that is, the ‘sum’ over all the output nodes of the DSN. Like the GPS, the GPD cannot be represented by a single number, except in common units of requirements such as a unit of “drive” or hedonic tension, but such a unit is still largely undefined. The gross money supply (GMS) is the sum of all funds available for a given product (PMSs) and these, in turn, is arrived at by the multiplication of ADP with the unit funds available for that product. Like the GMD, the GMS is clearly a single number. With the numbers used above, the GMS can be calculated:

\[
\text{GMS} = \text{6,789 units of Product K transacted at $5.15/unit} \\
+ \text{3,960 units of Product L transacted at $3.33/unit} \\
+ \text{3,394 units of Product M transacted at $2.90/unit} \\
= \text{$57,990, within round-off error of the $58,000 per year deemed available.}
\]

GMS is arrived at as the sum of all products between goods quantities and their prices. It is equal to \( PT \) in Fisher’s form of the equation of exchange

\[
MV = PT
\]

Eq. 3.6

where \( M \) denotes “money supply”, \( V \) is the velocity of circulation of money, \( P \) is the average price of all transactions concluded in the economy and \( T \) is the total number of transactions (Ison 2000: 207; Jackson 1986: 45; Vaggi and Groenewegen 2003: 260). The concept of the DSN, introduced here, suggests however that velocity and prices do not fluctuate in some arbitrary fashion, but that velocity and price changes are likely to be closely related to individual requirement categories. In other words, care must be exercised in utilizing central descriptors of velocity and prices lest they obscure more than they reveal. For example, it is
conceivable, based on the foregoing, that in a system with an increasing population and fixed monetary base, velocity increases may predominantly be driven by needs rather than other requirements.

**Network representations**

There are six distinct ways in which the same DSN network can be represented - analogous to that shown in Figure 2.3. As for the SSN, these representations do not affect the network structure or its function, but make explicit different aspects of the system. For reasons stated previously (i.e. for the SSN) and for reasons of symmetry and comparison, the fractional incorporation of requirements into products is taken as the basic representation of the network (Figure 3.3). The network representations are:

(i) fractional incorporation of demands (i.e. the network weights as estimated initially or subsequently calculated with the training procedure);
(ii) level of demands;
(iii) quantities of goods and services;
(iv) demand expressed per unit goods and services;
(v) money flows; and
(vi) “price” per unit demand.

In Figure 3.3, fractional incorporation is meant to indicate that certain fractions of requirements, i.e. a certain fraction of needs plus a certain fraction of wants plus a certain fraction of aspirations, are incorporated into the formulation of a given product by an enterprise as explained above. Since the total amount of a given product (e.g. Product K) estimated to be in demand (and hence “ordered”, thus demanded) could also be seen as fractional incorporations of the outputs of the different ETUs, I chose to use “fractional incorporation” to denote the weights of connections in the basic representation of the DSN in contrast to “fractional utilization” for the basic SSN representation.

Note that some discrepancies may exist between demands and tokens of demands (money). Nevertheless, if a universal ‘unit of requirement’ can be determined, there ought to exist a fixed ratio between ‘unit of requirement’ and unit token of demand in a stable economic system. Thus an equivalence exists between money and demands and this equivalence is more narrowly maintained than the equivalence between demands on one hand and goods and services on the other (in an economic system at stable equilibrium, however, they are all in narrow equivalence). Therefore, the representation of the level of demands may also represent, and be represented by, the flow of money. One may though, for theoretical or practical reasons, prefer to use one or the other.

**Discussion and conclusions**

In this chapter, I attempted to generate a connectionist model of the demand-side economy. To accomplish this, the concept of ‘requirements’ had to be formulated. This concept firmly anchors the DSN in a humanistic bedrock. The position of requirements as input nodes, and their derivation from individuals, should make it immediately clear that humans are pivotal in economic systems since their requirements (co-)determine economic demand. This is rather consistent with what one might expect. The DSN makes explicit and, I hope, more tractable the social nature of economics. It does so in a way that specifies the relationship of physiological, psychological, and social variables to other economic variables in a consistent and transparent manner. The ‘Individuals’ “layer” and a corresponding ‘Environment’ layer play pivotal roles in the whole system; they will be formally introduced, and their relationships to the networks will be specified, in a later chapter (Chapter 11).

This model uses the SSN as template, thus a close general correspondence and symmetry between the DSN and the SSN emerges. The demand-side network also functionally mirrors the supply-side network. Although the number of nodes in a given layer may not necessarily be equal, the layers perform qualitatively similar functions. My first conclusion, therefore, is that the modeling of the demand-side economy with a
connectionist model is at least plausible, but also meaningful by virtue of having links between human attributes and economic demands.

Because goods and services are in counterflow to demands in the DSN, a problem may arise in the ultimate distribution of a good or service to a given requirement. This should not be viewed as insurmountable since hidden nodes by their very nature transform their inputs (e.g. land, labor, and capital) into something different (e.g. bushels of wheat). Thus a raincoat could be seen as being transformed into a need (e.g. protection) and a want (e.g. status, appeal). However, it does raise an intriguing question – whether one should or could stick with a given unit of product and conceive one raincoat to consist of a certain amount of land, a certain amount of labor, and a certain amount of capital, just like fractions of the same raincoat meet the requirement of needs and wants. Potentially then, both resources and requirements could be represented in terms of raincoats (and all the other products on the market). Such an attempt at consistent representation may make an analysis of demand/supply ratio changes across a network interesting. It is reminiscent or Ricardo’s corn model (e.g. Vaggi and Groenewegen 2003: 144). For my present purposes, however, I wish to point out that the DSN inputs (i.e. needs, wants, and aspirations) are less tangible than those of the SSN (i.e. land, labor, capital). Consequently, when one considers that the “demands” of the DSN flow in the opposite direction to goods and in the same direction as funds, it becomes clear that money can be viewed as tangible manifestations of demands. This is my second conclusion.

**Figure 3.3**

The figure shows a basic representation of a demand-side economic network in terms of connection weights as fractional incorporation of requirements and demands. It is also augmented to show annual flows of demands through the nodes. The numbers differ slightly from those in the text due to round-off error. The requirements are in units of drive and other demands are in units of product.
The Core System
The Core System

Summary

The reconciliation of demand and supply lies at the heart of the economic process. The core of the connectionist theory of economics is therefore created by integrating the demand-side and supply-side networks by interfacing them along their output nodes. This core system is then used to define concepts of interest and examine them qualitatively. Markets are defined as the interfaces between layers: here products are transferred from one set of economic entities to another while money is exchanged in the opposite direction. Prices are defined as the ratio of the flow of money to the flow of goods along a specific connection at such an interface. Inflation and deflation are viewed as changes in price due either to changes in quantities of goods or to changes in the levels of funds available for those goods. Semi-inelasticities in the system result from fixed requirements (most often needs) or fixed supplies (most often limited resources). Full inelasticities occur when a given requirement and its corresponding resource are both fixed – a potentially dangerous combination. Finally, these concepts are discussed with brief reference to the historical context.
**Introduction**

The fundamental aspect of an economy is an inter-agent exchange process. However, for robust exchanges to occur, the parties must be agreeable to the process and content with its outcomes. It is often stated that a double coincidence of wants (i.e. demands in the present context) is required for barter and that this difficulty is one of the drawbacks of barter overcome by the use of money (e.g. Jackson 1986: 1). Nevertheless, a double coincidence of wants also presupposes a double presence of goods. Thus the exchange process requires a matching of goods and wants and this is still true in a monetary economy.

Having generated the concepts of demand- and supply-side networks, they can now be combined. Enterprises in the DSN estimate or make projections of the types and volumes of products that consumers require and these products form the outputs of the DSN. The outputs from the SSN are also types and volumes of products, but these are products that manufacturers can supply. Consequently, an interface between demand and supply can be constructed by juxtaposing the networks in such a way that their output layers face each other. Thus demands and supplies can be matched at the interface between the networks. By doing so, the functional core of the CTE is established. The point I want to make here and pursue in this chapter is that, when demands and supplies are brought together, a market is made and that market has attributes that are determined by demand and supply characteristics.

**Integration of demand- and supply-side networks**

Matching the two networks formally characterized in the previous two chapters as shown in Figure 4.1 creates the core system of the CTE. For an effective structural and functional matching, the products of the SSN ought to correspond in type and amount with the products of the DSN. Assuming this to be the case, one finds that goods flow from the ‘Resources’ layer (SSN input) to the ‘Requirements’ layer (DSN input) while demands flow from the ‘Requirements’ layer to the ‘Resources’ layer. This suggests that the environment supplies resources and individuals supply demands; a view however, that will be modified and refined in Chapter 11. Monies, as tokens of demands, flow in the same direction as demands and dynamically mirror demand flows. In an ideal and efficient system all these flows would be balanced; thus on both large (aggregate product) and small (individual product) scales, product supply would equal product demand.

Given the ultimate necessity of matching supply and demand to alleviate systemic stress, a core connectionist model is created where the number of output nodes of the supply-side determines the number of output nodes on the demand-side. One could claim that the demand-side is more important, and that the demand for product (i.e. the number of product demand nodes) should be used to constrain the number of product supply nodes. The reality is likely more complicated due to feedforward and feedback relationships between the networks and the point of this model is precisely to be able to address these and other complexities in a systematic, integrated, and coherent way. Nevertheless, the matching suggested above provides a starting point: it seems easier to interpret the supply-side network in terms of economic concepts and more information may be available to model its outputs satisfactorily.

To complete the integration, note that the networks, when matched, do not have to remain as separate entities. Thus they could be combined, at least conceptually, by joining their respective output nodes with weighted connections to form a single (bidirectional) network. I have elected however, to treat them as separate networks throughout this book - both for the sake of simplicity and because I am more familiar with multilayer perceptrons than with other architectures.

**Qualitative applications**

Having established the core of the connectionist model, I want to draw on one of the advantages of a model-based theory, namely, that of stating definitions with greater precision. More specifically, I want to address a number of key concepts such as market, price, equilibrium, and elasticity along with qualitative applications of their definitions.
Markets: Although in preceding chapters ‘market’ was defined as existing at the output of the DSN and SSN, thus at the interface between the demand- and supply-side networks, conjoining the juxtaposed networks in Figure 4.1 suggests that the definition of market can be expanded to include any interface where transactions occur, i.e. where the exchange of an agreed upon level of services or goods for an agreed upon amount of money takes place.

When the definition is expanded to include interfaces between any two layers of any network as shown in Figure 4.2, different aggregate markets can be delineated. Between resources and enterprises is found the market for resources (primary supply market, resource market, commodities market), between enterprises and products the market for enterprise output (secondary supply market, manufactured goods market), and between products supplied and products demanded the wholesale market (tertiary supply market, common to both supply and demand systems). Likewise, between requirements and enterprises is found the market for requirements (primary demand market, consumer market), between enterprises and products the market for enterprise demands (secondary demand market, retailers’ market), and between products demanded and products supplied again the wholesale (tertiary demand) market common to both systems.

When the definition is expanded even further to include any interface between any two connected nodes of any network, different individual product markets can be delineated, for example, a wholesale or tertiary market for Product K.
Prices: Figure 4.1 shows the flow of demands from the requirements layer to the resources layer and the counterflow of goods and services. Therefore, along every connection of the core system, a ratio of demands to supplies can be established. For a system in balance, where supplies equal demands, this ratio is approximately one (approximately because dynamic and adaptive systems will experience fluctuations).

![Diagram of demand and supply flows](Image)

*Figure 4.2*

The aggregate markets in a connectionist economic model occur between layers. The consumer market, for example, is a primary demand market and occurs between the ‘Requirements’ and ‘Enterprises’ layers; the resource market is the corresponding primary supply market and occurs between ‘Resources’ and ‘Enterprises’.

Because money flows occur in the same direction as demand flows, a ratio of money volume to product volume can also be determined along every such connection. This ratio however, will not necessarily approximate one, but will depend, *ceteris paribus*, on the number of tokens in the system. For example, if nothing changes except for an increase or decrease in the number of tokens, they will become redistributed, after accounting for transient effects, across all connections in the same proportions as before. It is this ratio, of money to goods along a specific connection at a given moment, which is defined as price. Since this ratio may fluctuate considerably, taking an average over a suitable time period may be more useful for some applications than instantaneous values. Thus price is demand expressed in terms of the monetary unit relative to supply.

As a reminder, recall that, for any given node, money flows on the demand downstream side are expenditures and on the demand upstream side are incomes. Price is equal to expenditures (e.g. the price of a given resource contributes to the expenditures to a supply side manufacturer) and equal to incomes (e.g. the price of a given product contributes to the incomes of a supply side manufacturer) given a specific connection. Thus “price” is the more generic and neutral term, while expenditures and incomes indicate how price affects the balance sheet. Furthermore, price neither refers to bid nor offer, but to what happens when an exchange is effected.
Since price is the ratio of tokens to supplies pertaining to a given connection, and by implication in a given market, it follows that prices can be classified along like lines. Tertiary prices obtain in tertiary markets and perhaps are the easiest to illustrate. Thus, assuming for illustrative use and with respective reference to Figure 2.2(d) and Figure 3.2 that Product K\textsubscript{supply} is 6,789 units per year and that Product K\textsubscript{demand} is equivalent to $34,980 per year then Price K = Product K\textsubscript{demand}/Product K\textsubscript{supply} = $34,980/6,789 units = $5.15 per unit. Primary and secondary prices are determined as defined and exactly as for tertiary prices.

If the supplier makes an offer higher than the bid of the buyer, a transaction does not occur and the market is at an impasse. The stalemate will only be resolved if adjustments have been made in the levels of demands and/or the amounts of goods and services such that transactions do occur. An inherent tension is therefore present that plays out along two dimensions: (i) the relative levels of supply and demand - if the level of funds stays constant and the supply drops, the price will increase; similar qualitative outcomes can be divined for other permutations and all are consistent with common consensus; and (ii) the elasticities of supply and demand – how do supplies and demands change if they cannot be satisfied at their current levels?

The foregoing dynamic also hints at how relative prices are established. Since price is defined as the ratio of funds flows to goods flows along a given connection, prices may vary within a connection over time and between connections at a given time. Given that some requirements are “hard” and inelastic (e.g. needs) and that some resources are limited and inelastic (e.g. land), relative prices must reflect this reality. Relative prices are further influenced by enterprises, specifically their production functions, which determine how requirements and resources are transmuted into products. In the final analysis, prices must reflect the ratio of requirements to resources and this will differ over time as populations and environments change; this will also differ by region due to extant differential populations and environments. More on this in Chapter 6.

Remunerations. Economic activities produce a circulating flow of funds in the system (Chapter 11). When these funds accrue to owners of specific supply-side economic entities, they constitute the retained earnings of such owners. Four of the six types of remuneration can be associated with nodes that are primarily in the supply-side network. The other two are mentioned here for the sake of completeness and are associated with the introduction of new nodes or the modification of existing nodes and the deletion of existing nodes. These funds are not meant to include profits, but do include a level of compensation sufficient to induce the economic agent to engage in and/or remain engaged in the given economic activity. The funds to accrue as earnings are labeled as follows.

\textit{Rents}. Rents are funds, net of expenditures, which accrue to owners of “land”.

\textit{Wages}. Wages are funds, net of expenditures, which accrue to laborors.

\textit{Interest}. Funds net of expenditures, which accrue to owners of capital, are denoted ‘interest’.

\textit{Earnings}. Earnings are funds, net of expenditures, which accrue to proprietors of enterprises.

\textit{Rewards}. Rewards are funds, net of expenditures, which accrue to entrepreneurs for creating or modifying enterprises.

\textit{Recompenses}. These are the fees, net of expenditures, paid to entrepreneurs that liquidate enterprises.

Equilibria. Due to the output layer-output layer interface between the networks, some equilibrium flow has to be established if money flows in the two networks are not initially the same across their output layers. In other words, not all markets have to be active simultaneously, but if any given market is prevented from functioning freely for a prolonged period of time, activities in the entire system will progressively become constrained and stressed. Put differently, there is some sense in which all markets are in ‘harmony’ when the system functions as an entity. For example, transactions concluded in a primary market that are not ultimately compatible with transactions concluded in all markets will cause a disruption of systemic activity. However, because an aggregate market consists of many connections, i.e. all those connections between two adjacent layers of nodes, a lack of activity along a given connection may not be systemically catastrophic except in the very unusual case where an aggregate market consists of a single, or very few, connections.
Consider now, as a condition of reference, a core system as shown in Figure 4.1 that is in equilibrium, i.e. demands and supplies are matched in type and volume and stable over time. Inflation is defined here with regard to the CTE, but is consistent with the general notion of "price inflation" as opposed to inflation of the money supply. Any perturbation to this system that causes prices to increase produces inflation and a perturbation that causes prices to decrease causes deflation. Changes in the supply side always produce push-inflation or push-deflation and changes in the demand side pull-inflation or pull-deflation. Note that such changes can have an origin either in the absolute/relative quantities of goods or the absolute/relative quantities of money; hence I characterize four types of inflation (and four types of deflation) as described below. Because inflation reflects changes in prices, inflation is also layer-dependent like prices and markets, hence one can distinguish between primary, secondary, and tertiary inflation/deflation along the same lines as discussed above for markets and prices. Inflation can also occur along a given connection or subset of connections.

In the following, note that three rather independent factors are operational – the first two relate to changes in supply and demand per se, the third relates to the number of tokens in the system and their differential allocation to requirements.

Supply inflation. When, in a reference system, a perturbation occurs such that the aggregate supply of the number of units of a given product drops but the number of tokens allocated in aggregate to that product remains stable, supply inflation will result. A supply shortfall may occur due to exhaustion of a resource, a bottleneck in or departure of an enterprise from the system, or for some other reason. If the supply shortfall is of short duration, the problem will become manifest mostly as one of empty shelves and warehouses and some hoarding may ensue; if there is a supply shortfall of sufficient duration, competition for product may force up the price of product since the level of funds (i.e. the number of tokens) available for that product has not changed. In other words, the price for a product, e.g. Product K, increases because the same number of tokens is now spent on fewer units of product. Because the product costs have not increased, (supernormal) profit arises. Profit, in turn, may induce new/other enterprises to supply additional product and/or can be invested to expand the supply of product. Thus profit that arises in this fashion constitutes an adaptive response to supply shortfalls.

Cost inflation. When a reference system suffers a perturbation such that the aggregate supply of the number of units of a given product remains stable but the aggregate number of tokens required to maintain the supply of product at existing levels increases, cost inflation will occur. Since there is no change in the initial level of funds available for this product, the price has, technically speaking, not changed. However, the product, e.g. Product K, is not sold at the old price or available at the old price, therefore the net effect is that of a reduction in supply. In this case the supply drops in a relative rather than absolute sense. This relative drop in supply will lead to an increase in price as people start to allocate additional funds to Product K to ensure that requirements satisfied by Product K can be met, especially so if they relate to needs. Opportunities for profit generally do not arise. However, in a variant of cost inflation, profit could occur where a monopolist tries to extract it from the market by restricting supply at the formerly prevailing price.

Demand inflation. Consider a reference core system suffering a perturbation such that the aggregate number of units of Product K demanded increases while the aggregate number of tokens available for acquisition of that product remains at prior levels, demand inflation may occur. Increases in the aggregate number of units of product demanded are most easily seen in the context of a population expansion, but could also occur in a stable population due to stressors (e.g. an epidemic creating increased demand for a given medication) or in a healthy, unstressed population where wants and aspirations have changed (e.g. a shift in demand occurs due to advertisement or education). Some of the effects are similar to those of supply inflation, but the causes are different due to their origins in the demand side of the system.

If the money supply does not increase proportionately, consumers will reallocate funds away from other products, mostly from aspirations, and to a lesser extent, wants. Hence the prices of some “cultural”
and “luxury” goods will decline. If the money supply does increase, the prices of cultural and luxury goods may not change, but more tokens will be allocated to the product with increased demand, thus the price of the latter will increase.

**Income inflation.** When a reference system suffers a perturbation such that the aggregate demand of the number of units of a given product remains stable but the aggregate number of tokens allocated to the supply of product at existing levels increases, income inflation will occur.

When extra funds are injected into an economic system without an accompanying increase in absolute demand levels, these surplus funds will be allocated to products that serve wants and aspirations since needs are assumed to be mostly met and consuming more essentials provide little benefit to consumers. However, consuming more wants or aspirations may satisfy sexual competition or social desires and therefore, in the absence of sustained increases in supplies of luxury and cultural goods, their prices will rise. In societies where wants and aspirations, like needs, show little interpersonal variation, across-the-board increases in prices due to a simple redistribution of tokens, allocated in the same proportions as before to needs, wants, and aspirations, will occur. Otherwise, the injection of funds in the absence of productivity increases will lead to an uneven distribution of price increases.

In both cases, initial increases in expenditures will be perceived at the local level as profits, thus spurring economic growth and subsequent increases in supply. This is further discussed in Chapters 13 and 15.

**Elasticities.** Elasticities relate to limitations. Thus, elasticities in demands occur when they are free to vary within broad boundaries and inelasticities occur when demands are constrained by narrow boundaries. Needs-related products are likely to be demand-inelastic because needs are related to physiological variables that are maintained within strict limits to support life. Therefore, if a product, say Product K, primarily satisfies needs, the demand for Product K is inelastic in proportion to the extent to which Product K satisfies needs; demand is more elastic dependent on the extent to which Product K satisfies wants, and most elastic for the satisfaction of aspirations. Consequently, if Product K satisfies mostly needs and Product L satisfies some needs, but less than Product K, Product L cannot readily be substituted for Product K. Even if Product L is now, after the cost increase of Product K, available at the same price as Product K, the ratio of funds to number of need units satisfied is higher for Product L. For example, at the old price, a dollar spent on Product K satisfied 2.5 units of needs (and none of the other requirements). After the cost increase, a dollar spent on Product K satisfies 2 units of needs but the same dollar spent on Product L satisfies only 1 unit of needs (and one unit of wants). Given the precedence of needs over wants, Product K is still cost-effective, substitution will not be observed, and demand will be inelastic. If a product similar to Product K is available at a price lower than that of Product K, a substitution effect will occur.

Now, if for lack of Product K or a substitute product, some demands, especially needs, go unmet, the demand for other (but dissimilar) products will increase and do so proportional to the extent that they conserve funds while meeting those requirements now unsatisfied due to the absence of Product K. That is, other products such as Product L will be bought in an attempt to make up for the shortfalls in supplies of Product K. This is not a substitution effect. This is an augmentation effect and occurs when only partial substitution is possible by any given other product. Therefore, if a similar product is not available, the unmet requirements must be satisfied by consuming a range of other products, each of which may satisfy only a fraction of the requirements met by the original. Consequently, more in total will be consumed since those parts of the products that do not meet the requirements satisfied by the original (i.e. the product in short supply), must also be consumed. For example, if one wishes to consume plain yoghurt, but only yoghurt with fruit is available, the fruit will also be consumed even if at the time there is no requirement for fruit, only for plain yoghurt. A substitution effect only occurs if another brand of plain yoghurt is available.

Consequently, a simple case is the following: if Product K primarily satisfies needs and a substitute product meeting the same needs is not available, a higher price will be accommodated; if neither Product K
nor a substitute is available (even at high prices), an augmentation effect will occur. In reality, some combination of substitution, augmentation, and price accommodation will ensue to optimize the satisfaction of needs at the lowest expenditure of tokens. Thus, Engel’s law - the poorer a family the larger the share of its income spent on food (e.g. Clark 2007: 52) - reflects inelasticities because needs must be accommodated first.

Likewise, supplies are elastic if they can vary within wide boundaries and inelastic if they are narrowly constrained. For example, water supplies in an arid land-locked country may be finite and renewal of the resource through rainfall and runoff strictly limited. Therefore, irrespective of price, a limited quantity of the resource is available.

An interesting consequence of this analysis of elasticities is the implication that an inelasticity, limited to either the supply-side or the demand-side is systemically a semi-inelasticity. This is because either supplies could eventually be ramped up to meet demands (due to increased manufacturing, extraction, etc.) or demands may fall off (e.g. due to consumption changes) to equilibrate with supplies. A full inelasticity on the other hand occurs when there is inelasticity of a given requirement coupled with inelasticity of the corresponding supply necessary to meet this inelastic requirement. Note that full inelasticities are more probable for needs, related resources (i.e. resources that are required for the satisfaction of needs and that are, purely by coincidence, also limited), and their corresponding products, but could conceivably also happen for other requirements such as those related to cultural goods. Full inelasticities harbor the potential for catastrophe when demands outstrip supplies because either resource collapse or population declines or both become likely. Narrowly constrained resources that serve to satisfy needs are rate limiting to population growth.

**Discussion and conclusions**

The core of the connectionist economic model is created by interfacing the demand-side and supply-side networks at their output layers. The model then makes explicit the flow of goods and services from resources to requirements (supply source to supply sink) and the counterflow of demands from requirements to resources (money source to money sink). This system is in equilibrium if demands and supplies are matched and stable flows of goods and funds occur. Although derived differently, the reader may not find the core system all too foreign on account of it being reminiscent of Quesnay’s *tableau économique* wherein the flow of expenditures between different economic agents is traced (Vaggi and Groenewegen 2003: 64).

An analysis of core system functionality reveals the dynamics that arise due to changes in requirements and/or resources and, if these are not system-wide, the transient adjustments along local interfaces that can occur. Decreases in supplies of a given good will lead to increases in price according to the definition of price, provide an opportunity for profit, and entice producers to augment the quantities produced of that good. Hence transient changes or fluctuations in price will reflect the adaptive aspects of the system. In contrast, permanent or unidirectional changes in price reflect inelastic components of the system. Inelasticities may occur in either the SSN or the DSN and may be surmountable, but when matched inelasticities occur, there is a potential for systemic collapse.

Based on the core system, a number of definitions can be made. Although that of price emerges logically from the present connectionist context, it has been formulated similarly already in the eighteenth century (Groenewegen 2003: 45). However, the ratio was often reversed. For example, Smith defined market price as a relationship of supply to demand (Vaggi and Groenewegen 2003: 110). Mill also defined price as a relationship between quantities supplied and those demanded, but as it occurs at equilibrium (Vaggi and Groenewegen 2003: 194). Furthermore, the relation here of price to the market wherein a transaction occurs, although it reflects in the present context the proximity to the resource, is compatible with the spirit of Quesnay’s differentiation between ‘first hand prices’ that reflect the proximity to the production process or
creation step and subsequent prices that merely reflect exchanges rather than new production (Vaggi and Groenewegen 2003: 61).

The definitions of remunerations have some interesting consequences that merit mention. They indicate that certain portions of the money stream are diverted to the owners of economic entities. These owners, to the extent that they are human beings (either proximally or distally), will have requirements. By implication then, they will also have wants and aspirations with wants predominating in the reproductive years and aspirations predominating perhaps in later years (see also Chapter 5). Especially in the case where wants predominate, competitive forces will operate and these will provide pressure on owners to maximize their remuneration. Thus wants-derived competitive forces will seek the maximization of rents by landowners, wages by laborers, interest by capitalists, and so on. Given that requirements are already related to human requisites, the definitions of remuneration in effect reveal the entire core system to be animated.
References

(All)


