Principles of Forecasting in Complex Economic Systems

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3rd November 2016

Abstract

In this note we develop principles for forecasting economies viewed as evolving networks formed by individuals acting on the basis of their psychology and social position following Markey-Towler (2016a). We review the basic formal apparatus required to understand economies as such before using results derived thereon to understand the determinants of the likelihoods that certain development paths will or will not be taken. We develop a view by which we can allow for radical uncertainty - “black swan” events - and maintain an ability to forecast. We make use of the qualitative view of the likelihood of certain development paths thus obtained to inform our quantitative estimations for the dynamics of meso-populations within the econometric framework developed by Foster and Wild (1999) for modelling in the presence of evolutionary change. We obtain thus a procedure for forecasting complex economic systems.

1 The purpose of this note

The purpose of this note is to extract a set of principles for forecasting complex economic systems from a recent view thereon developed in Markey-Towler (2016a). An integrated, holistic and systematic view is developed in that work of complex economic systems as evolving networks formed by individuals acting on the basis of their psychology and social position. Contained within it therefore is a set of principles by which the evolution of economic systems may be forecast.

We will begin by reviewing the basic formal apparatus required to obtain a view of complex economic systems as evolving networks formed by individuals acting on the basis of their psychology and social position. We will then make use of (primarily) five results derived in

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Markey-Towler (2016a) (the Mauss-Commons, Smith-Hayek, Chamberlin-Robinson, Lancaster-Ironmonger and Chinese Whispers theorems) in order to obtain a view of the microeconomic determinants of the likelihood that certain development paths will or will not be taken. We will then consider the means by which forecasting may proceed in the presence of radical uncertainty by considering how a view of the outcomes following localised “black swan” events may be obtained by means of the Chinese Whispers theorem. We obtain from these considerations a qualitative view of the likelihood of particular development paths being realised.

We then use the view thus obtained to inform our process for specification of econometric models of the quantitative dynamics of meso-populations (Dopfer et al., 2004) within the macroeconomy making use of the framework developed by Foster and Wild (1999) for modelling in the presence of evolutionary change\(^1\). We conclude by condensing the view developed over the course of this essay into a procedure for forecasting in complex economic systems.

2 The architecture of socioeconomic complexity

In Markey-Towler (2016a) a view is developed of the economy as an evolving network formed by individuals acting on the basis of their psychology and social position. If the economy is a network structure then it may be represented as a mathematical graph

\[
E_s = \{N \ g(N)\}
\]

\(^{1}\)This framework has been profitably used recently by Foster (2014, 2016) to obtain novel insights into the development of the British and Australian economies respectively.

\[
I_s = \{N \ g_v(N)\}
\]

\]
\begin{equation}
\{E_s^t \cup I_s^t\}^T_{t=0} \tag{2.3}
\end{equation}

If we expanded this mathematical object out visually, we would observe it as a progression of network structures evolving through time \( t \). The path would not be singular (as discussed in Markey-Towler (2016a, s7.1) and Markey-Towler (2014)), for there are a range of possible development paths through socioeconomic history which the economic system may take.

The function of economic science is to elucidate the process \( f_{\Delta t} \) by which one state of the world \( V_t \) containing the socioeconomic systems \( E_s^t \cup I_s^t \) is mapped into the next, \( E_s^{t+\Delta t} \cup I_s^{t+\Delta t} \).

\begin{equation}
f_{\Delta t} : \{V_t \supset E_s^t \cup I_s^t\} \rightarrow \{E_s^{t+\Delta t} \cup I_s^{t+\Delta t}\} \tag{2.4}
\end{equation}

The objective of forecasting is to make use of the elucidation by economic science of \( f_{\Delta t} \) in order to come to a view of which development paths are more or less likely to be taken in the course of socioeconomic history.

If the economy is formed by individuals acting on the basis of their psychology and social position then we understand the mapping \( f_{\Delta t} \) by characterising how the individual’s psychology effects their reaction to their social position. The social position of the individual \( i = c_i \lor \{\omega_i \in n_j\} \) (as consumer \( c_i \) or worker \( \omega_i \in n_j \)) consists of the information \( v_{N_i(g)} \subset V_t \) contained within their neighbourhood \( N_i(g) \) (which can be left defined no further without loss) in the world system \( V_t \).

In order for the individual to be able to react to this information, it must be mapped by perception \( \rho_i(\{v_{N_i(g)}\}) \) into objects in the mind so that it may be operated upon. Perception maps information \( v_{N_i(g)} \) in the individual’s environment into percepts of the objects of reality \( h \in H_i' \) and any apparent relations \( \{R_{hh'}\} \) between them.

\begin{equation}
\rho_i(\{v_{N_i(g)}\}) = \{H_i' \lor \{R_{hh'}\}\} \tag{2.5}
\end{equation}

The mind operates on this information by making use of a semi-permanent “map” of reality \( g_H(H_i) \) connecting the objects of reality \( H_i \supset H_i' \) together into a coherent understanding, a “worldview” or “weltanschaunng” expressed as a network of personal knowledge (see Markey-Towler (2016a, s4.2) for more interpretations of this object). From this “map” of reality emerges a “model” of the situation \( v_{N_i(g)} \) in which the individual finds themselves.

\begin{equation}
g_H(H_i') = g_H(\rho_i(\{v_{N_i(g)}\} \setminus \{R_{hh'}\})) \subset g_H(H_i) \tag{2.6}
\end{equation}

which is a subgraph of the overall network of personal knowledge as applies to a particular set of objects of reality in a particular environment. If an individual is to select an action \( a_i \subset A_i' \subset \{H_i' \lor g_H(H_i')\} \) in the set of possible actions \( A_i' \) in their situation, thus behave and form economic
structure, they form an assessment (conscious or otherwise) of the expected outcomes of those particular acts which are represented as chains of implications \( g_{a_i} \) in their understanding of the situation

\[
\begin{align*}
g_{a_i} &= \{ R_{hh'} \in g_H (H'_i) : hh' \in \{ h_k h_{k+1} \}^K_{k=0} \subset g_H (H'_i) \land h_0 \in a_i \} \\
\end{align*}
\]

(2.7)

These implications may be understood either as the iterations of behavioural rules or as the construction of ratio decidendi (Markey-Towler, 2016a, appendix B).

The conscious experience of these thought structures endows an aesthetics which allows us to postulate the existence of a preference structure \( \succeq \circ 2^{g_H (H_i)} \) by means of which we may establish that the outcomes \( g_{a_i} \) are more preferable to those \( g_{a_i'} \), \( g_{a_i} \succeq g_{a_i'} \) or vice versa, or both (in which case \( g_{a_i} \sim g_{a_i'} \)). If actions selected are constrained to be those which are feasible - contained within a set \( B \subset 2^{A_i} \) - then we may postulate further a theory of decision that the individual selects that course of action with the strictly most preferable construed outcomes

\[
a_i^* = \{ a_i \in B : g_{a_i} \succ g_{a_i'} \forall a_i' \in B \}
\]

(2.8)

We “close” our economic science and thus \( f_{\Delta t} \) by recognising that, collected together, these decisions cause the formation of economic structures \( g (N) \). A connection, an economic interaction, \( n_i n_j \in g (N) \) comes to exist where \( n_i \) or an element within it makes a decision to interact with another element

\[
g (N) = \{ [x_{n_i n_j} \ m_{n_i n_j}] \neq \emptyset \subset a_i^* : \forall a_i^* \} \lor \{ a_{k=\omega_i}^{*} \ \omega_i \in n_i \}
\]

(2.9)

The means by which market transactions (whereby \( x_{n_i n_j} \) and \( m_{n_i n_j} \) are deliberately connected, mediated, by a price \( p_{n_i n_j} \) in a quid pro quo exchange) within this structure can be recovered in order to form up the specific system of market interactions \( M_s \) from its physical primitives in \( E_s \) requires us only to recognise the connective and mutual nature of the act of market exchange and so

\[
g_{M_s} (N) = \{ [m_{n_i n_j} = p_{n_i n_j} x_{n_i n_j}] : [x_{n_i n_j} \ m_{n_i n_j}] \neq \emptyset \land p_{n_i n_j} : [m_{n_i n_j} = p_{n_i n_j} x_{n_i n_j}] \subset a_i^* : \forall a_i^* \} \lor \{ a_{k=\omega_i}^* \ \omega_i \in n_i \}
\]

This apparatus now in hand elaborating \( f_{\Delta t} \) we may proceed to investigate how it appraises us of which development paths are more or less likely to arise in the course of socioeconomic history.
3 The possibility of forecasting

Before we do investigate how our apparatus appraises us which development paths are more or less likely to arise we ought establish that we can in fact do this. It is a point of controversy in economic theory whether economic systems are in fact possible to forecast. The fundamental problem with forecasting development paths arises because of the nature of the economy as a system of human beings.

The philosophy of mind we hold to has major implications for our ontology of the economy as an evolving system (Markey-Towler, forthcoming). If we hold to a philosophy of mind in which we accept the human consciousness is real, we accept there are two means by which the mental maps $g_H(H_i)$ of individuals may evolve through the incorporation of new connections in their network of knowledge:

1. Suggestion by perception of apparent relations: A relation $R_{hh'}$ is contained within the set $\{R_{hh'}\} \subset \rho_i(v_{N_i(g)})$ of apparent relations within perception of a particular environment $v_{N_i(g)}$.

2. Genuinely creative thought: A bisociation, a thought $R_{hh'}$ is brought into existence for no other reason than that the phenomenological “I” has, in an act which contravenes the principle of sufficient reason (Koestler, 1964; Bergson, 1946; Shackle, 1972).

Radical uncertainty over the course of socioeconomic history exists when there are states of the world which exist in no way prior to their realisation, which is the case if we accept the possibility of 2. They cannot therefore take their place in the support of a well-defined probability distribution for the objective data do not exist to establish their existence let alone their frequency or likelihood (Shackle, 1969, 1972; Taleb, 2007). Our forecasts must therefore, as a matter of logic, if we accept the possibility of creativity in human affairs, be subject to the caveat “in the absence of ‘black swan’ events”.

Further to these problems of basic logic, Hayek (1989) quite devastatingly demonstrated the impossibility of having sufficient data to forecast development paths with any reasonable degree of certainty, and our apparatus here serves only to augment his case. To accurately forecast the future using $f_\Delta$ even up to “the absence of ‘black swan’ events” we would require all current information environments $v_{N_i(g)}$, the exact form of all perception mappings $\rho_i(\cdot)$ all mental maps $g_H(H_i)$, and all aesthetical systems $\preceq_2 g_{H(H_i)}$. This is patently impossible to know, and there is no manner of reducing this problem, for the apparatus is a picture of reality, just as it is (Wittgenstein, 1914-1916, 1921, 1953).

Not only logically, but practically, we cannot forecast economic systems with any reasonable degree of precision and those forecasts must always be subject to the “black swan” caveat. Does this condemn us, as Samuels (1993) guardedly argues, to nihilism as regards forecasting? No, for
we observe that there are patterns in development paths. There are patterns because socioeconomic history is path dependent (David, 1985; Arthur, 1989; Kay, 2013), a rather de rigeur point to make here, for we can see in equation 2.4 that the present and the past contain the “seeds” of the future. The future is only realised by its arising out of the past, by individuals responding to past environments, it is necessarily path dependent.

Thus demonstrated is the critical importance of economic history, not only the raw data, but its telling and its interpretation (Carr, 1961). When faced with a path dependent system, it may be chaotic indeed, but if we have some grasp of its history, its path, we may obviously have some intuition as to its future path in the absence of the radical change of minds or the sudden coming into relevance of large swathes of hitherto unknown knowledge states.

4 Microeconomic principles for forecasting

To elaborate our principles for forecasting the likelihoods of development paths in socioeconomic history we will make use of each of the five core results derived in Markey-Towler (2016a): the Mauss-Commons, Smith-Hayek, Chamberlin-Robinson, Lancaster-Ironmonger and Chinese Whispers theorems. The Mauss-Commons and Smith-Hayek theorems serve to appraise us of the factors which govern the formation of economic structures outright, while the Chamberlin-Robinson, Lancaster-Ironmonger and Chinese Whispers theorems appraise us of how they evolve if they evolve in a fairly ordered manner rather than by outright formation of new structures. We will consider each of these in turn, and in each case extract from them qualitative principles concerning the relative likelihood of certain development paths arising. It is important to be mindful that these conditions are not merely intuitive, they are derived from a rigorous logical system presenting a picture of the economy as it exists - an evolving network of individuals acting on the basis of their psychology and social position.

4.1 Smith-Hayek and Mauss-Commons: population density, communication infrastructure, public presence, resources and knowledge

The Mauss-Commons theorem informs us of the necessary and sufficient conditions for non-market exchanges to exist.

**Theorem 1** (Mauss-Commons theorem). Define for convenience \( R = c_i \cup \{ \omega_k \in n_i \} \) and suppose for what follows that \( [x_{ni}m_{ni}] \neq \emptyset \). The following conditions are necessary and sufficient for the existence of a non-market exchange \( [n_i n_j \in g(N) \subset E_s] \notin M_s \)
1. The individual or individuals within organisation \( n_i \) is aware of the individual or organisation \( n_j \)

\[ n_j \in \rho_R \left( v_{N_R(g)} \right) \]  \hspace{1cm} (4.1)

2. The individual or individuals within organisation \( n_i \) is aware of the elements of a non-market exchange to be formed with individual or organisation \( n_j \)

\[ [x_{n_i,n_j} \ m_{n_i,n_j}] \in \rho_R \left( v_{N_R(g)} \right) \]  \hspace{1cm} (4.2)

3. The elements of a non-market exchange to be formed with individual or organisation \( n_j \) is contained within some action within individual or individuals within organisation \( n_i \) ’s budget set

\[ [x_{n_i,n_j} \ m_{n_i,n_j}] \subset a_R \in B_R \]  \hspace{1cm} (4.3)

4. The elements of a non-market exchange to be formed with individual or organisation are contained within some action which individual or organisation \( n_i \) considers to have preferable implications when compared to those of all other feasible actions

\[ [x_{n_i,n_j} \ m_{n_i,n_j}] \subset a_R : g_{a_R} \succ g_{a_R'} \forall a_R \in B_R \]  \hspace{1cm} (4.4)

5. The conditions for market exchange are not met. There is no quid pro quo in the minds of individual or organisation \( n_i \) nor \( n_j \).

The Smith-Hayek theorem, similarly, informs us of the necessary and sufficient conditions for market exchanges to exist.

**Theorem 2** (Smith-Hayek theorem). Define for convenience \( R = c_i \cup \{ \omega_k \in n_i \} \) and \( \Xi = c_j \cup \{ \omega_k' \in n_j \} \) and suppose for what follows that \( [x_{n_i,n_j} \ m_{n_i,n_j}] \neq \emptyset \). The following conditions are necessary and sufficient for the existence of a market exchange \( \{n_i,n_j \in g(N) \subset E_3 \} \in M_s \)

1. The individuals or individuals within organisations \( n_i,n_j \) are aware of each other

\[ n_j \in \rho_R \left( v_{N_R(g)} \right) \land n_i \in \rho_\Xi \left( v_{N_\Xi(g)} \right) \]

2. The individuals or individuals within organisations \( n_i,n_j \) are aware of the elements to a market exchange between them

\[ [x_{n_i,n_j} \ m_{n_i,n_j}] \in \rho_R \left( v_{N_R(g)} \right) \cap \rho_\Xi \left( v_{N_\Xi(g)} \right) \]

3. The elements of a market exchange to be formed between individuals or individuals within organisations \( n_i,n_j \) are contained within some actions within individuals or individuals within
organisations $n_i,n_j$’s budget sets

$$[x_{n_i n_j} m_{n_i n_j}] \subset a \in B$$

$$[x_{n_i n_j} m_{n_i n_j}] \subset a \in B$$

4. The elements of a market exchange to be formed between individuals or individuals within organisations $n_i,n_j$ are contained within some action which individual or organisation $n_i$ considers to have preferable implications when compared to those of all other feasible actions

$$[x_{n_i n_j} m_{n_i n_j}] \subset a : g_{a \in B} \forall a \in B$$

$$[x_{n_i n_j} m_{n_i n_j}] \subset a : g_{a \in B} \forall a \in B$$

5. The ratio of exchange mediating the market exchange, the price $p_{n_i n_j} : m_{n_i n_j} = p_{n_i n_j} x_{n_i n_j}$, is contained within the minds of the individuals or individuals within organisations $n_i,n_j$, and within their perception of potential and realised behaviour

$$p_{n_i n_j} \in g_H (H) \cap g_H (\overline{H}) \quad (4.5)$$

$$p_{n_i n_j} \in \rho (v_{N_k(g)} \subset v_{N_\overline{k}(g)}) \cap \rho (v_{N_\overline{k}(g)} \subset v_{N_\overline{k}(g)}) \quad (4.6)$$

$$p_{n_i n_j} \in \rho (v_{N_k(g)} \subset v_{N_\overline{k}(g)}) \cap \rho (v_{N_\overline{k}(g)} \subset v_{N_\overline{k}(g)}) \quad (4.7)$$

Observe that by virtue of their providing both necessary and sufficient conditions, if a a particular development path $\{E_\tau\}_{\tau=1}^{T} \subset \{E_\tau\}_{\tau=0}$ is to eventuate, then the Mauss-Commons theorem must hold for every non-market connection and the Smith-Hayek theorem must hold with respect to the physical primitives in $E_s$ of every market exchange in that development path. So to ask “what particular development paths are more or less likely to eventuate” is to ask “under what conditions are the Mauss-Commons and the Smith-Hayek theorems likely to be satisfied”. Observe that the Smith-Hayek theorem, which is of most immediate interest to the forecaster of economic systems for its concerning the market exchanges by which the large part of income is made, is all but equivalent to the Mauss-Commons theorem for our purposes but for its important additional requirement of mutuality (what has, traditionally, a little crudely, been called “supply and demand”). We can thus consider the conditions of the Smith-Hayek theorem primarily for our purposes and keep in mind the weaker non-mutuality of the conditions required for non-market exchange by the Mauss-Commons theorem.

Condition 1. informs us that exchanges are predicated on the perception of the one party’s
existence by the other. Perception, it is a long established fact, is particularly contingent on the phenomenon of salience. The import of salience for perception can be well summarised by an oddly informative tautology: human beings only notice what is noticeable (Vernon, 1962; Kahne-man, 2003). In this context, the more noticeable the individuals who would be party to a exchange, the greater their presence in the environment and impact they have on the sensory organs, the more likely that exchange will come to exist. We are thus more likely to observe development paths in which economic exchanges are clustered in geographical areas of high population density where physical and social interaction is the more possible for the physical proximity between individuals. We are only likely to see economic exchanges densely clustered in geographical areas with low population density if communications infrastructure is sufficiently well developed to overcome the difficulties for social interaction posed by physical distance between individuals. We are also more likely to observe economic exchanges clustered around individuals and organisations which constitute a significant presence in the “public sphere” of which Habermas (1962) spoke (roughly, what we call here society). Thus our first principle for forecasting:

- Economic exchanges generally are likely to cluster in areas of high population density and only in those areas of low population density with well developed communications infrastructure, and to cluster around those individuals and organisations which occupy a significant presence in the public sphere.

Population density in a geographical area is quite easily quantified and data are readily available on it, and similarly with the state of communication infrastructure in a particular area. While intuitively quite sensible, “presence in the public sphere” may seem to be a nebulous concept in practice. But it is ever more easy to devise metrics, though crude, of this concept also, especially in the modern age. Simply the number of items in news items available to the public over a given time period would give a fairly good guide of “presence in the public sphere” for any individual, organisation, or group thereof in the public sphere.

Condition 2. indicates that exchanges presuppose that not only the individuals who would be party to an exchange are salient, but the opportunities they present for trade are also salient. Again the contingency of perception on salience is important for our understanding of when this condition is likely to be fulfilled. Opportunities for trade are salient when they are noticeable: occupy a significant presence in the environment and impact on the sensory organs. Were we to define the word in its broad original sense, condition 2. would be well called the “advertising” provision. Exchanges are more likely to exist where the opportunities to engage in them are more effectively advertised. By effectively advertised we mean not that more resources are devoted to the production of information concerning opportunities to trade (though this may stand in as a proxy), but instead that such information is prominent in the physical and public sphere. Thus our second principle for forecasting:
• Economic exchanges generally are likely to cluster around individuals and organisations which broadcast opportunities to exchange prominently in the physical and public sphere.

Again while intuitively quite sensible, “broadcast opportunities to exchange prominently in the physical and public sphere” might seem nebulous concept in practice. But it is ever more easy to devise metrics of this concept (and the marketing profession has dedicated some decades to precisely this). The number of advertisements in with privileged placement in broadcast media of various kinds is one obvious such metric.

Condition 3. brings the core of older traditions in economic theory into the present view of economic systems, which is that economic exchanges must be feasible, they must satisfy budget constraints, in order for individuals to be able to engage in them (Becker, 1962). The individuals to be party to an economic exchange must actually have material to exchange. But the logical conclusion of this condition is perhaps a little unsettling for those who might be uncomfortable with the implications demonstrated by Sraffa (1926) of the existence of increasing returns to scale. The more resources and income an individual or organisation has the more likely we are to observe economic exchange involving them, both from, to use the traditional terminology, the “supply” side and the “demand” side. Thus our third principle for forecasting:

• Economic exchanges generally are more likely to cluster around individuals and organisations the greater their current income and wealth.

This “Matthew effect”\(^2\) is singularly intuitive, and in fact logically prior even to (though it would be facilitated by) the investment dynamics to which Nelson and Winter (1982) and Downie (1958) attribute it, certainly to the elasticity effects to which Markey-Towler (2016b) attributes it.

Condition 4. is the core for economic analysis, demonstrating the centrality of knowledge to economic systems, not merely knowledge of how to engage in economic activity but also why to engage in it - the connective aspects of the act but also its construeable outcomes contained in \(g_a\) (equation 2.7). It is necessary for both parties to have that knowledge of those outcomes of engaging in economic activity which would be preferable to them over all others. Economic development is predicated on the presence and coordination of knowledge of how and why to engage in economic behaviour (Hayek, 1937, 1945, 1988; Loasby, 1999, 2001; Potts, 2001; Dopfer, 2004; Hidalgo, 2016). This is important, for it constrains the set of development paths an economy is likely take in socioeconomic history.

\(^2\)So called for its reminiscence of a fraction of the Gospel of Matthew

“For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken even that which he hath.”

- Matthew 25:29, King James Version.
Any development path \( \{ \hat{E}_t \}_{t=1}^T \subset \{ E_t \}_{t=0}^T \) which, by conditions 4. of the Smith-Hayek or Mauss-Commons theorems requires knowledge of how and why to engage in economic activity which is not present in the mental maps of the relevant individuals cannot arise by virtue of its presence being necessary. Thus we are more likely to observe development paths for which the necessary knowledge already exists. But minds can change, the mental maps \( g_H (H_i) \) can evolve by the addition of new links. The “Made to Stick” theorem informs us of the factors governing the likelihood of an idea being incorporated within the mind of the individual in its entirety, in this case the idea being the act and construed implications \( g_{ai} \) (equation 2.7 thereof).

**Theorem 3** (When are Ideas Made to Stick?). Suppose that individual \( i \)'s perception, \( \rho_i (\cdot) \), has the salience property\(^3\), and the likelihood \( p_i (\cdot) \) of the incorporation of relations \( R_{hh'} \) can be extended to map sets of relations. The likelihood of any proposed idea \( g_{ai} \) being incorporated into the mind of individual \( i \), \( p_i (g_{ai} \subset g_H (H_i)) \) in the particular environment \( v_{N_i(g)} \) is

1. Decreasing in the number of relations \( |g_{ai}| \) the idea contains:

\[
\frac{\partial p_i (g_{ai} \subset g_H (H_i))}{\partial |g_{ai}|} \leq 0
\]  
(4.8)

2. Increasing in the number of relations in the idea already incorporated in individual \( i \)'s mind, \( |R_{hh'} \subset g_{ai} : R_{hh'} \in g_H (H_i)| \):

\[
\frac{\partial p_i (g_{ai} \subset g_H (H_i))}{\partial |R_{hh'} \subset g_{ai} : R_{hh'} \in g_H (H_i)|} \geq 0
\]  
(4.9)

3. Increasing in the relative noticeability \( \sigma (v') - \sigma (v_{N_i(g)}) \) of the information \( v' \in 2^{v_{N_i(g)}} : h = \rho_i (v') \) which supports the percept \( h \) for each of the objects of reality \( h \) related by any individual relation in the idea \( R_{hh'} \subset g_{ai} \)

\[
\frac{\partial p_i (g_{ai} \subset g_H (H_i))}{\partial [\sigma (v') - \sigma (v_{N_i(g)})]} \geq 0 \forall v' \in 2^{v_{N_i(g)}} : h = \rho_i (v') \& R_{hh'} \subset g_{ai}
\]

4. Decreasing in the dissonance of each individual relation in the idea \( R_{hh'} \subset g_{ai} \):

\[
\frac{\partial p_i (g_{ai} \subset g_H (H_i))}{\partial \{|R_{hh''} \subset g_H (H_i) : R_{hh'} \implies h_{hh''} \}} \geq 0 \forall R_{hh'} \subset g_{ai}
\]  
(4.10)

where \( |\{R_{hh''} \subset g_H (H_i) : R_{hh'} \implies h_{hh''} \}| \) is the number of relations in \( g_H (H_i) \) the relation \( R_{hh'} \subset g_{ai} \) is dissonant with.

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\(^3\)If \( \sigma_i \) is some individual-specific mapping from the information environment to \( \mathbb{R} \) reflecting the “noticeability” of that information, then perception of certain information is contingent on its “noticeability” relative to the environment: \( h \in \rho_i (v' \subset v_{N_i(g)}) \iff \sigma (v') - \sigma (v_{N_i(g)}) \geq \sigma_i \).

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5. Decreasing in the centrality within the system of personal constructs, $g_H(H_i)$ of each individual relation $R_{hh'} \in g_{a_i}$, $c(C_{g_H(H_i)}(h), C_{g_H(H_i)}(h'))$ in the idea:

$$\frac{\partial p_i(g_{a_i} \subset g_H(H_i))}{\partial c(C_{g_H(H_i)}(h), C_{g_H(H_i)}(h'))} \geq 0 \forall R_{hh'} \in g_{a_i}$$

(4.11)

where $c(\cdot)$ is some combination of the network centralities $C_{g_H(H_i)}(h)$ and $C_{g_H(H_i)}(h')$.

Condition 1. here tells us that the more simple the requisite knowledge for a development path, the more likely it is to exist. Condition 3. relates again to the “noticeability” of the concepts which the idea connects, telling us that the more the objects the idea relates impress themselves upon the sensory organs, the more likely the knowledge required for a development path will come to exist. Conditions 4. and 5. tell us that the more the knowledge required for a particular development path challenge individual knowledge, or personalities (Kelly, 1963) (as elicited at any point in time) and at their “core”, the less likely that knowledge will come to exist.

Condition 2. of the “Made to Stick” theorem is particularly interesting because it allows us to demonstrate that a particularly “deep” substitutability, skill, or knowledge substitutability is key to constraining the likely development paths an economy can take in the course of socioeconomic history. We say that knowledge substitutability exists when knowledge concerning the outcomes and procedure of a course of action $a_i$, $g_{a_i}$ is roughly equivalent with the outcomes and procedure of another course of action $a_{i}'$

$$g_{a_i} \approx g_{a_{i}'}$$

(4.12)

Observe now that development paths which require knowledge for which roughly substitutable knowledge exists already are thus the more likely to arise for that knowledge is more likely, by condition 2., to exist. To summarise then, the more the requisite knowledge for a development path is simple, connects ideas which impress upon the sensory organs, do not contradict prevailing knowledge at the core of existing knowledge, and is substitutable for existing knowledge, the more likely it is to exist, and the more likely the development path which requires it is to arise. Thus we arrive at our fourth principle for forecasting:

- Those development paths are more likely to arise for which the requisite knowledge is already present in the minds of the population, or for which the requisite knowledge is simple, connects ideas which impress upon the sensory organs, does not contradict prevailing knowledge at the core of existing knowledge, and is substitutable for existing knowledge.

This principle presents a real challenge to empirical economics. For as Scannieri (1993) argued some time ago, and remains true today, economists since Cobb and Douglas (1928), even since Sraffa (1960) and Pasinetti (1977) have been reticent to see production theory as much more than finding an equation which adequately correlates input quantities with output quantities rather than
what it actually is - the application of an algorithm $\varphi_i(\cdot)$ which explains the exact steps involved in transforming a set of inputs into a set of outputs. In economics we do not presently have good techniques for assessing what knowledge is simple, salient, non-dissonant, non-central and substitutable for existing knowledge. That is not to say, however, that such techniques do not exist.

At this stage, subjective but reasoned ordinal metrics for topological distance in a logical space would likely be pragmatic stopgap method for assessing knowledge substitutability. However, the development of qualitative data analytics it is quite theoretically possible to be able to develop metrics for measuring knowledge substitutability as we define it in equation 4.12 as the inverse of distance in a logical space. The work of Cesar Hidalgo and Ricardo Hausman (Hidalgo and Hausman, 2009; Hausmann et al., 2011) on the “production space” (the network reflecting the “relatedness” of products), while still somewhat nascent, ought potentially be of some assistance in extrapolating the similarity of knowledge required to produce certain goods and services. Even simple input-output tables - the data on which Hidalgo and Hausman’s methodology operates - ought be of some assistance in establishing the similarity of production knowledge across outputs.

The “simplicity” of a production technique at least (excluding the why of knowledge) can be fairly well gauged by simply counting the maximum number of steps in the algorithm by which it can be represented. Organisational psychologists have been quite proactive in developing metrics which allow the forecaster to guage the resistance of an organisation to the change of its routines - its knowledge - on the basis of its current state of knowledge. The salience of the objects which knowledge will connect into understanding is in this case more problematic and understudied to the author’s knowledge. As these methods are developed and integrated more into economics proper it will become more possible to obtain better forecasts by assessing the likelihood that the knowledge requisite for certain development paths will exist.

Condition 4. of the Mauss-Commons and Smith-Hayek serves to further constrain the likely development paths which might arise in its interaction with the concept of complementarity.

**Definition 1** (Goods and services complimentarity). The goods and services $[x_n x_k] \in \mathbb{N}_{i} \subset a_{i=ci \lor a_i}$ are complimented by another set $[x_{n} x_{k}^{'}] \in \mathbb{N}_{i}^{'},$ in the context of $a_{i=ci \lor a_i}$ if and only if the implications of choosing both $(g_{a_{i}} x_{x}, x_{x}^{'})$ are more preferable to those of choosing the former alone $(g_{a_{i}} \backslash x_{x},),$ that is, if and only if

\[
g_{a_{i}} x_{x}, x_{x}^{'} \succ g_{a_{i}} \backslash x_{x}^{'}
\]

To put it in the vulgar manner: those things are complements which “go together”, are “better together than alone” (Earl, 1995). The satisfaction of Condition 4. with respect to certain economic exchanges might thus be contingent upon the existence of complements. We are thus more likely to observe economic exchanges made where any potential compliments for them exist. Thus we arrive at our fifth principle of forecasting:
Economic exchanges are likely to cluster in regions in which any potential complements for them exist.

Once again, complementarity in this sense is something economists have traditionally been uneasy about measuring. Economists traditionally prefer to define complementarity in the indirect manner as the existence of positive cross-price elasticities of demand and supply, and this may be of some assistance in determining which economic exchanges will tend to be made together for their complementarity. Here again though, even simple input-output data or Hausman and Hidalgo’s product space methodology ought be at least of some small assistance in assessing which production inputs or indeed outputs are complementary.

Condition 5. of the Smith-Hayek theorem is not quite so immediately important for our purposes, being fundamentally political in nature and relatively binary between political entities in which rule of law prevails and those in which it does not. In essence it corroborates the argument of John Commons (1924) that market exchanges can only come to exist if we have stable expectations that a *quid pro quo* exchange will arise or be enforced. Market exchanges are more likely to exist in jurisdictions with a strong system of enforceable property rights (by whatever means).

### 4.2 Chamberlin-Robinson and Lancaster-Ironmonger: available substitutes

The Chamberlin-Robinson and Lancaster-Ironmonger theorems shall be stated in their abbreviated form, for they are in their full form quite involved due to the three-body nature of the problem they consider. The Lancaster-Ironmonger theorem establishes how competition for custom proceeds on the basis of non-price attributes.

**Theorem 4.** Given two actions \( a_{c_j \cup \{ \omega_q \in n_j \}} \) and \( a'_{c_j \cup \{ \omega_q' \in n_j \}} \) as defined by some technical conditions and three additional technical conditions, if for a given set of product attributes \( \alpha (x_{n_i n_j}) \) and another set of product attributes \( \alpha (x_{n_i n_j})' \) the goods and services \( [x_{n_i n_j}] \subset a_{c_j \cup \{ \omega_q \in n_j \}} \), \( [x_{n_i n_j}]' \subset a'_{c_j \cup \{ \omega_q' \in n_j \}} \), the connection \( n_i n_j \) will be eliminated from \( M_s \) and the connection \( n_k n_j \) will be formed, that is, \( n_i n_j \in g_{M_s} (N) \), \( n_k n_j \not\in g_{M_s} (N) \) \( \rightarrow n_i n_j \not\in g_{M_s} (N) \), \( n_k n_j \in g_{M_s} (N) \) once the attributes \( \alpha (x_{n_i n_j}) \) exceed \( \alpha (x_{n_i n_j})' \) in a sequence of attributes ordered by the preferability of inferred outcomes they induce.

The Lancaster-Ironmonger theorem informs us that the robustness of economic exchanges to competition hinges on the substitutability of their attributes. The less potential economic exchanges have attributes which could induce their substitutability for a particular economic exchange, the more robust the particular economic exchange to competition and the evolutionary pressures of the economy. Conversely, if competing for custom, economic exchanges are more
likely to come to exist the more they have attributes which induce substitutability with those economic exchanges which currently exist. Thus our sixth principle of forecasting:

- Economic exchanges are more likely to be maintained the more it has attributes which are non-substitutable for any available alternatives, and more likely to be obtained in the presence of existing exchanges the more they have attributes which can be substituted for those existing.

Data on the existence of available substitutes are not difficult to obtain in principle. One only need determine what of the currently available goods and services in the economic system have attributes similar enough that they could be substituted for the particular goods or services under consideration, a project which has been feasible at least since Ironmonger (1972). The difficulty lies only in the collecting.

The Chamberlin-Robinson theorem establishes how competition for custom proceeds on the basis of prices.

**Theorem 5** (Chamberlin-Robinson theorem). Given two actions $a_{c_j \cup \{q_{i} \in n_{j}\}}$, $a'_{c_j \cup \{q_{i} \in n_{j}\}}$ as defined by some technical conditions and three additional technical conditions, if for a given price $p_{n_k n_j}$ and a price $p_{n_i n_j}$ the goods and services $[x_{n_k n_j}]$, $d'_{c_j \cup \{q_{i} \in n_{j}\}}$ are substitutable for the goods and services $[x_{n_i n_j}]$, in the context of $a_{c_j \cup \{q_{i} \in n_{j}\}}$, $a'_{c_j \cup \{q_{i} \in n_{j}\}}$, the connection $n_i n_j$ will be eliminated from $M_s$ and the connection $n_k n_j$ will be formed, that is, $n_i n_j \in g_{M_s}(N), n_k n_j \notin g_{M_s}(N)$ once the price $p_{n_i n_j}$ exceeds $p_{n_k n_j}$.

The Chamberlin-Robinson theorem demonstrates that price competition, as with attribute based competition, is predicated on the ability to produce substitutes for existing alternatives, which really is a matter first and foremost of attributes rather than prices. Price competition is a problem of first establishing the capability to produce substitutes for existing economic exchanges and then establishing a price which undercuts the prices mediating existing exchanges. Forecasting unless these can be established is moot. However, as well as establishing how custom may be successfully obtained through competition on the basis of prices, the Chamberlin-Robinson theorem also informs us of the bounds which are placed on prices, the bounds outside of which economic exchanges will cease to exist. If prices mediating economic exchanges exceed those of available substitutes by a certain amount (we would expect that amount to be close to zero in many markets), those economic exchanges will not exist. Thus our seventh principle of forecasting:

- The more substitutes for economic exchanges are available, the less prices which mediate economic exchanges may exceed those which mediate the exchange of those substitutes.
in those courses of socioeconomic history will take. Immediately we are in a position to determine that commodities (natural resources and certain agricultural products) cannot be a stable source of income for an economy - commodities are often used as the exemplar of substitutable items. If a high price exists for them it is only because those substitutes which are available in the market (and they may not be if demand is high) have a similarly high price. Again, data on the existence of available substitutes are not difficult to obtain in principle. The difficulty lies only in the collecting.

4.3 Chinese Whispers: the process of diffusion and counterfactual analysis

The Chinese Whispers theorem provides necessary and sufficient conditions for the diffusion of changes from one point in the economic system to another over the course of socioeconomic history. We will be concerned here with changes which cause the endpoint of diffusion to engage in economic exchange with some “original” individual or organisation.

**Theorem 6** (The Chinese Whispers theorem). Suppose we take a block of history \( \{E_t^i \cup I_s^t\}_{t=1}^T \), and we hold constant the progression of non-socioeconomic history in \( \{V^t \setminus E_t^i \cup I_s^t\}_{t=1}^T \), and also the progression of psychologies \( g_H(H_i) \) for each individual \( i \). For diffusion of a behavioural change at \( \mathcal{R} = c_i \lor \{ \omega_k \in n_i \} \) in \( \{E_t^i \cup I_s^t\}_{t=1}^T \) to \( \mathcal{S} = c_j \lor \{ \omega_k \in n_j \} \) in \( \{E_t^i \cup I_s^t\}_{t=1}^T \), supposing that initial behaviours remain feasible throughout it is necessary that

1. (The “absent firewall” condition): A chain \( \{n_{t_1}n_{t+\Delta} \in E_t^i \cup I_s^t\}_{t=1}^T \) reflecting changed behaviours \( n_{t_1}n_{t+\Delta} \in E_t^i \cup I_s^t \rightarrow n_{t_1}n_{t+\Delta} \in E_t^i \cup I_s^t \) with respect to the initial block \( \{E_t^i \cup I_s^t\}_{t=1}^T \) exist between \( n_{T_1} = n_i \) and \( n_{T_2} = n_j \).

And it is sufficient that

2. (The “sufficient conduits” condition): There exist chains \( \{n_{t_1}n_{t+\Delta} \in E_t^i \cup I_s^t\}_{t=1}^T \) reflecting changed behaviours \( n_{t_1}n_{t+\Delta} \in E_t^i \cup I_s^t \rightarrow n_{t_1}n_{t+\Delta} \in E_t^i \cup I_s^t \) with respect to the initial block \( \{E_t^i \cup I_s^t\}_{t=1}^T \) between \( n_{T_1} = n_i \) and \( n_{T_2} = n_j \) with the property that

\[
\{d^\omega_{t_1}\}_{t_1 \in N_{\gamma_{t+\Delta}}(g)} \subset V_{N_{\gamma_{t+\Delta}}(g)} : d^\omega_{t_1} \in B \& g_{a_{t_1+\Delta}} > g_{a_{t_1+\Delta}} \forall d^\omega_{t_1+\Delta} \in B \tag{4.14}
\]

for every \( \gamma_{t_1} \in \{n_i : \{n_{t_1}n_{t+\Delta} \in E_t^i \cup I_s^t\}_{t=1}^T \} \) and \( \gamma_{t_1} = c_i \lor \{ \omega_k \in n_i \} \). That is, every changed action of elements \( n_i \) in the environment of elements \( n_{t+\Delta} \) at each point in these chains is contained within the set of information which would induce a changed action on the part of \( n_{t+\Delta} \) to be feasible and associated with the most preferable implications of all actions.

The necessary, “absent firewall” condition, requires that there exist a chain of changed behaviours between the original individual or organisation and any individual or organisation who is to change their behaviour to form economic exchange with the original individual or organisation. The more any individual or organisation is central to socioeconomic networks, or is close (in the
network sense) to such a central individual or organisation, the more likely the absent firewall condition will be satisfied with respect to a greater number of other individuals or organisations. Thus the more any individual or organisation is central to socioeconomic networks, or is close to such a central individual or organisation the more likely they are to accrue economic exchanges.

The “sufficient conduits” condition requires that sufficient changes of behaviour exist in chains between the individual or organisation and the individual or organisation with whom they are to form economic exchange. If we realise that the process by which new nodes in socioeconomic networks are “reached” by changes of behaviour is on a multiplicative order, not additive, we realise that the “sufficient conduits” condition will be likely satisfied at an increasing rate in the initial phases of the diffusion process\(^4\). For every one node in the immediate neighbourhood of the original individual or organisation, there are the nodes in that nodes neighbourhood in the original individual or organisations “two-step” network. And so on and so forth. So, in the early phase of the diffusion process, provided the necessary condition is met, we are likely to see economic exchanges accrue at an increasing rate, even exponential.

However, counteracting this tendency of economic exchange to accrue at an increasing rate is the effect of exhausting the population of potential counterparties to economic exchange. The population of counterparties within any given system is necessarily limited to be \(N\), and as yet more of this population engages in economic exchange with a particular individual or organisation, the more the individual or organisation will be left only with the “periphery” of socioeconomic networks to accrue economic exchange from, the more difficult it will be for there to exist “sufficient conduits” to that periphery to change its behaviour. This countervailing effect of exhausting the population for potential economic exchanges will eventually come to outweigh the multiplicative process by which that population becomes part of the individual or organisations “\(n\)-neighbourhood”, and we will likely see economic exchange accrue at a decreasing rate. We provide here a microeconomic perspective on the process of self-organisation in the presence of evolutionary change offered by Foster (2005, 1997). We will likely observe a “logistic” diffusion process with, accelerating in the early phases of an individual or organisation’s existence then decelerating.

Hence we arrive at the eight, final, principle of forecasting:

- The more any individual or organisation is central to socioeconomic networks, or is close to such a central individual or organisation the more likely they are to accrue economic exchanges initially at an increasing rate moderating into a decreasing rate.

The Chinese Whispers theorem also indicates to us the process by which we can go about “run-
ning counterfactuals”, engaging in thought experiments about how the economy might respond to changes in growth factors. A change in a growth factor manifests in a change in of behaviour which will always be localised to a particular individual or organisation, ℵ in the theorem above, or group thereof. We can directly assess the effect of a change of income, prices, technology and such like on this entity. The Chinese Whispers theorem indicates that this will ahve an effect elsewhere in the system, ℶ in the theorem above, if there are absent firewalls and sufficient conduits in the socioeconomic structures mediating interaction between the two elements, the two economic entities ℵ and ℶ.

So, to assess the impact of some change of growth factor we would, after observing its impact locally upon a particular entity, look to that entity’s network neighbourhood (the nodes connected to it, and the nodes it is connected to) and assess the impact it will have upon that neighbourhood. Once we construe how that neighbourhood responds to that impact and changes its behaviour (if at all), we may repeat the exercise with respect to the neighbourhood of the neighbourhood and so on. Thus to our principles of forecasting we would add a principle for counterfactual analysis:

- If we introduce a change to some entity in the socioeconomic system, we may assess its systematic impact by observing the impact on and response thereto of that change in the entity’s socioeconomic network neighbourhood, repeating the exercise with respect to the neighbourhood’s neighbourhood and so on until the impact causes no behavioural response.

This process is facilitated by observing the network structure of the economic system (the topology of which can be recovered quite straightforwardly from input-output tables), and the development of computational techniques to simulate changes occurring within the structure of that network. Such techniques have been notably applied to financial systems by Andy Haldane (Gai et al., 2011) and Sheri Markose (Markose, 2013).

Observe the apparent weakness of this method. We must judge the response of various entities to changes in their neighbourhoods. But this weakness is shared by all models of economic systems with any accounting for their disaggregated nature. Traditional “computable general equilibrium” models (descendents of Arrow and Debreu (1954) and Debreu (1959)) not only have this weakness, but also that the manner in which the response functions are dependent on assumptions input is obscured by the conflation of utility, production and budget constraint functions in the process of deriving the closed form model. Further, the dynamic process by which movement between equilibria is obscured by the comparative static nature of CGE models, the process by which one static equilibrium is transformed into another by changes to relative prices remaining thus a “black box”. What appeared to be a weakness in the network of response functions approach actually transpires to be a strength, for our assumptions about the response functions of various entities in the economy must be transparent, open to scrutiny, and thus our counterfactual analysis reveals dynamics which are therefore more transparent and comprehensible.
4.4 “Black swan” events

We related above the controversy in economics concerning forecasting if the possibility of “black swan” events is admitted. These events, by definition non-extant prior to their realisation and so non-present in the support of any distribution over future states of the world. There is no objective data to support their presence in that distribution, let alone the distribution over that portion of the support (Shackle, 1969, 1972; Taleb, 2007). We cannot, therefore, forecast them before they come to exist, in many cases we cannot even think of them. We are speaking here of events such as the invention of the steam engine, of personal computers, of the internet, of social media, and recently, of blockchain technology.

Once radical uncertainty is realised however, once it is introduced to the economic system, we ought in principle be able to arrive at some assessment of its accrual of economic exchanges based on the regularities of economic systems. Carlota Perez (2010) demonstrates that such regularities exist with respect to radical innovations, in particular, that omnipresent in every radical technological innovation in history is the logistic diffusion curve. Once radical uncertainty is realised, we can apply the principles of forecasting above to the economic exchanges of the individual or organisation which brings a radically novel good or service into being.

Our forecasts must always therefore be subject to radical uncertainty - even if there is no genuine creativity the economy is simply too complex for us to be able to foresee all possible events (Hayek, 1989). This must be always recognised and a caveat attached to any projections the forecaster construes. But once a radical uncertainty is realised, we may project its likely effect on the development path of the economy applying our principles as we would to any other sector of the socioeconomic system.

5 Mesoeconomic principles for forecasting

Clearly we will rarely have sufficient data to be able to forecast economic structures at anywhere near disaggregated a level as the individual. So for this purpose we stand in want of some method of aggregation to a higher unit of analysis for which insights into the formation of economic exchanges on an individual basis can be carried. Such a method is offered by the micro-meso-macro framework of Dopfer et al. (2004). As we broaden our view of the economic system beyond the individual and their economic exchanges, individuals may be coalesced into “meso-populations” classified by that population adhering to a particular “meso-rule” - a routine (Dopfer, 2004) existing with sufficient regularity and sufficiently little variation that the behaviour of the meso-population may be analysed as a coherent whole. The economic system as a whole - the macroeconomy - then becomes a more manageable network of economic interaction between meso-populations.
In Markey-Towler (2016a, Appendix B) it is discussed how such routines can be represented as behavioural rules $f_K(\cdot) \in g_H(H'_1)$, and so the meso-population $m$ is defined as the set of individuals and organisations within $N \subset E_s$ which act according to the dictates of a rule $f_K(\cdot)$ which is roughly identical across that population. That is, if $f_K^M(\cdot)$ is our meso-rule, then

$$m = \left\{ n_i \in N : a_{\mathcal{C}_i \cup \{o_k \in n_j\}} = f_K(B) \in g_H \left( H'_{\mathcal{C}_i \cup \{o_k \in n_j\}} \right) \right\}$$

(5.1)

here we suppose (without loss) that the behavioural rules $f_K(\cdot)$ operate on the set of feasible actions $B \subset 2^A_i$. Often our specification of meso-populations will not in fact be determined by the questions we wish to ask, but instead the disaggregation of the data which we have on hand. Industry-level classifications, for instance, are proximate enough to the idea of meso-classifications as to be workable. It is to these meso-populations then that we may carry over the principles for forecasting above in order to develop a qualitative appraisal of the likely development path thereof, and thus the economic system as a whole.

Specifying the meso-population $m \subset N \subset E_s$ allows us to define quantity metrics with respect to it by operating on the contents of connections $n_i n_j \in g(N)$ its elements $n_i \in m$ maintain with others in the economic system

$$q_m = q_m \left( \left\{ x_{n_i n_j} x_{n_j n_i} m_{n_i n_j} m_{n_j n_i} \right\}_{n_j \in N_n_i(g)} \right)_{n_i \in m}$$

(5.2)

For instance, the “sales”, of the meso-population would be (part of, if we did not exclude non-market exchanges), in terms of monetary turnover

$$q_m = \sum_{n_i \in m} \sum_{n_j \in N_n_i(g)} m_{n_i n_j}.$$

The input structure of the meso-population would be the vector sum

$$q_m = \sum_{n_j \in m} \sum_{n_i \in N_n_i(g)} x_{n_j n_i}$$

and so on.

We may get some rough idea of the path of these quantity metrics of meso-populations with the econometric methodology developed by Foster and Wild (1999) for estimating diffusion curves by making use of the mathematics of interactive population dynamics. The quantity metrics of meso-populations are path dependent (equation 2.4) and will evolve at the margin by interactions between populations in a manner which can be qualitatively forecast according to the principles above, though they must inevitably be constrained by the size of the overall system. Augmented logistic diffusion curves of the kind presented by Foster and Wild (1999) reflect exactly these properties as well as the nigh-axiomatic empirical fact (explained here by the provisions of the Chinese Whispers) that quantity metrics of meso-populations always tend to slow as they approach the limit after a more rapid initial growth.

The “augmented logistic diffusion” approach makes use of the “Mansfield” variant of a diffusion curve for a quantity metric $q_m$ of meso-population $m$
\[ q_{m}^{t+\Delta t} - q_{m}^{t} = q_{m}^{t} \beta \left[ 1 - \frac{q_{m}^{t}}{K} \right] + \mu_{t} \]  

(5.3)

or, approximately, using natural logarithms to approximate the proportional instantaneous rate of change

\[
\ln q_{m}^{t+\Delta t} - \ln q_{m}^{t} \approx \frac{\dot{q}_{m}^{t}}{q_{m}^{t}} = \beta \left[ 1 - \frac{q_{m}^{t}}{K} \right] + \epsilon_{t}
\]  

(5.4)

where \( \epsilon_{t} = \frac{\mu_{t}}{q_{m}^{t}} \), \( \beta \) is the rate of diffusion and \( K \) the limit to which the quantity metric \( q_{m} \) may grow \( (q_{m} \leq K) \) and \( \mu_{t} \) is a residual error term.

Equation 5.4 captures the basic path-dependency of a particular meso-population within the macroeconomy and the regularities of its diffusion process along that path. But to this basic equation we may add an inner product \( \delta d_{m}^{t} \) of a coefficient vector \( \delta \) and a vector \( d_{m}^{t} \) of attributes such as those we have derived in our microeconomic essays above which we can measure of the particular meso-population within the macroeconomy which augment the diffusion path. We may also add an inner product \( \gamma q_{m}^{t} \) of a coefficient vector \( \gamma \) and a vector \( q_{m}^{t} \) of quantity metrics of other relevant meso-populations \( m' \in R \) in a set \( R \) to capture the interaction of the meso-population \( m \) with others \( m' \) in the overall socioeconomic system. The makeup of the set \( R \) is that which our microeconomics informs us of, and thus informs us of the specification of econometric models of the quantitative dynamics of meso-populations following the functional full form

\[
\ln q_{m}^{t+\Delta t} - \ln q_{m}^{t+\Delta t} \approx \beta \left[ 1 - \frac{q_{m}^{t}}{K} \right] + \delta d_{m}^{t} + \gamma q_{m}^{t} + \epsilon_{t}
\]  

(5.5)

This equation is linear in the parameters \([\beta, \delta, \gamma, 1]\) and so equation 5.5 may be estimated using standard linear regression techniques.

6 Conclusion: the forecasting procedure

If the reader might permit the breaking of an old writing nicety, we might introduce new material in our conclusion. We may conclude this note by condensing the view developed over its course into a procedure for forecasting in complex economic systems.

The basic procedure of economic forecasting is to treat the principles for forecasting above as a questionnaire to be applied to whatever disaggregated entities in the economy as data of sufficient quality can be obtained for. Our principles are:

1. Economic exchanges generally are likely to cluster in areas of high population density and only in those areas of low population density with well developed communications infra-
structure, and to cluster around those individuals and organisations which occupy a significant presence in the public sphere.

2. Economic exchanges generally are likely to cluster around individuals and organisations which broadcast opportunities to exchange prominently in the physical and public sphere.

3. Economic exchanges generally are more likely to cluster around individuals and organisations the greater their current income and wealth.

4. Those development paths are more likely to arise for which the requisite knowledge is already present in the minds of the population, or for which the requisite knowledge is simple, connects ideas which impress upon the sensory organs, does not contradict prevailing knowledge at the core of existing knowledge, and is substitutable for existing knowledge.

5. Economic exchanges are likely to cluster in regions in which any potential complements for them exist.

6. Economic exchanges are more likely to be maintained the more it has attributes which are non-substitutable for any available alternatives, and more likely to be obtained in the presence of existing exchanges the more they have attributes which can be substituted for those existing.

7. The more substitutes for economic exchanges are available, the less prices which mediate economic exchanges may exceed those which mediate the exchange of those substitutes.

8. The more any individual or organisation is central to socioeconomic networks, or is close to such a central individual or organisation the more likely they are to accrue economic exchanges initially at an increasing rate moderating into a decreasing rate.

As forecasters we may arrive at a basic qualitative assessment of the development path of the socioeconomic system on the basis of these principles applied as a questionnaire to various sectors of the economic system. The questionnaire of conditions implied by these principles for forecasting are as follows:

1. Is the entity located in a geographical area with high population density or with well developed communications infrastructure and occupy a significant presence in the public sphere?

2. Does the entity broadcast opportunities to exchange prominently in the physical and public sphere?

3. Does the entity have and interact with entities which have a high level of current income and wealth?
4. Does the entity engage in activities for which requisite production and consumption knowledge is already present in the minds of the population, or is simple, noticeable, uncontroversial and similar to knowledge already present in the minds of the population?

5. Does the entity engage in activity for which potential complements are available?

6. Does the entity engage in activity for which substitutes are available?

7. Is the entity central to socioeconomic networks, and at an early stage of its existence?

If we answer “yes” to questions 1.-6. of a particular entity within the economic system we say of it that it is likely accrue economic exchanges. If we answer “yes” with respect to question 6. furthermore, we can expect prices to be free to rise to relatively high levels, and if we answer “yes” with respect to question 7. we can expect the accrual of economic exchanges to a particular entity to occur at an increasing rate. The contrary holds if we answer “no” to any of these questions. A more involved answer to each question allows us to form a more nuanced qualitative assessment.

We may, further, obtain a more quantitative assessment (though necessarily tentative to the radical uncertainty of the economy) of the development path of these sectors and the economy by the application of equation 5.5 in a regression analysis:

\[ \ln q_{t+\Delta t} - \ln q_{t-\Delta t} \approx \beta \left[ 1 - \frac{d_{m}}{K} \right] + \delta a_{t} + \gamma q^{-m}_{t-\Delta t} + \epsilon_{t} \]

We may input into \( a_{t} \) and \( q^{-m}_{t-\Delta t} \) those data available which we are guided to by our microeconomic principles. These microeconomic principles serve to provide some guard against “overfitting” our regressions and obtaining spurious results by giving us a theoretical guide to the likely statistically significant content of \( a_{t} \) and \( q^{-m}_{t-\Delta t} \). We may set principle 8. aside for this aspect of the development paths of meso-populations is already captured in the functional form of equation 5.5.

Into \( a_{t} \) our principles would commend our inputting:

- The population density in the region(s) in which the meso-population is physically located, as well as metrics for the state of communication technology in any such region (principle 1.)

- Metrics which reflect the “presence”, of the meso-population in the public sphere both broadcast by the meso-population and otherwise (principles 1. and 2.)

- The current share of systemic resources and income held by the meso-population (principle 3.)

Into \( q^{-m}_{t-\Delta t} \) our principles would commend our inputting:
• The inputs and outputs of any meso-population $m'$ with a knowledge base which can be adjudged sufficiently similar to the meso-population $m$ as to be substitutable for it (principle 4.)

• The outputs of any meso-population $m'$ as can be adjudged to be complementary to (not forgetting public infrastructure) or substitutable for the activities of meso-population $m$ (principles 5. and 6.).

With our regressions in hand we may add rough quantitative estimates of the future path, subject to irreducible radical uncertainty, of meso-populations within the macroeconomy to our qualitative assessment of the rates of change of quantity-metrics of our meso-populations.

To this method for forecasting we may add our principle for counterfactual analysis:

• If we introduce a change to some entity in the socioeconomic system, we may assess its systematic impact by observing the impact on and response thereto of that change in the entity’s socioeconomic network neighbourhood, repeating the exercise with respect to the neighbourhood’s neighbourhood and so on until the impact causes no behavioural response.

In which our assessments of the response functions for each meso-population may be augmented by our econometric estimates for the evolution of their quantity-metrics. And thus we arrive at a rich transformation of economic data using an integrated, holistic, systematic apparatus for viewing the economy as a network formed out of the behaviour of individuals acting on the basis of their which gives us forecasts of its likely evolution along particular development paths in socioeconomic history.

References


