The Structure and Equilibrium Conditions of a Generalized Economic Canopy: A Note
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V. Heinrich S. Amavilah
REEPS
PO Box 38061, Phoenix, AZ 85069-8061
vhs@ziplip.com

Abstract: This note draws upon ecological models to describe the structure and equilibrium conditions of a generalized economic canopy consisting of three interactive economies assumed to be in competitive *epiphytic*, *parasitic*, and *host* relationships to each other. The maintained hypothesis is that generally (a) parasites are a drag on their hosts, (b) epiphytes interfere with normal functioning of both parasites and hosts, and (c) hosts must support their own performance as well as the survival of epiphytes and parasites. The results show that hosts must perform twice as better to support the other competitors, and question the notion that individual economies fend for themselves. The challenge is firmly grounded in ample real-life evidence; for example, primary sectors have historically supported economic growth of nations, especially in the early stages of development. In some cases, primary sectors transform themselves and other sectors, as in the lumber industry giving birth to Nokia, and thereby transforming both Finland and the world. In other cases the emergence of tertiary sectors consisting mainly of governments (parasites) has diminished the performance of other sectors and along with them economic growth. The world may be flatter today than it was even a decade ago, but how economies perform remain constrained and/or promoted by individual intra-actions as well as by the interactive dynamics between and among economies.

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The single finite movement from disturbance to a restoration of equilibrium is not enough if genesis is to be followed by growth. And, to convert the movement into a repetitive, recurrent rhythm, there must be an elan vital (to use Bergson's term) which carries the challenged party through equilibrium into an overbalance which exposes him to a fresh challenge and thereby inspires him to make a fresh response in the form of a further equilibrium ending in a further overbalance, and so on in a progression which is potentially infinite (AJ Toynbee, 1958, p. 187). Growth is achieved when an individual or a minority or a whole society replies to a challenge by a response which not only answers that challenge but also exposes the respondent to a fresh challenge which demands a further response on his part (AJ Toynbee, A Study of History, 1958, p. 241).

In the past two decades or so, many people have become accustomed to thinking of socio-economic stratification as a defunct Marxist idea (Galor and Moav, 2004, cf. Heller, 1987). Consider two very popular recent books: Thomas Friedman's *The World is Flat* (2005) and Jared Diamond's *Collapse* (2004). Diamond explains how individual ancient societies failed and/or succeeded, and then goes on to predict similar paths for the modern societies that ignore history's dire lessons. According to Friedman the digital anvil and hammer have flattened the world to the advantage of many small market participants, with many more to follow in the future. An obvious reading of Friedman is that the world is a featureless prairie stretching into the horizon as far as the eye can see. Without valleys to cross or mountains to climb, developing countries can now run uninhibited to catch-up with developed ones, and many already are, to the potential detriment of the industrialized countries.

Diamond, on the other hand, appears to slight the interconnectedness of societies by failing to observe that often the success and failure of some societies comes not because of what they did or did not do themselves, but because of what other societies did or did not do - the familiar Myral-Kaldor's circular and cumulative causation (Thirlwall, 1982, Choi, 1983). The latter part of the preceding statement reflects on one aspect of the phase of modern globalization in that it localizes the effects of change, making difficult the interpretation of globalization in terms of black and white statistics. Take NAFTA as a crude example. The outward expansion of US, Canadian, and Mexican markets can be thought of as representing the head of globalization, and the enlargement of the intersections between and among the three economies as representing its tail. Economic geographers refer to this paradoxical phenomenon as the localization of globalization (), quite distinct from economic integration.

The fact that the performance and good fortune of some economies is not independent of the decline, stagnation, and misfortune of others, even given Friedman's flat world, is evident from the contentious issues between the developed and developing economies relating to debt and farm subsidies cancellations, for instance. Yet even ecological economists continue to ignore the interactive aspects of the (world) economic canopy, and especially what bio-ecological research calls "inter- and intra-specific competition". Becker, Eβlinger, Hedtke, and Knudsen (2005) indicate that prominent economists like Schumpeter (2005) caution against the tendency toward biological models to explain growth and development, mainly because "development is a discontinuity of the steady state, a disruption of the static equilibrium leading to an indeterminate future equilibrium" (p. 110). However, Schumpeter's own discussion of the adaptation of an economy to a novel breakaway from the static equilibrium (development) is characteristic of bio-ecological models in that it has teleological elements to it. While admitting the role of atomic individualism, historians have long-argued that the "atomic way of life is ascribed to no ordinary human beings ... , for man is essentially a social animal inasmuch as social life is a condition which the evolution of man out of sub-man pre-supposes and without which evolution could not conceivably have taken shape" (Toynbee, 1958, p. 209). The power of the social over the individual explains the difference between what Toynbee calls "developed civilizations" on the one hand versus "abortive and arrested civilizations" on the other hand, and it all suggests that rather than being independent, or even independent in a flat world, economies are often in "exploitative", "interference" and/or "mutualistic" relationships just like many biological species (Roughgarden, 1979, Putman and Wratten, 1984, Hartl, 1980, Hirshleifer, 1985). If so, how fast can any economy run or walk the flat plain with one economy on its back, and another clinging to its ankle?

1. Structure of economic canopy

This paper characterizes a general economic canopy as consisting of three broad types of economies: (a) *epiphytic* economies (*E*), *parasitic* economies (*P*) and *host* economies (*H*). It draws the analogy and terminology from the structure of the rainforest to suggest the intricate relationships between these economies and their implications for the sustainability of the entire system. Epiphytic economies are those economies capable of generating their own growth, but are dependent on host markets for a significant part of their overall performance. Parasitic economies are a drag on host economies upon which their survival depends. Host economies are those economies that are capable of generating their growth internally as well as support other economies. Hence, the level of production of each economy depends on that of the others, i.e., $Y_E(Y_H, Y_P, X_E), Y_P(Y_H, Y_E)$, and $Y_H(Y_P, Y_E, X_H)$, where Y_E, Y_P, and Y_H are production output by E, P, and H, respectively.[1]

Examples of this kind of canopy at the country level abound. However, at the macroeconomic level of aggregation where discussion is easy to sustain, the difficulty is that classifying countries into H, P, and E is a political hot potato. Even so, the analogy to canopy does not lose value as it can be generalized to lower levels within one economy. For example, most developing economies consist of three distinct sectors: primary, secondary, and tertiary. The primary sector is a raw materials sector and the anchor of most developing economies. It can be likened to H. The secondary sector, of which a small manufacturing industry is an important component, can be likened to E, while the tertiary sector, made up mainly of government, is not unlike P. At even lower microeconomic levels primary resource firms are the H, manufacturing firms the E, and most state-owned firms, whichever industry they are in, are the equivalent of P.

Here is some theoretical support from recent literature. Grossman and Kim (1996) find that prey dynasties that are tolerant of predation accumulate capital faster than those that are better at deterring predation. Biologists Gilchrist and Sasaki (2002) utilize a mechanistic mathematical model to describe host-parasite relationships, and find that the co-evolutionary equilibrium conditions depend on the stability and fitness of both host and parasite, as well as the response of the host to the growth of the parasite. Epidemiological models that seems relevant to this subject indicate variable and case-specific effects of parasite but there the evidence is clear that such effects weaken the host (Ebert, Lipsitch and Mangin, 2000). In fact Deredec and Courchamp (2003) caution against "detrimental consequences" of "overlooking the existence of parasite and host thresholds" (p.115). Jack Hirshleifer (1977) provides a lucid theoretical justification of sociobiological models of the economy.

[1]In the rainforest epiphytes grow on other plants, but they generally do everything else themselves.

Assume production by each economy obeys the following rules:

$$Y_E(Y_H,Y_P,X_E)=AY_H^{a_1}Y_P^{a_2}X_E^{a_3}\ \ [a_1,a_3>0,\ a_2<0]\ \ (a),$$

$$Y_P(Y_H,Y_E)=BY_H^{b_1}Y_E^{b_2},\ [b_1>0,b_2>0 \vee b_2<0] \qquad (b) \qquad (1)$$

$$Y_H(Y_P,Y_E,X_H)=CY_P^{c_1}Y_E^{c_2}X_H^{c_3}\ \ [c_1<0,c_2<c_1,c_3>0]\ \ (c).$$

To simplify the structure of the economic canopy, substitute 1(a) and 1(b) into 1 (c) so that

$$Y_H=\Phi Y_H^{b_1+a_1b_2c_1+a_1c_2}Y_P^{a_2b_2c_1+a_2c_2}X_E^{a_3c_2}X_H^{c_3} \quad [\Phi=A^2\cdot B\cdot C]. \qquad (2.1)$$

While the strings of exponents in (2.1) are informative in interpretting (1), they are too messy, and slow down comprehension. For further simplicity define

$$b_1+a_1b_2c_1+a_1c_2\equiv\alpha>0\ \ \mathit{iff}\ \ b_1>0,\ b-1>b_1+a_1b_2c_1+a_1c_2$$

$$a_2b_2c_1+a-2c_2\equiv\beta>0\ \ \mathit{iff}\ \ a_2c_2>0,\ a_2b2_{c_1}<0 \qquad (2.2)$$

$$a_3c_2\equiv\gamma>0\ \ \mathit{iff}\ \ a+3>0 \quad c_3\equiv\delta>0,$$

where $\alpha+\beta+\gamma+\delta\leq 1.$ Given (2.2), (2.1) can be restated as

$$Y_H^{1-\alpha}=\Phi Y_P^{\beta}X_E^{\gamma}X_H^{\delta}, \qquad (2.3)$$

which upon solving for Y_H in terms of Y_P and X_i leads to

$$Y_H=\Phi Y_P^{\beta^*}X_E^{\gamma^*}X_H^{\delta^*}, \qquad (3)$$

where $\beta^*=\frac{\beta}{1-\alpha}, \gamma^*=\frac{\gamma}{1-\alpha}, \delta^*=\frac{\delta}{1-\alpha}$, and X_i are the conventional factors of production such as labor, human and physical capital, and the like.

2. Equilibrium Conditions

The average effect of each economy is found by dividing both sides of (3) by Y_P, X_E, and X_H such that

$$y_{hp} = \phi x_{ep}^{\gamma^*} x_{hp}^{\delta^*}$$

$$y_{he} = \phi y_{ep}^{\beta^*} x_{he}^{\delta^*} \qquad (4)$$

$$y_{hh} = \phi y_{hp}^{\beta^*} x_{he}^{\gamma^*}$$

where y_{hp} is the average drag of P on H, y_{he} is the average influence of E on H, and y_{hh} is the average productivity of X_H, and x_{ep}, x_{hp}, y_{ep}, x_{he}, and y_{hp} are "input" intensities.

Furthermore, the marginal products of Y_P, X_E, and X_H on Y_H are given by

$$\frac{\partial Y_H}{\partial Y_P} = \phi \beta^* x_{ep}^{\gamma^*} x_{hp}^{\delta^*}$$

$$\frac{\partial Y_H}{\partial X_E} = \phi y_{ep}^{\beta^*} x_{he}^{\delta^*} \qquad (5)$$

$$\frac{\partial Y_H}{\partial X_H} = \phi y_{hp}^{\beta^*} x_{he}^{\gamma^*}$$

By Euler's theorem, (5) leads to

$$\begin{aligned} Y_H &= Y_P \cdot \frac{\partial Y_H}{\partial Y_P} + X_E \cdot \frac{\partial Y_H}{\partial X_E} + X_H \cdot \frac{\partial Y_H}{\partial X_H} \\ &= \phi [Y_P \cdot MD(hp) + X_E \cdot MI(he) + X_H \cdot MP(hh), \end{aligned} \qquad (6.1)$$

where MD(hp) is the marginal drag of P on H, MI(he) is the marginal influence of E on H, and MP(hh) is the traditional marginal products of X_H on Y_H. Eq. (6.1) suggests that

$$(\beta^* = \frac{Y_P \cdot MD(h,p)}{Y_P}) + (\gamma^* = \frac{X_E \cdot MI(h,e)}{X_E}) + (\delta^* = \frac{X_H \cdot MP(h,h)}{X_H}) \leq 1, \qquad (6.2)$$

where from (1) and (2.2)

$$\beta^* = \frac{a_2 b_2 c_1 + a_2 c_2}{1-(b_1 + a_1 b_2 c_1 + a_1 c_2)} = \frac{\beta}{1-\alpha},$$
$$\gamma^* = \frac{a_3 c_2}{1-(b_1 + a_1 b_2 c_1 + a_1 c_2)} = \frac{\gamma}{1-\alpha}, \qquad (6.3)$$
$$\delta^* = \frac{c_3}{1-(b_1 + a_1 b_2 c_1 + a_1 c_2)} = \frac{\delta}{1-\alpha}.$$

Although (6.3) appears complicated, those parameters can be estimated by taking the natural logarithms (ln) of both sides of (3) [or (4)] as

$$\ln Y_H = \ln\Phi + \beta^* \ln Y_P + \gamma^* \ln X_E + \delta^* \ln X_H. \qquad (7)$$

The growth rate of (7) becomes

$$\frac{d\ln Y_H}{dt} = \frac{d}{dt}[\ln\Phi + \beta^* \ln Y_P + \gamma^* \ln X_E + \delta^* \ln X_H], \qquad (8.1)$$

which is similar to

$$\frac{dY_H}{Y_H dt} \equiv r_{YH} = (r_{YP} \equiv \frac{\beta^*}{Y_P}) + (r_{XE} \equiv \frac{\gamma^*}{X_E}) + (r_{XH} \equiv \frac{\delta^*}{X_H}) \qquad (8.2)$$

It follows that

$$\frac{dY_H}{dt} = Y_H \cdot r_{YH} \qquad (8.3)$$

and by differential identity

$$dY_H \equiv Y_H \cdot r_{YH} dt \Rightarrow r_{YH} = \frac{dY_H}{Y_H dt} = \frac{1}{Y_H}(r_{YP} + r_{XE} + r_{XH}). \tag{8.4}$$

Bottom line: $r_{YH} = f(Y_H, r_i), i = Y_P, X_E, X_H$. This rather simplistic result can be recast in terms of Lotka-Volterra (LV) differential competition equations on the assumption that, given a fixed capability (K_i), the contribution of an individual economy to the general economy depends on its size and the sizes of its competitors. To do so let $Z_i = Y_i \times Y_j = Y_j \times Y_i$ be the combined interaction term between any two economies. Then the following LV equation system describes intra- and inter-economic competition in this economic canopy:

$$\frac{dY_P}{dt} = r_{YP} Y_P [\frac{K_P - (Y_P + \mu_{PH} Y_H + \mu_{PE} Y_E + \mu_{PZ} Z_P)}{K_P}]$$

$$\frac{dY_E}{dt} = r_{YE} Y_E [\frac{K_E - (Y_E + \mu_{EH} Y_H + \mu_{EP} Y_P + \mu_{EZ} Z_E)}{K_E}] \tag{9.1}$$

$$\frac{dY_H}{dt} = r_{YH} Y_H [\frac{K_H - (Y_H + \mu_{HP} Y_P + \mu_{HE} Y_E + \mu_{HZ} Z_H)}{K_H}],$$

or compactly,

$$\frac{dY_i}{dt} = r_i Y_i [\frac{K_i - (Y_i - \sum \mu_{i,j} Y_i - \sum \mu_{i,j} Z_i)}{K_i}]. \tag{9.2}$$

The capacities of Yp and YE are, at least important, functions of K_H, i.e., $K_P = Y_H - K_E = f(X_H, X_E), K_H = f(X_H), K_E = K_H - K_P = f(Y_H, X_E)$.

From (9.1) or (9.2) generally, $1/K_i$ represents the effect of the ith economy on its own performance (growth), μ_{ij}/K_i is the overall impact of the ith economy on the performance of the jth, where $i \neq j$ and

μ_{ij} and μ_{ji} are direct competition effects and μ_z are indirect impacts. By implication, $\frac{\mu_{ij}}{K_j} < \frac{1}{K_i}$, then either one or the other economy is self-destructive. In the limit the ith economy dominates the jth economy if Y_i approaches K_i as Y_j approaches zero. An interesting case is where three economies coexist, i.e., when in (9.1)

$$\frac{dY_H}{dt} = \frac{dY_E}{dt} = \frac{dY_P}{dt} = 0 \tag{10}$$

because then one can solve for Y_H, Y_E, and Y_P. Moreover, for (10) to hold it is the case that

$$\begin{aligned} &K_P - Y_P - \mu_{PH}Y_H - \mu_{PE}Y_E - \mu_{PZ}Z_P = 0 \\ &K_E - Y_E - \mu_{EH}Y_H - \mu_{EP}Y_P - \mu_{EZ}Z_E = 0 \\ &K_H - Y_H - \mu_{HP}Y_P - \mu_{HE}Y_E - \mu_{HZ}Z_H = 0 \end{aligned} \tag{11.1}$$

Therefore,

$$\begin{aligned} &K_P = Y_P + \mu_{PH}Y_H + \mu_{PE}Y_E + \mu_{PZ}Z_P \\ &K_E = Y_E + \mu_{EH}Y_H + \mu_{EP}Y_P + \mu_{EZ}Z_E \\ &K_H = Y_H + \mu_{HP}Y_P + \mu_{HE}Y_E + \mu_{HZ}Z_H \end{aligned} \tag{11.2}$$

For example, solving for Y_E in (11.2(b)) in terms of K_E, μ_{Ei}, Y_P, Y_H, and Z_{Ei} gives

$$Y_E = K_E - \mu_{EH}Y_H - \mu_{EP}Y_P - \mu_{EZ}Z_E \tag{11.3}$$

Inserting (11.3) into (11.2(a)) and rearranging leads to

$$K_P = (1 - \mu_{PE}\mu_{EP})Y_P + (\mu_{PH} - \mu_{PE}\mu_{EH})Y_H + \mu PE(K_E - \mu_{EZ}Z_E) + \mu_{PZ}Z_P \tag{11.4}$$

Hence,

$$Y_P = \frac{K_P - \mu_{PE}(K_E - \mu_{EP} Z_E) - (\mu_{PH} + \mu_{PE}\mu_{EH}) Y_H + \mu_{PZ} Z_P}{1 - \mu_{PE}\mu_{EP}} \tag{11.5}$$

Since μ_i depends on the behavior of Y_i subject to K_i, from this example it is not difficult to show that a general solution is

$$Y_i = \frac{K_i - \sum \mu_{ij} K_j + \sum \mu_{iZ} Z_i}{1 - \sum \mu_{ij}\mu_{ji}} \tag{12}$$

Estimating (12) is a bit challenging because it throws the two-variable correlation out the window. However, Pan and Harris (2000, pp. 134-137) suggest a triple-variable correlation which they generalize into a similarity coefficient. I do not intend to go into that here as that would take us afield.

From (9.1) the size of the economy that would yield the strongest *overall* growth rate is

$$\begin{aligned} \frac{\partial}{\partial Y_i}\frac{dY_i}{dt} &= \frac{\partial}{\partial Y_i}\left[\frac{r_i Y_i K_i - (r_i Y_i^2 - r_i \sum \mu_{i,j} Y_i^2 - r_i Y_i \sum \mu_{iZ} Z_i)}{K_i}\right] \\ &= r_i - 2r_i Y_i - 2r_i \sum \mu_{i,j} Yi - r_i \sum \mu_{iZ} Z_i. \end{aligned} \tag{13}$$

It is important to note here that (10) cheats to avoid complication arising from the fact that $Z_i = Y_i \times Y_j \Rightarrow \partial Z_i / \partial Y_i = dZ_i / dY_i \cdot Y_j + Yi \cdot dZ_i / DY_j$. Even so, setting (13) to zero and solving for Y_i (or ri if needed) leads to the following logistic equation:

$$Y_i = \frac{1}{2 + \sum \mu_{i,j} + \sum \mu_{Zi})} \Rightarrow Y_i = f(K, \mu). \tag{14}$$

Given (9) - (14) we can evaluate the sustainability of intra- and inter-relationships among the three parts of the general economic canopy. Example: for the three economies to co-evolve in a co-existent fashion one would expect relatively small μ's for all three economies. For H to be able to support both P and E it is important that $\mu_{iH} < \mu_{iP} + \mu_{iE}$, otherwise H collapses. In other words, (11) would mean that H must change at a rate double the rate of competitors to stay ahead; alternatively H must fall at a rate half slower than its competitors. Evidence shows that an equilibrium exists; it is the stability and attainability that are at issue since those depend on other factors such as the environment.

3. Concluding remarks

Despite the now famous Cournot-Nash equilibrium which indicates clearly that competing economic agents sometimes end up worse-off in pursuing their self-interest individually than pursuing the same co-operatively, experts (including economists) remain wed to the simplistic idea of economic independence. Economic independence is assumed desirable only in human as opposed to other living societies, and ecological research indicates the difference is largely an artificial one. Drawing on that research this note describes how economic performance, even for hardest working economies, may be slow by the impersonal reaction with other economies. This shows that in an interconnected economic canopy the natural rate of economic growth (r_i) is not as important as K_i and μ's. In fact, r_i depends on Y_i, and the capacity of H is the limit of the capacities of other economies. *The broader implication of this analysis to me is that economic species, just like their bio-ecological counterparts, must learn to share growth, for growth is just one big externality*.

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