Volatility in the Knowledge Economy

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1 Introduction

In the halls of academia one hears that David Cass is 'charismatic', an unusual term for a university professor. Its meaning can be different in different languages, representing a challenge for the authors of this article who straddle uneasily between different cultures. Yet we came to the conclusion that Dave's 'charisma' can be attributed to two personality traits: (1) Dave's passion for economics, particularly economic theory, and (2) his uncompromising intellectual integrity in casting a cold and implacable eye on the accuracy and creativity of all intellectual work, and particularly his own.

The issue has a bearing on this article. Any red-blooded economist has at least one conjecture about what happened in the technology sectors of the US economy in the last 6 years.[1] Three years of unprecedented 'boom' were followed by an equally unprecedented 'bust' of more or less similar duration – and by a sluggish economy with high unemployment and a reticence to start going. This piece reflects on this extraordinary period, and the policy lessons we learned from it.

As any other passionate economic theorist, Dave would naturally seek an explanation for this unprecedented sequence of events – yet as his passion is restrained by integrity, he would reject any hypothesis that can't withstand the scrutiny of a solid theory, such as general equilibrium or growth theories. Equally, Dave's integrity would not allow him to accept a theory – no matter how correct in analytical terms – if there is not at least a suggestion in the data that the explanation is solidly attached to reality. This context provides the rationale for the article and the way we go about it .

The article aims to develop an explanation of the 'boom and bust' phenomenon. It is based on a general equilibrium model of an economy with two sectors: one with increasing returns to scale – the knowledge sector– and another with constant returns to scale–the traditional sector; and it captures the connection

[1] Most notable was the performance of the *dot.com* sector.

with US macro economic data observed during this period. We hope– indeed we believe– that the topic and the way we are going about it, could fit Dave's own taste – although of course what is written here may not match what he would have written himself.

This article relates also to Dave Cass' work in more conventional terms. In 1990 together with Herakles Polemarchakis, Dave Cass[7] published an article, "Convexity and Sunspots: A Remark", in *Journal of Economic Theory* showing that sunspots disappear in economies with non convexities[2]. Increasing returns to scale sectors often create non convexities. The work of Dave and Herakles therefore suggests that sunspots may not be a sufficient explanation for the 'boom and bust' cycle we observed, because of the non convexities created by increasing returns would have made the sunspots disappear. One needs therefore a 'real' explanation for the phenomenon, not one that is based solely on 'expectations' such as the sunspots theory. The explanation we provide here is thus a candidate, providing at least a starting point.

Our hypothesis is that increasing returns sectors tend to grow faster than the rest of the economy during expansions, and to contract faster than the rest of the economy during downturns. In this sense, increasing returns sectors display more 'volatility' than other industries. As the knowledge sector becomes increasingly important and leads to major productivity increases, it could destabilize the economy. The problem is posed here within a general equilibrium model with two sectors, one with constant returns and the other with external economies of scale. This model was treated first in Chichilnisky [8], [9] and [10] for a different purpose and application– and the issue of 'virtuous and vicious' cycles in economies with increasing returns to scale was developed also in Chichilnisky and Heal [11] and in Heal [15]. Chipman (1970)[13] provides an excellent general equilibrium model with external economies of scale. His model differs from ours in several ways[3]. The main difference however, is in that it has only one factor and the extent to economies of scale are exogenously given, where as here (and in Chichilnisky 1993, 1994, and 1998) there are two factors and the extent of IRS is endogenously determined.

It is obviously difficult to prove our hypotheses in complete generality. One problem is to find a theoretical explanation that fits the existing data, because the data of the last ten years is particularly complex. There was a change in index numbers in 1987. Also, as is well know, when one uses nominal data, those sectors with increasing returns (whose prices drop when production expands) can be underrepresented in GDP– while the opposite is true for sectors with constant returns to scale[4]. We sought to use a measurement of volatility that

[2] We owe this comment to Paolo Siconolfi.

[3] Chipman's general equilibrium model has N firms and N industries. Firms produce with a single factor (labor) under constant returns to scale. There are external economies of scale on the level of the industry that are exogenously determined by the full employment and homogenous utility functions of all consumers/workers with uniform expenditure proportionality (also exogenous) in consumption. The model has an unique full employment equilibrium that is Pareto Optimal if production functions are homogenous of the same degree in each industry.

[4] This observation is related to comments by William Baumol on productive and unproductive sectors, and to the November 2002 publication of Survey of Current Business, U.S.

is independent of the units of measurement. For this we created the concept of 'real beta' which is a statistical relative of the "beta" that is frequently used in financial markets to measure stock price volatility. However, our 'real beta' measures real macro data on output, rather than financial data on stock prices.

In the theoretical front, we use our general equilibrium model to show that the 'real betas' of the increasing return sectors are typically larger than those of the rest of the economy. On the empirical front, we measure the 'real betas' of the appropriate sectors, and observe that the explanation appears to fit the data.

What about policy implications? There are many. First is the need for financial structures and tools that can alleviate the excessive capitalization of the increasing returns sector during the upswing and the equally excessive lack of capitalization during the downturn– both of which have serious implications for labor markets and for overall economic welfare. These financial policies could follow the footsteps of financial policy organizations such as FEMA which was created to offer financial support for catastrophe insurance, and Ginnie Mae that was created to offer financial support for mortgages accessible to low income families. Second, if the knowledge sectors expand – and some of us predict that the Knowledge Revolution^{TM} will proceed[5]– their destabilizing impact could become increasingly important. There are also implications for the global economy– changes in the pattern of trade and the volatility of the world economy as developing countries such as India 'leapfrog' from the agricultural society to the knowledge economy. We discuss some of these policy implications in the Conclusions.

The structure of the article is as follows: first we explain our working hypothesis in more detail defining our "real beta" measure of macroeconomic volatility for the different sectors of the economy. Second, we present the general equilibrium model of an economy with two sectors and two inputs, having increasing returns to scale that are external to the firm and internal to one of those sectors. We then show how to solve analytically this general equilibrium model finding all prices, production, employment levels and net trades in equilibrium, by means of a single 'resolving' equation. Then we show explicitly, using the equations of the model, that the 'real beta' is typically higher for the increasing returns sector than for the rest of the economy. Finally we provide details of the data used, and present the observed real betas during the relevant period (1977-2001). The last section provides a brief review of the literature, and the policy conclusions.

2 Volatility in the Knowledge Sectors

Our hypothesis is that increasing returns to scale industries (IRS) amplify the business cycles. More specifically, we believe that during an upswing of the

BEA[29].

[5] Namely a change in the economy in which there is a shift in the importance of inputs of production, with knowledge becoming the most important inoput rather than capital.

economy, IRS industries grow faster than the economy as a whole and specifically faster than the CRS or DRS industries; and during downturns, the opposite is true, the IRS industries contract faster than the CRS or DRS. Intuitively this hypothesis comes from the fact that as the IRS industry grows its costs fall allowing prices to fall and generating increased demand for IRS goods. This contributes to a cycle of increased production, sales and profits. For example, in the period between 1990 and 2000, the expansion in output in the computer hardware industry led to yearly doubling of the computing power available per dollar, leading to an exponential increase in CPUs per dollar (a standardized measure of processing power) and to the corresponding rapid increase in demand and consumption of CPUs across the entire economy. Under increasing returns, increased production reduces costs further, allowing for a additional fall in prices. This process goes on until there is a significant correction in demand due to a shift in the business cycle. For the decreasing returns (DRS) or constant returns (CRS) industries, increases in production can increase costs, and therefore increase prices, eventually dampening demand which in turn decreases output. This simple example suggests intuitively how an expansion in the economy can generate higher growth rates in IRS industries than that in CRS or DRS industries. The opposite happens in a downswing. Two types of cycles occur simultaneously in the economy–one for IRS sectors, the second for CRS sectors. Formal examples of "virtuous" and "vicious" cycles for the economy as a whole can be found in Chichilnisky and Heal [11], chapter 9.

2.0.1 Volatility Index– the 'real beta'

To prove our hypothesis, we use an index to measure volatility that is independent of the scale of the variables. For this purpose we define a new concept denoted 'real beta' which is a statistical relative of the financial markets concept of 'beta' that is frequently used to measure volatility of stock prices:

$$\beta = \frac{Cov(X,Y)}{Var(Y)} \tag{1}$$

Here X and Y are real variables rather than stock prices, X representing the output of the sector and Y the output of the entire market. In the following we compute separate 'real betas' for the IRS sector or for the CRS sector X, taking GDP, Y, as the market.

In a two sector economy, let β_{IRS} denote the real beta associated with the increasing returns sector, and let β_{CRS} denote the beta associated with the constant returns to scale sector. Our hypothesis can now be stated simply as follows

Hypothesis:

$$\beta_{IRS} > \beta_{CRS}$$

when the IRS industry and its 'returns to scale' are large enough[6].

[6] A parameter γ measuring 'returns to scale' is defined in the GE model below.

3 Economies of Scale

3.1 Definition of Increasing Returns to Scale

A firm or an industry is said to have *increasing returns to scale* (IRS) when its unit costs fall with increases in production.[7] Here we differentiate between two 'types' of economies of scale: *internal* and *external* to the firm. In reality, no firm is a perfect example of either; typically one has a combination of both characteristics. Economies of scale are *internal* to the firm when a firm becomes more productive, i.e. more efficient in utilizing its resources, as its own size increases. These economies of scale are typical to firms with large fixed costs such as aerospace, airlines, and oil refineries. This type of increasing returns can lead to monopolistic competition due to high entry costs.

Increasing returns to scale are *external* to the firm when the increased productivity comes about as a result of decreasing unit costs at the level of the industry as a whole. Each firm in these industries could have constant unit costs as its production increases, and these firms are typically competitive. But as the industry as a whole expands, positive externalities are created among them – for example in the production of R&D– leading to increased productivity for all firms in the industry. The free movement of skilled workers from one firm to another can have this effect, as the firm may benefit at no cost from the training that a worker has received in another firm[8]. Equally, a firm can benefit from unspecific research and development innovations developed in other firms, which are accessible to it at little or no cost. These positive 'knowledge spillovers' often originate from innovations generated by each of the firms during the course of production. As the new knowledge spreads to all the firms in the industry, total productivity in the industry increases and unit costs fall. Any industry that depends on knowledge or skilled labor could benefit from such knowledge spillovers and thus could benefit from external economies of scale. In the growth literature related phenomena are known as 'learning by doing', a concept introduced by Arrow [2] and developed further by Romer [25]. But in this literature 'learning by doing' often refers to increasing returns that are internal to the firm. From now on, we will focus on increasing returns that are external to the firm and internal to an industry.

4 General Equilibrium Model with External Economies of Scale.

We follow closely the general equilibrium framework with increasing returns to scale that was created by G.Chichilnisky [8], [9], and [10], for different economic application.

[7] Sometimes it is 'average' unit costs that decrease with production.

[8] Workers in the knowledge sectors move between firms more than others, on average one in two years or less.

An open economy produces and trades two goods B (basic goods) and I (industrial goods). B is a traditional (CRS) industry, whereas I is produced under external economies of scale (IRS). Both goods are produced using two inputs, labor L and capital K. Firms in each industry are perfectly competitive. They minimize their costs given the world prices in the economy. Consumers maximize their utility given their budged constraints. Walras' law is satisfied, so the value of excess demand is equal to zero. At equilibrium all markets for goods and factors clear.

Production functions are given as:

$$B^s = L_1^{\alpha} K_1^{1-\alpha} \tag{2}$$

$$I^s = \gamma L_2^{\beta} K_2^{1-\beta}$$

where $\alpha, \beta \in (0,1)$, $\gamma > 1$ indicating increasing returns to scale in the I industry; $\gamma = 1$ in the B industry, indicating that it has constant returns to scale. $L_1, K_1$are inputs in the B sector, and L_2, K_2 are inputs in the I sector. The total amount of labor and capital in the economy are L^s and K^s respectively. Prices for I and B are p_I and p_B respectively. We assume that I is the numeraire so that:

$$p_I = 1 \tag{3}$$

then

$$Y^s = I^s + p_B B^s \tag{4}$$

indicates the value of total production in the economy.

Factor prices are denoted as usual, w for wages and r for rental on capital. We assume for simplicity that demand for basic good is a function of initial endowments and p_B[9]:

$$B^d = B^d(L^S, K^S, p_B) \tag{5}$$

By Walras Law, demand for industrial goods in equilibrium is given by:

$$I^d = (wL^s + rK^s - p_B B^d) \tag{6}$$

In equilibrium all markets clear:

$$p_B^* B^{s*} + I^* = wL^* + rK^* \text{ (zero profits)} \tag{7}$$

$$K^* = K^s = K_1 + K_2 \text{ (capital market clears)}$$

$$L^* = L^s = L_1 + L_2 \text{ (labor market clears)}$$

$$B^{s*} = B^{d*} + X_B^* \text{ (}B\text{ market clears)}$$

$$I^{s*} = I^{d*} + X_I^* \text{ (}I\text{ market clears)}$$

where X_B^* is the equilibrium level of net exports in B sector and X_I^* is the equilibrium level of net exports in I sector.

[9] The results of the model do not depend on the demand specification.

4.1 Solving the Model

Chichilnisky[8], [9], and [10] provides step by step instructions on how to solve the model which are reproduced in the Appendix to this article. She proves the existence of a 'resolving equation' $F(p_B) = 0$. This resolving equation is a single equation on the variable p_B from which the equilibrium value p_B^* can be obtained– from this value the equilibrium values of all the other variables are in turn found.

In obtaining the resolving equation, there is an additional level of complexity since the returns to scale depend on a scale parameter γ – but this scale parameter is itself unknown until the output of the I sector has been computed at an equilibrium. This is because the economies of scale in the I sector are external to the firm and they depend on the industry size (at an equilibrium). We resolve this problem by performing a simple additional 'fixed point' argument, in which the scale parameter and the level of equilibrium output are simultaneously determined. Below we show how this is achieved. For the complete computation of the resolving equation see the Appendix.

The equilibrium level of output is a function of equilibrium prices p_B^* and the scale parameter γ:

$$I^{s*} = \gamma \Phi(p_B^*) \tag{8}$$

or equivalently,

$$p_B^* = \frac{\Phi^{-1}(I^{s*})}{\gamma} \tag{9}$$

As shown in the Appendix, Φ is a function of both γ and p_B, while γ depends on the equilibrium level of output in sector I. We postulate that:

$$\gamma^* = \gamma(I^*) = I^\sigma, \text{ with } \sigma > 1, \tag{10}$$

Therefore, in order to obtain the resolving equation as an explicit functions of equilibrium prices alone, we must also find the equilibrium value of $\gamma = \gamma^*(I)$. This is a 'fixed point' problem because γ depends on p_B and at the same time p_B depends on γ. This 'fixed point' problem is fully solved in the Appendix. Here we indicate how this is achieved. Taking (11) and (10) into account, (2) can be rewritten as:

$$I^{s*} = \Phi(p_B^*)^{1/(1-\sigma)} \tag{11}$$

$$B^{s*} = \Psi(p_B^*)$$

These relationships express output solely as a function of prices, and are used in the following proposition:

Proposition 1 *The 'real betas' of the IRS sectors are larger than those of the CRS sectors, i.e.* $\beta_{IRS} > \beta_{CRS}$, *when the size of the IRS industry and its scale* γ *are large enough.*

Proof. We want to prove the following inequality:

$$\beta_{IRS} = \frac{Cov(I_t, Y_t)}{Var(Y_t)} > \beta_{CRS} = \frac{Cov(B_t, Y_t)}{Var(Y_t)} \tag{12}$$

or equivalently:

$$Cov(I_t, Y_t) > Cov(B_t, Y_t) \tag{13}$$

because the denominators are positive.

We proceed by rewriting (12) in a form in which the inequality becomes clear. Equation (13) can be written as

$$E(I_t - \bar{I})(Y_t - \bar{Y}) > E(B_t - \bar{B})(Y_t - \bar{Y}) \tag{14}$$

where $\bar{I}, \bar{B}$,and $\bar{Y}$ are as: $\bar{Y} = \frac{1}{T}\sum_{t=1}^{T} Y_t$

Rewriting the covariance and opening up the parentheses, this becomes:

$$E(I_tY_t - I_t\bar{Y} - \bar{I}Y_t + \bar{I}\bar{Y}) > E(B_tY_t - B_t\bar{Y} - \bar{B}Y_t + \bar{B}\bar{Y}) \tag{15}$$

or

$$E(I_tY_t - B_tY_t + B_t\bar{Y} + \bar{B}Y_t - \bar{B}\bar{Y} - I_t\bar{Y} - \bar{I}Y_t + \bar{I}\bar{Y}) > 0 \tag{16}$$

i.e.

$$E(I_tY_t) - E(B_tY_t) + E(B_t\bar{Y}) + E(\bar{B}Y_t) - E(I_t\bar{Y}) - E(\bar{I}Y_t) - E(\bar{B}\bar{Y}) + E(\bar{I}\bar{Y}) > 0 \tag{17}$$

Multiplying both sides by $\frac{1}{T}$ we obtain

$$\frac{1}{T}[E(I_tY_t) - E(B_tY_t)] + \bar{B}\bar{Y} - \bar{I}\bar{Y} > 0. \tag{18}$$

Let $\bar{B}\bar{Y} - \bar{I}\bar{Y} = \bar{Z}$, (thus $\bar{Z}$ =constant) and substituting in for Y_t from (4), the last equation can be rewritten as

$$\sum_{t=1}^{T}[I_t(p_BB_t + I_t) - B_t(p_BB_t + I_t)] + T\bar{Z} > 0 \tag{19}$$

or

$$\sum_{t=1}^{T}[I_t^2 + (p_B - 1)I_tB_t - p_BB_t^2] + T\bar{Z} > 0 \tag{20}$$

substituting in for p_B from (9) we obtain:

$$\sum_{t=1}^{T}[I_t^2 + (\frac{\Phi^{-1}(I_t^{s*})}{\gamma} - 1)I_tB_t - \frac{\Phi^{-1}(I_t^{s*})}{\gamma}B_t^2] + T\bar{Z} > 0 \tag{21}$$

For every t this relationship is obviously true if the scale parameter γ and I, the size of the industry, are both large enough, therefore proving the proposition. ■

5 Empirical Issues

5.1 Data Sources and Structure

We use data provided by the *Survey of Current Business (SCB)*[10], prepared by the *U.S. Department of Commerce, Bureau of Economic Analysis* (BEA), in Washington, DC. This survey offers data on GDP by industry (2-3 digit Standard Industry Codes (SIC))[11]. There is a "break" in the time series of this data due to the SIC reclassification. Thus, 1977-1987 data uses 1972 SIC classification, whereas 1987-2001 uses 1987 SIC classification (the estimates of 1977-1987 have not been adjusted to 1987 SIC code due to "lack of adequate data" according to BEA May 2003 publication[28]). Figure 2 lists the available sectors used for our study.

Data is available in several forms:

1. GDP by industry in current dollars
2. GDP by industry in current dollars as a percentage of GDP
3. Chain-type Quantity Index for GDP by Industry, 1996 as a base year.
4. Chain-type Price Indexes for GDP by Industry

5.2 Data Issues

Several issues should be noted. In 1996 the BEA revised national income and product accounts introducing chain-type annual-weighted indexes, also known as Fisher indexes, to measure real output and prices. This new measure takes into account the changes in the relative prices and in the composition of the output over time. Thus, the chain-type index eliminates the major source of the bias in the previously used fixed-weighted, or Laspeyres' measure. "The chain-type estimates provide users with dollar-denominated measures of real GDP by industry, but they do not provide accurate estimates of industry shares of real GDP or of industry contributions to real GDP growth," see SCB November 2002 publication [29]. Due to this nonadditivity property of the data we could not compute an index of IRS industries. In this November 2002 publication the BEA advises to use nominal shares for such computations, but it warns that such measures will understate the share, especially for fast growing industries with plummeting prices, such as information technology, (the problem lies exactly in the industries of our primary interest). But even though real GDP series should not be used for share computations, real GDP level or growth rates data is preferred to nominal GDP. "The chain-type indexes eliminate an understatement of growth in investment spending in the past and an overstatement in current

[10] Monthly government publication to be found in www.bea.gov.
[11] Detailed data series are available at the BEA webpage:
http://www.bea.gov/bea/dn2/gpo.htm

periods. It also avoids misstatement of growth by industry." [31]. In view of this, in computing our 'real betas' we used real GDP by industry figures.

5.3 IRS and Traditional Industries

Due to the importance of IRS industries several studies have tried to quantify IRS empirically. Though these studies carefully examined manufacturing industries, neither of them looked at the disaggregated service sector as a whole, nor at finance data. In this paper, we reviewed the literature and adopted its findings about IRS sector as shown in Figure 1. We also use a simple correlation between quantities produced and prices charged on the level of industry to identify IRS industries (IRS if correlation is negative)[12]. A more careful investigation of this issue is left for future research. Thus, when choosing the IRS sectors for our study we closely followed the findings of the studies outlined in Section 6 of this article and the results from the correlation coefficients analysis. From the list of industries in Figure 1 we separated out the industries with economies of scale that seem to be internal to the firm in order to conform to the model specification, or industries that have well-known high fixed costs. We were left with 7 industries which could be said to have 'external' economies of scale:

1. Credit agencies other than banks (SIC 61)
2. Electronic equipment and instruments (36, 38)
3. Machinery, except electrical (35)
4. Retail Trade (52-59)
5. Security and commodity brokers (62)
6. Telephone and telegraph (481, 482, 489)
7. Wholesale Trade (50, 51).

6 Brief Review of the Literature

Although economies of scale have received a lot of attention in economic theory, to our knowledge, the effect of the business cycles on the various industries with economies of scale has not been examined. Thus, for example, the focus of the Real Business Cycle models has been on including IRS in order to generate cyclical productivity[13]. In international trade, IRS is seen as determining the pattern and the factor content of trade[14]. In growth literature, learning by doing leads to endogenous growth in the economy[15]. In theoretical macrodynamic

[12] Specifically, we used chain-type quantity index for GDP by industry and chain-type price index for GDP by industry from BEA for our correlation computations. Detailed data files can be downloaded at: http://www.bea.gov/bea/dn2/gpo.htm.

[13] See for example S. Basu and J. Fernald [3] and [4] for a short review of the litrature.

[14] See for example Krugman [18], [19], [20], and [21], Panagariya [22], and Antweiler et al. [1].

[15] See Arrow[2], Romer [25], and Rivera-Batiz and Romer [24].

general equilibrium models, IRS may lead to unstable systems and may generate "vicious" and "virtuous" cycles in the economy[16].

Several recent empirical studies identify returns to scale for some of the industries detailed in Figure 2. Work by W. Antweiler and D. Trefler [1] examine 27 manufacturing and 7 non-manufacturing industries (no services) for 71 countries over 1972-1992 period and identified 11 industries with increasing returns:

1. Petroleum and Coal Products
2. Pharmaceuticals
3. Electric and Electronic Machinery
4. Petroleum Refineries
5. Iron and Steel Basic Industries
6. Instruments
7. Non-Electric Machinery
8. Forestry
9. Livestock
10. Crude Petroleum and Natural Gas
11. Coal Mining.

Their general equilibrium model estimates scale for these industries in the rage of 1.10 to 1.20.

A study by S. Basu and J. Fernald [3] find IRS in:

1. Metal Mining
2. Construction
3. Furniture
4. Paper
5. Primary Metals
6. Fabricated Metals
7. Electrical Machinery
8. Motor Vehicles
9. Transportation
10. Communication
11. Electric Utilities
12. Wholesale and Retail
13. Services (various).

Paul and Siegel [23] find that scale economies are prevalent in US manufacturing. In particular, this study finds evidence of external economies of scale due to supply-side agglomeration.

The following Figure 1 lists the IRS sectors identified in the above mentioned studies, showing in each case the respective sources.

7 Empirical Results

The market 'real beta', by definition, is equal to one. Figure 3 provides real betas for industries with external economies of scale and for some traditional

[16] See Chichilnisky and Heal[11] and Heal [15], [14] for more detail.

Figure 1: List of Increasing Returns to Scale Industries Identified by the Literature Review and Correlation Coefficient Specification.

	1977-2001	1977-1987	1987-2001	Identification
Agriculture, forestry, and fishing	1.13	1.64	1.08	AT
Credit agencies other than banks	3.97		3.97	corr=<0
Coal mining	1.28	0.86	1.56	AT
Communications	1.46	0.92	1.89	BF
Construction	0.69	0.45	0.84	BF
Electronic equipment and instruments	2.05	0.98	3.07	BF, AT
Fabricated metal products	0.61	0.52	0.73	BF
Furniture and fixtures	0.67	1.27	0.7	BF
Machinery, except electrical	2.18	0.93	3.09	AT
Metal mining	1.88	0.33	2.25	BF
Motor vehicles and equipment	0.58	0.56	1.18	BF
Oil and gas extraction	0.06	-0.01	-0.24	AT
Paper and allied products	0.4	0.75	0.02	BF
Petroleum and coal products	0.8	2.59	0.33	AT
Primary metal industries	-0.02	-2.54	0.71	BF
Retail trade	1.24	1.43	1.55	BF
Security and commodity brokers	2.87	0.85	4.65	corr<0
Services	1.06	1.14	1	BF
Telephone and telegraph	1.55	1.08	2.16	corr<0
Transportation	1.1	0.8	1.25	BF
Wholesale trade	1.55	1.45	1.94	BF

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Detailed annual series can be found at: http://www.bea.gov/bea/dn2/gpo.htm.
Note: BF stands for S. Basu and J. Fernald study of 1997.
AT stands for W. Antweiler and D. Trefler study of 2000.

industries. What is immediately apparent is that betas for IRS industries are larger than one and are larger than that of traditional industries. In addition, breaking the data into two sub-periods, 1977-1986 and 1987-2001 (chosen arbitrarily at the break of the series) provides another interesting view of the data. The betas for IRS are larger in the second period than in the first. This phenomenon could be explained by our model: as the scale of the industry in the economy grew overtime, γ and I reached an appropriate level at which beta of IRS became larger, according to the results of the Proposition 1 above. Figures 4 and 5 illustrate graphically the differences in volatilities in the IRS and traditional sectors of the economy.

8 Conclusions

We saw that many increasing returns to scale industries are more volatile than the rest of the economy, in the sense of having higher 'real betas'. We interpreted this by saying that these sectors expand faster in an upswing and contract faster in a downswing than the rest of the economy[17]. The general equilibrium model on which these results are based has one sector with external economies of scale and another with constant returns to scale. It appears that the empirical results may hold for other forms of increasing returns as well, beyond those which appear in this general equilibrium model. This includes those IRS that are internal to the firm and are based on fixed costs– such as those in oil refineries and the airspace industry.

The results seem to confirm an intuitive view of a modern economy with rapidly growing productivity in sectors that could destabilize the economy. Indeed, the most productive sectors could be the most volatile. Obviously one does not want to miss the productivity gains of the IRS sectors – while at the same time it seems desirable to curb their volatility. What is the policy solution for this dilemma?

One possibility is to develop financial mechanisms that can 'smooth' the volatility of the increasing returns sectors as the economy goes through the business cycle. In the financial sectors, 'futures' markets served historically this role for commodity markets, which are notoriously volatile. It has been shown that they can do this job well if properly managed, see for example the work of Jerome Stein [27] and other authors. The policy of choice could involve creating the equivalent of futures markets for moderating the volatility of the technology industry, rather than for moderating the volatility of the stock and the prices of commodities. Another solution would be to create an institution that uses the Law of Large Numbers (such as Ginnie Mae was created to do). For example, an organization that is 50% government owned and 50% privately owned— with a public aim (in this case, to control volatility) while at the same time being a for-profit organization.

[17] In principle, a higher 'real beta' could be associated with the opposite effects, namely a countercyclical movement of the IRS sectors– but our empirical observations eliminate this possibility.

More empirical analysis is needed about what type of returns to scale lead to the most extreme forms of volatility. The industries with external increasing returns to scale could have this role. Equally the results need to be expanded to explain the changes in international trade patterns as developing countries 'leapfrog' their industrial counterparts and take advantage of the external returns to scale industries. A good example is software development that is based on knowledge and yet requires little capital or equipment, therefore having small fixed costs. India's Bangalore region is a leader in software exports and fits this pattern.

9 Appendix.

9.1 Finding a resolving equation for the General Equilibrium Model

This Appendix draws on the results of G. Chichilnisky [8] pages 189-195, but unlike those previous articles this model has one industry, I, with external economies of scale, and the other, B, with constant returns to scale, and this is an open economy — rather than two trading economies– with trade balances given as exogenous parameters.

To solve the model presented in this article, there are three prices to be determined: the "terms of trade" p_B^*, and two factor prices w and r. The quantities to be determined in an equilibrium are: the use of factors in each sector: K_1, K_2, L_1, L_2, the outputs of the two goods B^S and I^S, the corresponding parameter γ determining the external economies of scale, and the demand for each good B^{d*} and I^{d*}.

We now solve the model by finding an explicit function of the terms of trade p_B which otherwise depends only on exogenously given parameter of the economy: $\alpha, \beta, \sigma, B^{d*}, L^S$ and K^S. To obtain the resolving equation we write the market clearing conditions in the B market, exports equal imports, and find a way to express them as a function of only one variable: p_B. Solving this equation gives the equilibrium value of p_B. From the terms of trade in equilibrium p_B^*, we show that all other endogenous variables listed above can be found. Note that we have given no supply behavior outside of an equilibrium; in particular, there is no information for carrying out stability analysis. Since the model has constant returns to scale at the level of the firms, we derive the equilibrium relations between supplies and prices from the condition of full employment of factors together with an equilibrium condition which incorporates the external economies of scale.

Denote:

$$l_1 = \frac{L_1}{K_1}$$

$$l_2 = \frac{L_2}{K_2}$$

Since by assumption each firm takes the scale parameter γ as given, from the production functions (2), marginal conditions and zero profits imply:

$$w = \alpha(l_1)^{\alpha-1} p_B \tag{22}$$

$$r = (1-\alpha)(l_1)^{\alpha} p_B$$

$$w = \gamma\beta(l_2)^{\beta-1}$$

$$r = \gamma(1-\beta)(l_2)^{\beta}$$

so that:

$$\frac{r}{w} = [\frac{(1-\alpha)}{\alpha}]l_1 \text{ and } \frac{r}{w} = [\frac{(1-\beta)}{\beta}]l_2 \tag{23}$$

and in particular:

$$l_1 = \frac{[(1-\beta)\alpha]}{[\beta(1-\alpha)]} l_2 \tag{24}$$

Our next step is to define the "resolving equation" denoted $F = 0$ which, when resolved, yields the equilibrium value of the terms of trade p_B as a function of all the exogenous parameters of the model, of which there are 12 as listed above, and from which all other endogenous variables at equilibrium can be explicitly computed.

Indicating logarithms with the symbol "$\sim$" the four equations in (23) can be rewritten as:

$$\widetilde{w} = (\alpha-1)\widetilde{l_1} + \widetilde{\alpha} + \widetilde{p_B} \tag{25}$$

$$\widetilde{r} = \alpha\widetilde{l_1} + (\widetilde{1-\alpha}) + \widetilde{p_B}$$

$$\widetilde{w} = (\beta-1)\widetilde{l_2} + \widetilde{\beta} + \widetilde{\gamma}$$

$$\widetilde{r} = \beta\widetilde{l_2} + (\widetilde{1-\beta}) + \widetilde{\gamma}$$

so that:

$$(\alpha-1)\widetilde{l_1} + \widetilde{\alpha} + \widetilde{p_B} = (\beta-1)\widetilde{l_2} + \widetilde{\beta} + \widetilde{\gamma} \tag{26}$$

$$\alpha\widetilde{l_1} + (\widetilde{1-\alpha}) + \widetilde{p_B} = \beta\widetilde{l_2} + (\widetilde{1-\beta}) + \widetilde{\gamma}$$

or equivalently:

$$(\alpha-1)\widetilde{l_1} - (\beta-1)\widetilde{l_2} = \widetilde{\beta} - \widetilde{\alpha} - \widetilde{p_B} + \widetilde{\gamma} \tag{27}$$

$$\alpha\widetilde{l_1} - \beta\widetilde{l_2} = (\widetilde{1-\beta}) - (\widetilde{1-\alpha}) - \widetilde{p_B} + \widetilde{\gamma}$$

Solving for $\widetilde{l_1}$ and $\widetilde{l_2}$ we obtain:

$$\widetilde{l_1} = \frac{(\widetilde{\beta} - \widetilde{p_B} - \widetilde{\alpha} + \widetilde{\gamma})(-\beta) - (1-\beta)[(\widetilde{1-\beta}) - \widetilde{p_B} - (\widetilde{1-\alpha}) + \widetilde{\gamma}]}{[\beta - \alpha]} \tag{28}$$

and

$$\widetilde{l_2} = \frac{(\alpha - 1)[(\widetilde{1-\beta}) - \widetilde{p_B} - (\widetilde{1-\alpha}) + \widetilde{\gamma}] - \alpha(\widetilde{\beta} - \widetilde{p_B} - \widetilde{\alpha} + \widetilde{\gamma})}{[\beta - \alpha]} \tag{29}$$

from (28) and (29) we obtain

$$\widetilde{l_1} = \frac{\widetilde{p_B}}{(\beta - \alpha)} + A \tag{30}$$

and:

$$\widetilde{l_2} = \frac{\widetilde{p_B}}{(\beta - \alpha)} + B$$

where:

$$A = \frac{(\widetilde{\beta} - \widetilde{\alpha})(-\beta) - (1-\beta)[(\widetilde{1-\beta}) - (\widetilde{1-\alpha})] - \widetilde{\gamma}}{[\beta - \alpha]}$$

and

$$B = \frac{(\alpha - 1)[(\widetilde{1-\beta}) - (\widetilde{1-\alpha})] - \alpha[\widetilde{\beta} - \widetilde{\alpha}] - \widetilde{\gamma}}{[\beta - \alpha]}$$

and observe that

$$A > 0 \text{ and } B < 0 \text{ if } \beta < \alpha$$

Therefore:

$$l_1 = e^A p_B^{1/(\beta - \alpha)} \tag{31}$$
$$l_2 = e^B p_B^{1/(\beta - \alpha)}$$

Now:

$$l_2 = \frac{L^S - L_1}{K^S - K_1} \tag{32}$$

or

$$L^S - L_1 = l_2(K^S - K_1)$$

and

$$L_1 = L^S - l_2(K^S - K_1)$$

at same time:

$$l_1 = \frac{L_1}{K_1} \tag{33}$$

or

$$L_1 = l_1 K_1$$

so that:

$$L^S - l_2(K^S - K_1) = l_1 K_1$$

or

$$K_1(l_1 - l_2) = L^S - l_2 K^S$$

Thus the quantity of K and L demanded in the B sector are:

$$K_1 = \frac{L^S - l_2 K^S}{(l_1 - l_2)} \tag{34}$$

and

$$L_1 = \frac{l_1}{(l_1 - l_2)}(L^S - l_2 K^S) \tag{35}$$

from which together with (32) we obtain the levels of supply of labor and capital used in each sector. From (31), (34), (35) we obtain:

$$L_1 = \frac{e^A L^S}{(e^A - e^B)} - \frac{e^A e^B}{(e^A - e^B)} K^S p_B^{1/(\beta-\alpha)} \tag{36}$$

and:

$$K_1 = \frac{L^S}{(e^A - e^B)} p_B^{1/(\beta-\alpha)} - e^B(e^A - e^B)K^S \tag{37}$$

which are functions of a single variable p_B. The constants A and B depend in turn on the scale factor γ. From (2), (36), and (37) we obtain the quantity of B and I produced at each level of relative prices, p_B.

Equations (36) and (37) hold for any level of γ. In particular, taking $\gamma = 1$, we denote these as $\Phi(p_B)$ and $\Psi(p_B)$ respectively. Therefore, from (2) we obtain the equilibrium level of output as a function of equilibrium prices:

$$I^{s*} = \gamma \Phi(p_B^*) \tag{38}$$

and

$$B^{s*} = \Psi(p_B^*)$$

However for industry I, this does not express output as an explicit function of equilibrium prices alone as we wished, because $\gamma = \gamma(I)$, and $I(\gamma, p_B)$. In order to obtain output as explicit functions of equilibrium prices we must therefore find out the equilibrium value of the scale parameter $\gamma^* = \gamma^*(I)$. As already mentioned in the text, this is an additional "fixed point" problem, since γ depends on I while I depends on γ. We solve this as follows.

The economy has increasing returns which are external to the firm, and the parameter γ increases with the level of output of I. We postulate for example, that

$$\gamma = I^{\sigma}, \tag{39}$$

where $\sigma > 1$.

At an equilibrium equations (38) and (39) must be simultaneously satisfied, i.e.:

$$\gamma = [\gamma \cdot \Phi(p_B)]^{\sigma} = \gamma^{\sigma}\Phi(p_B)^{\sigma} \tag{40}$$

or

$$\gamma^{1-\sigma} = \Phi(p_B)^{\sigma}$$

Thus,

$$\gamma = \Phi(p_B)^{\sigma/(1-\sigma)}$$

Therefore at an equilibrium from (38) we obtain a relation between the outputs of B and I and p_B:

$$I^{s*} = \Phi(p_B^*)^{1/(1-\sigma)} \tag{41}$$

$$B^{s*} = \Psi(p_B^*)$$

Observe that:

$$\text{when } \sigma > 1,\ \theta = \frac{1}{1-\sigma} < 0$$

so that $I^{s*} = \Phi(p_B^*)^{1/(1-\sigma)}$ decreases with p_B across equilibria, since $\Phi(p_B)$ is an increasing function of p_B for each fixed γ.

We can now find the 'resolving equation' for the model. Consider the market clearing condition in B. At a world equilibrium, the B market must clear so that:

$$B^{d,1}(p_B) - B^{s,1}(p_B) = TB(p_B) \tag{42}$$

where $TB(p_B)$ is trade balance parameter, taken as given in this model (which could be =0),

or:

$$F(p_B) = B^{d,1}(p_B) - B^{s,1}(p_B) - TB(p_B) = 0$$

From (5), (6), (23), (32), and (41), equation (42) is a function of the variable p_B alone, which we call a "resolving" equation for this model. Solving this equation gives equilibrium values of p_B from where all equilibrium values of other variables can be computed as shown above. The model is thus solved.

9.2 Charts and Figures

Figure 2: List of All External Increasing Returns to Scale and Traditional Industries Used in This Study, Their 'Real Betas' and Nominal Shares

	1977-2001		1977-1987		1987-2001	
Industry (SIC)	**beta**	**shares[1]**	**Beta**	**shares**	**beta**	**shares**
IRS						
Credit agencies other than banks (61)	2.9	0.9	0.8	0.6	4.7	1.1
Electronic equipment and instruments (36, 38)	2	2.6	1	2.7	3.1	2.6
Machinery, except electrical (35)	2.2	2.1	0.9	2.5	3.1	1.8
Retail trade (52-59)	1.2	9	1.4	9.1	1.5	8.9
Security and commodity brokers (62)	4	0.5		0.4	4	0.5
Telephone and telegraph (481, 482, 489)	1.5	2.2	1.1	2.3	2.2	2.1
Wholesale trade (50, 51)	1.6	6.8	1.5	6.9	1.9	6.7
Total Share of IRS Industry		*24.8*		*25*		*24.6*
Traditional						
Apparel and other textile products	0.1	0.5	0.7	0.6	-0.5	0.4
Chemicals and allied products	0.9	1.8	0.5	1.7	0.7	1.9
Food and kindred products	0.5	1.7	1.4	1.8	0.1	1.5
Furniture and fixtures	0.7	0.3	1.3	0.3	0.7	0.3
Leather and leather products	-1.1	0.1	-2.6	0.1	-1.3	0.1
Lumber and wood products	0.2	0.6	1.6	0.7	-0.4	0.5
Miscellaneous manufacturing industries	1	0.3	0.8	0.4	0.9	0.3
Paper and allied products	0.4	0.8	0.8	0.8	0	0.7
Printing and publishing	-0.1	1.2	1.1	1.2	-0.6	1.2
Real estate	0.9	11	1	10.4	0.9	11.3
Textile mill products	0.4	0.4	0.6	0.5	0	0.3
Total Share of Traditional Industry		18.7		18.5		18.5

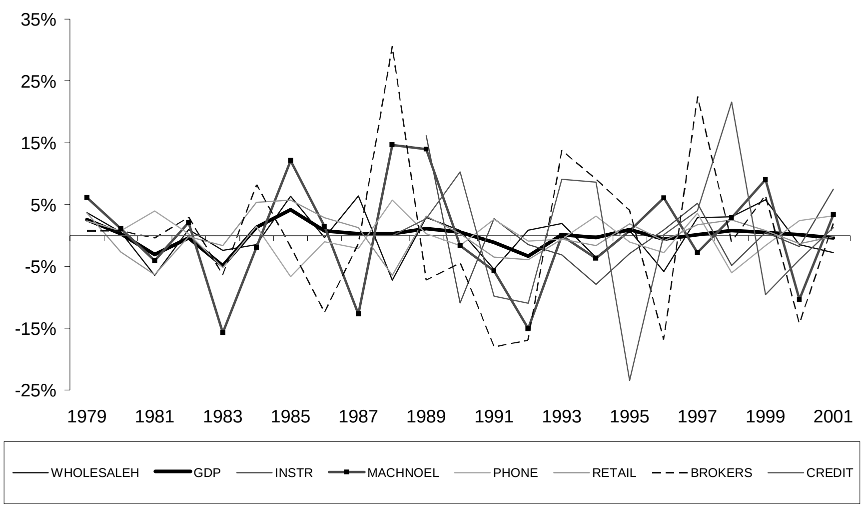
Source: U.S. Department of Commerce, Bureau of Economic Analysis. Detailed annual series can be found at: http://www.bea.gov/bea/dn2/gpo.htm.
Note: Gross Product Originating by Industry Share of Gross Domestic Product in percent.

Figure 3: List of All U.S.Industries by 2-digit SIC Classification Used by BEA.

Gross domestic product	Wholesale trade
Private industries	Retail trade
Agriculture, forestry, and fishing	Finance, insurance, and real estate
Farms	Banking
Agricultural services, forestry, and fishing	Credit agencies other than banks
Mining	Security and commodity brokers
Metal mining	Insurance carriers
Coal mining	Insurance agents, brokers, and service
Oil and gas extraction	Real estate
Nonmetallic minerals, except fuels	Nonfarm housing services
Construction	Other real estate
Manufacturing	Holding and other investment offices
Durable goods	Services
Lumber and wood products	Hotels and other lodging places
Furniture and fixtures	Personal services
Stone, clay, and glass products	Business services
Primary metal industries	Auto repair, services, and parking
Fabricated metal products	Miscellaneous repair services
Machinery, except electrical	Motion pictures
Electric and electronic equipment	Amusement and recreation services
Motor vehicles and equipment	Health services
Other transportation equipment	Legal services
Instruments and related products	Educational services
Miscellaneous manufacturing industries	Social services
Nondurable goods	Membership organizations
Food and kindred products	Miscellaneous professional services
Tobacco products	Private households
Textile mill products	Statistical discrepancy
Apparel and other textile products	Government
Paper and allied products	Federal
Printing and publishing	General government
Chemicals and allied products	Government enterprises
Petroleum and coal products	State and local
Rubber and miscellaneous plastics products	General government
Leather and leather products	Government enterprises
Transportation and public utilities	Not allocated by industry
Transportation	Electronic equipment and instruments
Railroad transportation	Depository and nondepository institutions
Local and interurban passenger transit	Business, miscellaneous professional,& other services
Trucking and warehousing	
Water transportation	
Transportation by air	
Pipelines, except natural gas	
Transportation services	
Communications	
Telephone and telegraph	
Radio and television	
Electric, gas, and sanitary services	

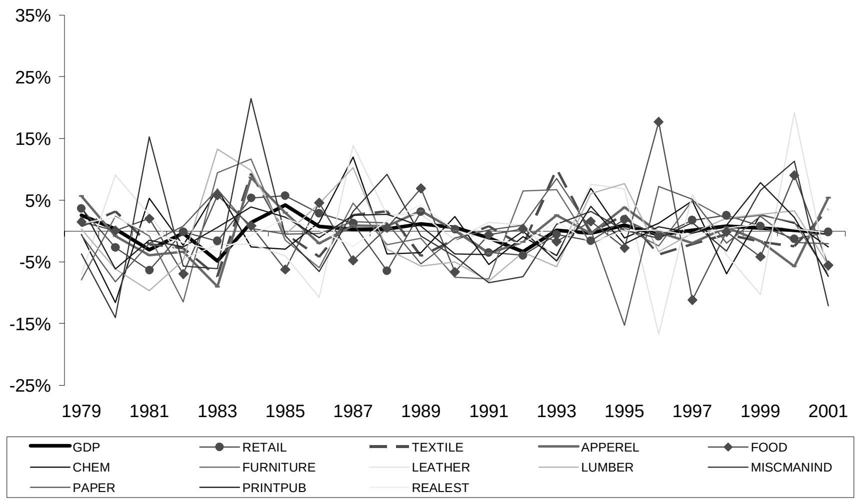
Source: U.S. Department of Commerce, Bureau of Economic Analysis, in any Survey of Current Business.

Figure 4: Graphical Illustration of Volatility in the Increasing Returns to Scale Sectors



Source: U.S. Department of Commerce, Bureau of Economic Analysis. Detailed annual series can be found at: http://www.bea.gov/bea/dn2/gpo.htm.
Note: 1. The graphed series are the growth rates in real GDP by industry detrended using the Hodrick-Prescott filter.
2. For detail on industries chosen for this figure please see the text and Figure 3.

Figure 5: Graphical Illustration of Volatility in the Traditional Sectors



Source: U.S. Department of Commerce, Bureau of Economic Analysis. Detailed annual series can be found at: http://www.bea.gov/bea/dn2/gpo.htm.
Note: 1. The graphed series are the growth rates in real GDP by industry detrended using the Hodrick-Prescott filter.
2. For detail on industries chosen for this figure please see the text and Figure 3.

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