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AN ASSESSMENT OF THE REAL EFFECTS OF FLEXIBLY ORGANIZED PRODUCTION

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Graduate School of the Ohio State University

by

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* * * * *

The Ohio State University 1995

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CHAPTER I - INTRODUCTION

1.1 Objective

Recently the literature of industrial geography has been substantially impacted by emergent notions concerning new ways in which manufacturing production is organized. The presence of flexibly organized production systems is said to entail regionally and sectorally defined dynamics that have greatly enhanced productive efficiencies in manufacturing. The objective of this dissertation is to empirically evaluate the extent to which measurable attributes of such production systems have real productivity effects. The study is confined to three industries that are heavily referenced in the literature focusing upon this thesis of flexible production (that is, of flexible specialization).

1.2 Background

In order to incorporate these attributes into a model that conforms to the broad suggestions of the
flexible specialization thesis, the assumption is made that productivity growth is concentrated in locations where output growth is comparatively high. This relationship, the positive association of productivity growth and the growth of output is represented by the Verdoorn Law. It has been at the center of a literature that has focused upon international and interregional variabilities in rates of labor productivity growth (Kaldor, 1967; McCombie and deRidder, 1984; McCombie, 1985; Casetti, 1984a, 1984b, Casetti and Jones, 1983, 1987; Casetti and Tanaka, 1992). However, it is related to the flexible specialization literature through its emphasis upon the way economic development tends to geographically concentrate rather than diffuse. The Verdoorn Law is, as an empirical regularity, representative of a more general relationship between productivity growth and output growth than are the specific conditions under which flexible specialization promotes productive efficiencies. This dissertation posits the Verdoorn relationship as fundamental, one that is subject to the influence of flexibly organized production contexts. If a real productivity effect with respect to flexible specialization exists, it should be evidenced in a premium to Verdoorn productivity effects.
that are associated with these contexts.

The geography based literature concerned with flexible production systems is situated so as to locate the spatially defined conditions of expanding manufacturing output. It therefore tends to stress the particular importance of externalities associated with agglomerative growth, rather than the firm or plant level adaptation to flexible machinery and work processes. In short, the geographic variant of the flexible specialization thesis is a theory of agglomeration fashioned to underscore the significance of externalized organizational relationships. These agglomerative externalities are associated with attributes of manufacturing plants, and are measurable at spatially aggregated resolutions. They include indicators of changes to mean plant size and to the vertical (dis)integration of production.

The importance attributed to spatially constructed externalities is evident in much of the literature on flexible specialization (Piore and Sabel, 1984; Sabel, 1989; Becattini, 1990), but it is crucial to the geographical variant, and therefore needs to be systematically evidenced. Nevertheless, the literature has largely appealed to such indicators, if at all, in
order to selectively identify the existence of agglomerative flexibilities. It has thus far not sought to measure the real effect of these identified externalized flexibilities.\textsuperscript{1} The mere presence of flexible attributes does not validate their significance to production efficiencies, and specifically to the growth of labor productivity. However, only through their positive impact upon economic efficiency are they viable long run elements of production systems.

1.3 Analytical Framework

The analysis of chapters 4, 6, and 7 entails the construction of a model, its estimation, and a review of the results.

The three industries examined, electronics/instruments, machinery, and apparel, are those held to be especially subject to the agglomerative flexibilities (Scott, 1988a, 1988c; Storper and Walker, 1989). For the first two, this is mostly a function of their market instabilities created by comparative technology-

\textsuperscript{1}Recently, Signorini has accounted for these effects in Prato relative to other regions of Italy with respect to the wool textile industry (Signorini, 1994).
intensities, and rapid rates of product innovation. The latter of the three is representative of craft type industries that are impacted by increased product differentiation and intensified competitive pressures due to the heightened significance of product quality and timely delivery.

During the 1977 to 1987 time frame of this study, all three are considered to be advancing through a process of reorganization at the industry level of resolution. The market pressures they face are said to create requisites of external cooperation and coordination that make agglomeration (or reagglomeration) increasingly desirable and necessary. The resulting agglomerative growth impels vertical disintegration making interfirm (and interplant) coordination yet more crucial (Scott and Storper, 1987; Scott, 1988a, 1988c, Walker, 1988). As a result, the reorganization process is not uniform, and is, by definition, spatially concentrated. We should, therefore, expect flexibility trends overall, as well as significant variance in them among the state level observations of the analysis. Both premises are, in fact, validated by the empirical evidence, but this study's findings indicate that each industry experiences
distinctive impacts, making it difficult to draw generalizable inferences.

An augmented Verdoorn model (AVM) accounting for the Verdoorn and capital deepening components of productivity growth is developed. Employing Casetti's expansion method (Casetti, 1972, 1982), the parameters of the AVM are redefined as functions of contextual variables indicating the externalized organizational effects of agglomerative flexibilities. The initial AVM and the expanded equations are estimated in order to evaluate the Verdoorn effect, and the impact of the production contexts upon the Verdoorn and capital deepening productivity effects. The results are considered in light of, especially, notions of agglomerative flexibilities. The contextual influence upon the Verdoorn effect is, therefore, of particular interest. Finally, parameter values for individual states are obtained in order to examine the interregional pattern of Verdoorn and capital deepening variability.
1.4 Dissertation Outline

A review of the literature concerning productivity growth and flexible production is presented in chapter 2. Chapter 3 reviews the development of the three industries examined in the analysis. The model is specified, and the methodology and variable construction is explained in chapter 4. In chapter 5 the interregional productivity and output growth patterns of the three industries over the 1977 to 1987 period are described as prelude to the analysis of estimation results. Chapter 6 examines the parameter estimations, and chapter 7 reviews the regionalization of these estimations. The conclusion follows in chapter 8.
2.1 Introduction

The review of literature in this chapter considers, in turn: 1) the foundations of spatial growth theory (section 2.2); 2) the attributes of flexible production systems (section 2.3); and 3) the characteristics of agglomerative growth corresponding to the Verdoorn and capital deepening production contexts examined in the analysis portion of this study (section 2.4). Discussion is limited to material deemed relevant to the present study.

2.2 Theories of Interregional Productivity Growth

Observed patterns of interregional growth have been explained largely by reference to theoretical perspectives reviewed in section 2.2.

Neoclassical growth theory has undergone some transformation, particularly recently, with the advent
of "new growth" theory. Neoclassical theory ascribes regional variations of productivity growth to marginal adjustments in factor reallocation. As a result, it is a theory of growth that posits a long run convergence of interregional productivity disparities.

This supply orientation is challenged by the demand emphasis of post-Keynesian theories. Demand oriented approaches range widely, and include most models that seek to account for uneven interregional development. Broadly this would include export base and cumulative causation theories. Mostly, the thesis of agglomerative flexible production emphasizes the importance of increases in (differentiated) demand. The Verdoorn Law has typically been interpreted as a relationship that is constrained by demand rather than by underlying factor supply limitations.

Sections 2.2.1 and 2.2.2 review the convergence expectations of neoclassical theory, and the salient aspects of the Verdoorn Law, respectively.

As neither of these theoretical perspectives are explicitly concerned with the interregional growth patterns of particular manufacturing industries, section 2.2.3 provides a brief discussion of the major model, the product life cycle, that attempts to generalize the
regionalization of more narrowly defined industrial sectors.

2.2.1 Neoclassical Convergence

The regional neoclassical theory of growth is the spatial adaptation of the general neoclassical model of growth. The former is largely distinguished from the latter in that it is less fully abstract, typically contending with problems of interregional factor mobility and the costs of factor reallocation across space. However, it is useful to consider the neoclassical model in its more basic abstract form.

Under its standard assumptions of perfect competition, completely employed factors of production, positive but decreasing marginal productivities, no externalities nor returns to scale, with exogenously determined savings and labor force growth rates, the neoclassical model relates increases in labor productivity to increases in the capital to labor ratio. Increased capital intensities result in increased labor productivities, but at a diminishing rate. A continued increase in the capital to labor ratio results in decreases to the marginal product of capital. In the
long run the labor productivity growth attributable to capital deepening is exhausted and further growth is achieved only through technological progress. In the standard model such progress is considered autonomous and freely available (Solow, 1956, 1957).

Therefore, when relating national (or regional) economies to one another, the only distinction between them that would influence the rate of productivity growth is the variance in the capital to labor ratio. This distinction, however, is an initial and temporary condition, disappearing once marginal capital products among economies are equalized. Economies with lower capital-labor ratios grow faster in terms of labor productivity (or income per capita) as capital in such economies achieves a higher rate of profit, and a greater per capita rate of accumulation (Baumol, 1986; Baumol, Blackman and Wolff, 1989; Barro and Sala-i-Martin, 1991; Wynne, 1992; Fagerberg, 1994). Where factor mobility between economies is less restrained, the pace of equalization is yet more rapid. This is due to the migration of each of the factors to those regions where they are in comparatively short supply. As fewer impediments to such mobility typically exist interregionally within national economies than between
countries in the international economy, the equalization of regional rather than national labor productivity growth rates is expected to occur more rapidly (Barro and Sala-i-Martin, 1991).

Eventually, the more rapid rate of capital accumulation and labor productivity growth in economies with initially low capital-labor ratios diminishes, and the rate of productivity growth converges upon that of economies with initially higher levels of capital intensity. Thereafter, in the absence of supply shocks impacting the established equilibrium of factor growth, the rate of labor productivity is determined by autonomous technical progress; that is, by the steady state rate of growth. Hence, the neoclassical theory of growth can be understood to be a theory of long run convergence, and represented as:

\[ p_{1T} = a - b(Y/L)_{10}, \]  

with \( i \) indexing national or regional economies, where \( p_{1T} \) is the rate of productivity growth through the T time period, and \( (Y/L)_{10} \) is labor productivity at the outset of the T time frame. Under neoclassical assumptions, \( (Y/L) \) is computed as the capital-labor ratio divided by the capital elasticity of output. The parameters \( a \) and \( b \) indicate, respectively, the steady state rate of growth
in the absence of convergence, and the rate at which convergence occurs. The expected negative $b$ denotes the reduction in the variance of labor productivity among the $i$ economies, or the convergence of labor productivities due to neoclassical assumptions of diminishing marginal products and the free reallocation of factors (Baumol, Blackman, and Wolff, 1989).

The relationship is not strongly supported by empirical estimations, however. Among countries, convergence only occurs within the OECD group, or among OECD and selected newly industrializing countries, and generally only through the post war period (Abramovitz, 1986, 1994; Baumol, Blackman, and Wolff, 1989). The validity of the relationship is, then, highly circumscribed and not universally valid.

Studies of convergence for U.S. states show mixed results. The early studies of the 1960's (Borts and Stein, 1964; Williamson, 1965), measuring trends in income per capita had indicated long run convergence trends. By the 1980's, studies of post-war labor productivity growth show rates that are largely indistinguishable among U.S. regions (Hulten and Schwab, 1984), or slightly enhanced in sunbelt areas (Casetti, 1984b). More recently, specific estimations of equation
(1) indicate weak to moderate support of such a relationship, finding the rate of convergence to be typically very slow (Barro and Sala-i-Martin, 1991). Crandell, however, shows that labor productivity convergence has accelerated since 1977, with sunbelt levels of productivity catching up to those of the snowbelt despite the lack of a corresponding reduction in the dispersion of manufacturing wages. He suggests that this comparative rigidity in labor compensation explains part of the apparently inexorable interregional shift in economic activity. (Crandell, 1993). His argument follows, to a degree, the institutional thesis of Olson (1982), where it is suggested that the policy environment in older core regions of development tends to limit new investments, redirecting growth to selected erstwhile peripheral areas. Recently as well, and more generally, a number of studies question the manner in which convergence has occurred, whether the growth of standardized production and branch plant activity is merely specious convergence (Williamson, 1980; Falk and Lyson, 1988), and essentially ephemeral.

The mixed empirical results have redirected neoclassical studies toward a reevaluation of why convergence might never be complete, or why it might be
interrupted by a spatial (ie. in terms of cross national and cross regional distinctions) reconcentration of activity. The Solowian treatment of technological progress is a particular difficulty in this respect, as it precludes the possibility of technology being specific to firms or interfirm organizational structures. The notion of a technological gap existing among economies, nationally or regionally defined, may be more realistic, as it suggests that technological capabilities are localized within certain types of environments (Baumol, Blackman and Wolff, 1989). At the international level, the existence of a gap in technological capability is argued to be the barrier encountered by some economies that are unsuccessful in catching up to the productivity lead of those at or near the technological frontier. On the other hand, those economies that have similar social and institutional capabilities are able to close productivity gaps where they appear, a process that seems to have occurred for some European and Asian countries relative to the U.S. during in the post war period. The thesis of a technological gap, implying the existence of different steady state rates of productivity growth to which different economies, with different underlying
technological conditions, converge, conforms somewhat better to empirical realities (Nelson, 1981; Abramovitz, 1986; Baumol, 1986; Gomulka, 1990; Nelson and Wright, 1992; Fagerberg, 1994).

The gap's existence at the interregional level would seem more speculative, as, within countries, similar technological systems more reasonably assumed. However, the striking unevenness of development (which may be more or less in evidence at different time periods) at the interregional level in the U.S. and elsewhere has lead economic geographers and regional scientists, for some time, to evaluate the way economic growth appears to spatially concentrate. The notion of regional specialization itself implies interregional differentiation along technological lines. However, the tendency of industrial production to variably concentrate is more than a function of regional sectoral specialization, as it extends to intraindustrial functional specializations, as is represented by the product cycle model (section 2.2.3). The particular functions that tend to be agglomerated in centers of localized or urbanized growth are those especially associated with technology and innovative intensive development. Such agglomerations appear to have the
organizational and infrastructural environments conducive to further growth that sets them apart as locations where steady state rates of growth are higher because the technological context is different (Malecki, 1985; Aydalot, 1988; Scott, 1988c; Storper and Walker, 1989; Storper, 1993).

If the likelihood of nationally or regionally distinct systems of production is accepted, than the possibility of achieving a steady state rate of growth becomes less tenable. In fact, the idea of a steady state becomes generally less meaningful, as different rates of technological progress are likely to be functions of production systems that are localized. It is the variability of organizational structures, the different possibilities that these create for innovation and learning, and the extent of externalities that allow for technological spillover and cumulative development of products as well as process efficiencies, that determine a range of productivity growth rates. These may appear empirically as converging rates, if, for instance, they occur in new agglomerations of former peripheries, as in the U.S. sunbelt. Or, they may appear as cumulative divergencies, where existing agglomerations continue to be centers of growth. That
systems of production are associated with agglomerated concentrations of growth is a central theme of the geographically oriented thesis of flexible production (Storper and Walker, 1989). At least in the sense that growth at its most dynamic takes on polarizing attributes, the arguments concerning the geographical basis of flexible specialization broadly correspond to notions of distinctive organizational structures and technological trajectories across economies at large.

There has been an accounting for agglomeration and human and physical infrastructural effects upon productivity in neoclassical theory at both the international and interregional levels of resolution (Denison, 1967; Carlino, 1982; Moomaw, 1983; Beeson, 1987). However, what is accounted for in most of these studies is an existing effect, which, while of varying importance, is distinct from the impact of agglomerative growth. Existing agglomeration advantages may enable a region to retain, all other factors being equal, a higher level of productivity, but it is the growth of a localized system of production that creates a premium to the rate of productivity growth. This latter mechanism is the essence of the Verdoorn Law, where the rate of labor productivity growth is a function of the rate of
output growth (Kaldor, 1967; McCombie, 1983; Casetti, 1984a, 1984b; Casetti and Jones, 1983, 1987).

"New growth" theory has recently become the foremost accommodation within the neoclassical paradigm to the realities of spatially polarized and uneven development. It represents an attempt to explain the dynamism of technological growth and of increasing returns to scale as interrelated and endogenous features of output growth (Romer, 1986, 1994; DeLong, 1992). Physical and human capital create learning and spillover economies that are external to the firm (although they can be internal to a geographically defined agglomerative production complex; Jaffe, Trajtenberg, and Henderson, 1993). Perfect competition of firms is, therefore, retained as an assumption, and factor allocations remain functions of marginal products. However, agglomerations can continue to grow and capital can continue to accumulate because the external benefits of output growth maintain (or increase) the marginal productivity of capital, even with higher capital intensities (Fagerberg, 1994).
2.2.3 Verdoorn Law

Though Kaldor did not find it necessary, nor even desirable, to retain neoclassical production function assumptions, his reasoning for employing the Verdoorn Law as a productivity relationship was similar, in many respects, to that of the new growth theory. Specifically, the external learning and technological effects of output growth were considered to underpin the Verdoorn relationship (Kaldor, 1967). Therefore, in Kaldor's interpretation of Verdoorn, it is not the existence of industrial localization that is significant, but rather the growth of localization itself that generates substantial and sustained labor productivity growth. With $q$ indicating the growth in output, $p$ the growth in labor productivity, and $i$ indexing the unit of observation, the general Verdoorn relationship is:

$$p_i = f(q_i).$$

The growth of labor productivity in manufacturing (or in a specific industrial sector) is a function of the growth in manufacturing output (or the output growth of a sector). In essence, the Verdoorn relationship is a statement concerning the productivity premium that
occurs with the growth of output. It is a scale effect, but the effect is obtained, according to Kaldor and others (McCombie, 1983; Thirlwall, 1983), by increasing degrees of industrial specialization.

The concept of returns to specialization is well known in economic geography, deriving from Adam Smith’s observations concerning the division of labor as the source of productivity growth. Kaldor’s interpretation of the Verdoorn Law is heavily dependent upon Young’s seminal statement of the relationship between economic growth and changes to the scale of production (Young, 1928). Young suggested that specialization tends to create the possibility and impetus for even greater specialization, making growth cumulative. Further this process is a "macro-phenomenon" (Young, 1928; Kaldor, 1967) where productivity growth in all sectors derives from general industrial expansion. Both intrasectoral and intersectoral linkages intensify, therefore creating additional possibilities for greater specialization.

This association of specialization and organizational externalization with the Verdoorn Law has close affinities to explanations of spatially defined flexible specialization processes. The following passage concerning industrial complex formation is
typical of the geographically oriented flexibility literature:

...production costs tend steadily to decrease everywhere on the terrain of the complex in sympathy with the widening rounds of specialization and diversification which are the inner symptoms of its growth. This process is the source, first, of deepening external economies of scale...and second, of powerful and explicitly spatial agglomeration effects. These phenomena are in turn the foundation of a distinctive Verdoorn process in which rising levels of output in a given region lead eventually to increments in industrial productivity (Scott, 1988b: 58).

It clearly follows that the Verdoorn effect is dependent upon certain, flexible, characteristics of output growth. In short, from the perspective of the flexibility literature, the particular conditions of agglomerative flexibilities offer contextual grounding for the Verdoorn relationship.

In general, the Verdoorn Law, as interpreted by Kaldor along post-Keynesian lines, or in the flexible specialization literature, is a technical relationship (Dixon and Thirlwall, 1975; Scott, 1988a, 1988c). Both perspectives identify demand, rather than factor supplies, as the constraining element to growth. Flexible specialization purportedly arises from altered types of markets, greater product specificity requisites favoring the growth of specialized output, where product lines are highly differentiated. Regional post-
Keynesian models emphasize less specified export based growth (North, 1955; Kaldor, 1970), although considerable effort has been made to identify basic (ie. exporting) and non-basic (ie. local) activity as a foundation for planning forecasts (Alexander, 1954; Richardson, 1985). Even in the context of very rapid regional growth, demand oriented theories do not often give much consideration to the possibility of supply constraints, as it is typically argued that interregional systems are open enough to enable sufficient migration of factors (Thirlwall, 1980).

As a generalization, manufacturing as a sector has typically been viewed as the exporting industry of a regional economy. Overall expansion, through the multiplier, derives from the output growth of manufacturing. This corresponds to the empirical evidence obtained from variously specified Verdoorn Law estimations (mostly cross national, but also interregional). Estimations of the Law are only significant for manufacturing, as opposed to other sectors of the economy (McCombie, 1983, McCombie and DeRidder, 1984).

As an additional theoretical matter, it has largely been assumed that the Verdoorn Law holds only at the
level of total manufacturing (Bairam, 1987). This is the
notion Kaldor voices in his early statements concerning
the fundamental returns to scale mechanism he believes
most essential (of several contributing) to the Verdoorn
Law. He says:

Precisely because so much of the economies of scale
result from increased differentiation, new processes,
and new subsidiary industries, they cannot be 'discerned
adequately by observing the effects of variations in the
size of an individual firm or of a particular industry.'
Economies of scale are derived not only from the
expansion of any single industry but from a general
industrial expansion, which should be seen, as Young put
it, 'as a interrelated whole.' With the extension of
the division of labor, 'the representative firm, like
the industry of which it is part, loses its identity.'
(Kaldor, 1967: 14; with quotes from Young, 1928: 538-
539).

The use of total manufacturing rather than industry
specific measurements, therefore, derives mainly from
theoretical considerations. In effect, the argument of
Kaldor and others (McCombie, 1983; Bairam, 1987) is that
the Verdoorn relationship is not merely a localization
phenomenon. On the other hand, it is not fully an
urbanization phenomenon either. Urbanization effects go
beyond the manufacturing sector to consider returns to
producer services, utilities, and the like. Such
effects may, however, be significant as a context within
which the Verdoorn relationship operates, a notion that
is considered in the present analysis (sections 2.4.4,
However, there exists an implied assumption that Verdoorn effects, particularly as they are related to flexible agglomerative growth, are localization effects (Scott and Storper, 1987; Storper and Walker, 1989). Moreover, some empirical evidence does indicate a localization effect at the two-digit sectoral level (McCombie, 1985). Given that the primary aim of the present study is to examine individual industries as they are impacted by the organizational context of flexible production systems, the assumption is made that the Verdoorn Law is appropriately estimated at the two-digit level.

While it can reasonably be argued that the Verdoorn Law is properly conceived as a demand constrained relationship, when modelled as an estimable function, it is potentially misspecified if the capital component of labor productivity growth is not accounted for (McCombie, 1983; Bairam, 1987). Capital deepening could account for a portion of productivity growth that might otherwise be attributed to rapid output growth. However, it could also strengthen the overall relationship by accounting for productivity growth that occurs in the absence of significant output growth.
Therefore, the Verdoorn relationship of equation (2) can be more properly specified as a returns to scale relationship augmented by a capital component, such that:

\[ p_i = f(q_i, k_i), \]  

(3)

where \( k \) is capital deepening.

This augmented Verdoorn model (3) is specified in detail in chapter 4.

2.2.3 Product Life Cycles

The product life cycle, and a set of its corollaries, has been widely used as a construct of interregionally defined growth processes. Despite considerable criticism of its rigid and linearly staged notion of product, or process and industry, development (Storper, 1985; Taylor, 1986), it has become a standard basis for conceptualizing differentiated growth across the production space economy.

The product life cycle, a model associated initially with business marketing and international trade (Vernon, 1966), defines regional industrial distinctions in terms of production activities. Regions become functionally specialized in production activities.
that are related only to a specific stage of the product life cycle. The notion has some affinity to ideas of spatial divisions of labor (Massey, 1984), and at the global level of resolution, to international divisions of labor (Froebel, Heinrichs, and Kreye, 1980). However, these latter notions emerge from a set of much different theoretical concerns, and not from the product development and production process emphasis associated with product cycles.

The increasing importance of flexible production systems, particularly, appears to significantly challenge product cycle assumptions. Underpinning flexible production are the notions of a continual contraction of demand for standardized products, and of the integration of ongoing innovation into the spheres of manufacturing itself. These contradict the existence of product or industry development stages. Under flexible organization, the design and processing phases of production are likely to become less distinguishable, and the differences between product and process innovations, critical to life cycle notions, are likely to become less distinct. In essence, the argument from the view of the flexibility thesis is that the notions of the product and related cycles are (if they ever
were) valid only in the context of mass production and Keynesian regulation, making them incommensurable with flexible (i.e. postfordist) models (Storper and Walker, 1989).

The stages that typify a product cycle are distinguishable phases of the transition from product innovation to standardized production (Vernon, 1966; Norton and Rees, 1979; Utterback, 1987). The first stage is characterized by the initial development of a product, where it is subject to significant enhancements and refinements; its market potential is assessed and it is physically tested. In a growth stage, the product, already successfully developed and with a comparatively large market potential, goes to mass production, where process innovation becomes more significant. The product is no longer subject to fundamental modifications, and an emphasis is placed on standardized production at scale, in order to reduce unit costs. Finally, a product reaches a mature stage of production, where markets are saturated, and both the product and its production process are standardized. A few, typically comparatively large firms that dominate the product's market emphasize cost containment, apply rigid managerial control over the production process, and are

The product life cycle generates an interregional segregation of phased activity. Those, relatively few, places with agglomerative advantages tend to be the source locations of product innovations. They are the loci of technology intensive activity, augmented by labor market attributes and externalized organizational characteristics associated with enhanced innovative environments. Through the growth and maturing stages, the increasing standardization of the production process, and the desire to limit (particularly labor) costs, influence firms to move production to more peripheral areas (Malecki, 1991).

Clearly, the product life cycle is the idealized formula of mass production. It remains, in fact, "a fundamental concept in marketing, where it is used to generalize about circumstances across stages for a product class or product brand" (Malecki, 1991). Undoubtedly, however, each industry, subject to its own set of technological opportunities and constraints for both products and processes, and their associated
organizational attributes, does not strictly follow such a linear and idealized path of product development. As well, industries change over time, as does the macro environment of consumer demand and available technology. Further, products are not independent of one another, and, as Malecki puts it:

Products...build upon one another and are interconnected in technological systems, families, or clusters of technologies. These might evolve as successive products following each other in rapid succession. This means that each 'new' product benefits from the knowledge and experience developed for its predecessors and its producer profits from previously generated externalities. As product lives become shorter, their ultimate sales volume also tends to shrink (Malecki, 1991: 134).

Thus the product life cycle is broadly a useful conceptual device, but is not fully valid. Its validity rests upon industry level organizational contexts, upon firm capabilities (which may vary by size) and competitive strategies with respect to product standardization. The product cycle, then, is associated to a greater or lesser extent with different industries, and within industries, with different firms. Further, this will, to some measure, correspond to technological imperatives. As Malecki's passage indicates, rapid technological innovation is likely to be both cause and effect of the breakdown of distinct product cycles.
From the point of view of the firm, the product cycle may or may not have normative, if not positive, validity. Significantly, however, at the interregional level, characteristics associated with different product cycle stages may well be distinguishable among different regions regardless of the irregularities of the model with respect to industries and firms. This is, of course, because different regions exhibit distinct attributes, and, broadly speaking, attract different types of production activities.

These considerations suggest that flexible production and product life cycles are not so much incommensurable as they are both partial theories, and apply, in varying degrees, to different industries and firms. The intermediate growth stage of the product cycle can be viewed as the source of disagreement, as it

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In the apparel industry, for instance, larger firms are likely to seek to mass produce certain products, while smaller firms must compete in small specialized product markets (Glassmeier, Thompson, and Kays, 1993). In electronic components, large producers may formulate different strategies with respect to standardization based upon their particular corporate strengths as they have evolved, as they are perceived, and as new process technology offers distinctive opportunities (Schoenberger, 1989). At the industry level, the possibility, technically, strategically, and in terms of demand, of standardized production may vary, as it does between textile and apparel manufacturing (Dertouzos, Lester, and Solow, 1989).
is here where a product's mass production commences. From the perspective of the flexibility thesis, it is at this stage where different possibilities for a product's further development remain manifold, and where standardization is merely one such possibility. This is particularly true in innovation rich industrial environments where large scale production may fail to be implemented because of uncertainties concerning the temporal resilience of the product, and the fact that the process technologies themselves take on more flexible characteristics. Indeed, as is argued by proponents of the flexibility thesis, the increased significance of scope rather than scale as a determinant of productivity gains increasingly restrains incentives for firms to follow products through to mass production (Scott, 1988c; Cusumano, 1992). Competitively, in fact, the advantage is said to increasingly favor capabilities of scope.

2.3 Flexible Production Systems

There is no doubt that recognizably significant changes to manufacturing production systems are occurring. These changes are nearly always accounted
for by reference to production "flexibility", though the term is used in many different contexts and refers to many different types of production advances (Piore and Sabel, 1984; Bessant and Haywood, 1988; Scott, 1988a, 1988c; Schoenberger, 1988; Gertler, 1988, 1992). Some of these changes are identical to those represented by "lean manufacturing" (Klier, 1993), a notion that is really less broadly encompassing, and is used more often by those directly involved in such changes, the operations and production managers themselves.

2.3.1 Introduction

In large part, these changes do not represent an integrated system of methods and processes. Rather they are a set of evolving technologies and organizational forms that potentially complement one another. As yet, the general significance of flexible production and the complementarity of its many forms has not yet been fully established. A first caveat to the possibility of the universal applicability of flexible production is that different manufacturing sectors are likely to be variously impacted by such changes. Further, different sectors and different firms are likely to adapt various
forms of flexible production systems, employing them in distinctive ways. A second caution concerning such changes is that they are going to be adopted to a greater and lesser extent, and in different ways, interregionally and internationally (Salais and Storper, 1992; Storper, 1993). That is, they may represent a technological update to the space economy, and may be associated with evidenced shifts in international and interregional economies, but they are unlikely to represent both a fundamental and universal change to systems of production (Gertler, 1992).

Forms of flexible production can be categorized into three broad classes: manufacturing technology, labor relations, and organizational externalization (Malecki, 1991).³

³This conforms to the three way classification used by Hoffman and Kaplinsky (1988) and reported on in Malecki (1991). Malecki ranges widely in his synthesis. He refers to flexible production, a term used generically in this dissertation, as manufacturing technology only. Other classifications are possible of course, and will undoubtedly alter with further developments to flexible production. Recent alternative classifications are found in Ettlinger (1992) and Klier (1993).
2.3.2 Manufacturing Technology

Flexible technology entails the use of computer programmable machinery (microprocessing technology) that enables labor saving processes to be introduced without the traditional requirement of product standardization. Rather than producing large quantities of the same product, as has been the prevailing fordist method of reducing production costs, this machinery allows economies of scale to be achieved with differentiated product specification. Some observers suggest that this allows for large reductions in minimally efficient production volumes (Bessant and Haywood, 1988). As a result, it has been proposed that flexible technology reduces or eliminates the importance of internal economies of scale relative to economies of scope (Scott and Storper, 1987; Scott, 1988a, 1988c). This claim is suspect, however, as it is not clear that the long run potential for more integrated flexible manufacturing systems cannot reimpose scale economies (Gertler, 1992).  

"Of course, future changes in demand for differentiated products will be significant in anticipating the reduced importance of scale. As well, opportunities for systems of mass production and
Programmable technology also potentially improves quality control by identifying the source of product imprecision and quickly rectifying it. Extended runs of defective products are eliminated (Jaikumar, 1986; Best, 1990), reducing dramatically the waste of materials and time. As well, retooling time and expense is vastly curtailed (Shaiken, 1984).

At present (1995), programmable processes are not yet highly integrated into all phases of production. Often they are being used at only particular stages of designing and manufacturing, though this depends upon the industry in question (and varies among firms as well). The possibility of integrating within different stages of a production sphere (ie. integrating multiple stages of design of manufacturing) is potentially widespread. While dedicated (non-flexible) capital equipment allows for the combining (integrating) of processes in order to produce standardized products, it typically also requires the increased production scale of such products (for both technical and cost flexibility to be combined within plants (firms) may establish a minimum scale requirement for efficient flexible specialization. Some evidence concerning firms' production strategies suggests that such a trend is developing (Schoenberger, 1989).
considerations). Given supposed increases in differentiated demand, this could become a particular difficulty. However, with programmable machinery, vertical integration does not, in theory, make requisite (or preferable) any changes to the scale (horizontal) of production. This flexible integration, known as flexible manufacturing systems, or FMS, of otherwise separate process stages has thus far been most heavily adopted in machinery production (Malecki, 1991).

The flexible integration of different production spheres (ie., design, manufacturing as well as inventory, sales and shipments coordination) into a single process, computer-integrated manufacturing (or CIM), is an ultimate objective of many firms. However, it requires long term planning as well as organizational capabilities that may favor large firms and those with longer planning horizons (ie. Japanese rather than American) (Bessant and Haywood, 1988; Cusumano, 1988;  

As product (or process) cycle theories would predict, reduced minimum production scale of integrating technologies occurs at formative and more experimental phases of a process innovation’s technical development. Eventually, the scale requirements increase. In the long run production at scale is likely to be necessary. Continuous casting in the primary steel sector is an example. Relatively small scale billet production had been subject to continuous casting long before it could be perfected for larger scale slab casting.

2.3.3 Labor Relations

Flexible production also entails changes to labor relations. In fordist mass production, workers engage in highly specialized and routine tasks, their job classifications being very narrowly defined and rigidly separated. Though this routinized labor system can exist independently of fordism (Ettlinger, 1992), it is thought to invariably accompany production processes associated with competitive efforts to expand product output and control costs through standardization (Braverman, 1974; Piore and Sabel, 1984; Aoki, 1984). 6

In contrast, flexible production is said to reduce task specialization and repetitiveness. Technical divisions of labor become less pronounced, as formerly separate tasks are integrated in order to produce small to moderately sized product batches. Efficiency improvements are realized by promoting labor involvement in a range of operations such that worker understanding of both the broad production process and many of its

6 ie. the standardization that is associated with mature phases of product life cycles (section 2.2.3).
details creates continuous and integrated innovations. It emphasizes the significant role of learning-by-doing in productivity gains through a system of continuous and cooperative worker monitoring of operations. This, referred to as functional labor flexibility, emphasizes multiple but shared responsibilities, rendering teamwork within production units, cooperation between production and non-production workers, and less hierarchically structured management-labor relations highly significant (Ettlinger, 1992; Klier, 1993).

Given the entrenched nature of older systems of labor practices, particularly in many long industrialized regions, it is not surprising that such a transformation to labor flexibility is not yet widely evidenced. It is also good reason to suspect (as do many of the flexibility theorists) that the growth of new flexible agglomerations are likely to occur at some sociospatial distance from older manufacturing cores (Walker 1988; Scott, 1988c; Storper and Walker, 1989).

In addition to functional flexibility, labor is

[Author's note: However, individual examples exist. Some transformation of the auto industry and its midwestern (and north central southern) complex (including machinery and metals sectors) has been observed, much of it under Japanese auspices (Mair, Florida, and Kenney, 1988; Florida and Kenney, 1988).]
said to be subject to numerical and pay flexibility as well. Numerical flexibility pertains to the firm’s capability to quickly alter the size of the labor force given demand conditions. It is represented by increasing firm reliance upon employee overtime and upon contingent employment (i.e., the dual, core/peripheral workforce) as well as by the expansion of flex-time scheduling between and among shifts. Pay flexibility refers to the trend to link wages specifically to worker capabilities within the functional flexibility production framework (Ettlinger, 1992).

Theoretical (and ideological) rifts among those who accept flexibility as the next dominant system of production are manifest concerning the labor issue. The potential flexibility effect upon the welfare of labor has been the subject of substantial conjecture and a small bit of empirical evidence. While functional flexibility seems to offer some positive change, including upskilling in less routinized and more creative work environments (Piore and Sabel, 1984), it also could bring detrimental change as well (Pollack and Bernstein, 1986; Bluestone and Harrison, 1982; Amin, 1989). Numerical and pay flexibility are typically seen as areas of potential labor abuse (Pollert, 1988).
It bears noting that, when and if flexible equipment is successfully integrated into production systems, labor content, particularly that of production labor, may contract to the point where it is no longer a strategic factor in firm, including locational, decisions (Schoenberger, 1989).

2.3.4 Organizational Externalities

Organizational externalities under flexible production denote networks of close interfirm relations, and are closely aligned to locational questions. As a consequence of firms and plants becoming more interdependent, it is said that flexible production encourages networks of producers. The industrial organization literature has shown that control and coordination priorities tend to effect, all other factors being equal, an integration of the production process (Williamson, 1981, 1985; Shapiro, 1991; Davies, 1987). Nevertheless, in the post-mass production environment it is supposed that demand uncertainties can lead, rather, to the disintegration of production and ultimately to the creation of networks of small firms and plants (Sabel, 1989; Walker, 1988;
Scott, 1988a, 1988c).

Given the demand environment, the costs of vertically integrating, particularly via standardized processes, may be too great, and options to subcontract may be preferable. Small firms may arise independently or as spinoffs of larger firms. However, the relationships between either a network of small firms, or between many small subcontractors and a few larger producers upon whom the former are reliant, are closely cooperative. The need for control over the production process, particularly at the high quality/high specificity end of the product range is undiminished, and is assured by cooperative networks. So, despite the increasing externalization of the process, control over production is maintained through the imposition of intensified interfirm relations (Scott, 1988a; Walker 1988).

Again, because of the nature of demand, input specifications are subject to abrupt alterations, such that inventories are necessarily minimized, making, in turn, effective and timely delivery of (perfectly specified) supplies essential. This system of rapid manufacturing turnaround, material waste minimization, and highly coordinated transactions, the "just-in-time"
(JIT) system, makes locational proximity of plants and firms highly desirable (but apparently not always necessary; Gertler, 1992) (Scott, 1988c). The overall notion is that firm networks operate as localizations (creating network economies), accrue other agglomeration advantages, which may include urbanization economies, from which they derive technological and innovative spillovers, all of which sustains system wide output growth by attracting other producers and endogenously generating spinoff firms.\(^8\) Malecki succinctly describes

\(^8\)Output growth continues also because the sectors in question are mostly characterized by rapid growth and technology intensity. Even where that is not the case, some versions of the flexibility thesis argue that localized centers of flexible production will continue to attract and create growth in polarizing fashion owing to superior efficiencies and greater market orientation and sensitivity (Scott, 1988c). The apparel industry exemplifies this, as it is assumed that producers will be more attracted to centers of production in industrialized economies (ie. where the markets are located) despite the deglomerative trends of the last half century.

Some of the literature pertaining to agglomerative flexibilities does not make the distinction between urban and/or high technology growth centers on one hand, and the typically smaller, yet more intensely interlinkaged, industrial districts on the other (Scott, 1988c). This makes sense when they are viewed as variations on a theme (ie. they are all seen as various examples of the universal growth of flexible production systems). However, the industrial districts of Europe (particularly of north east central Italy and in parts of Denmark and Portugal), Mexico, and Japan are often considered distinct from what has been evidenced say in California. In these districts there is much more
these locational dynamics as follows:

Economies of agglomeration are a composite of the distance-minimization efforts of numerous enterprises. Similarly, economies of infrastructure (or network economies) impose spatial organization on a region, permitting some places to obtain advantages which less well-connected places cannot. A well-connected place also tends to accumulate infrastructure investments over time, giving it yet further advantages (Malecki, 1991: 230-231).

Furthermore, while existing agglomeration advantages may serve to benefit this locationally based disintegration, the process very often arises in places without especially favorable conditions. But once begun, the process reinforces itself in the manner described above.

This is the "territorial development" described by Storper and Walker, of Scott’s "new industrial spaces" (Storper and Walker, 1989; Scott, 1988c). It is dynamic, as it depends upon the continued growth of external demand, although the agglomerative nature of the growth helps to maintain this increasing demand. This is because the products manufactured in such flexibly organized agglomerations are likely to be particularly specialized or innovative, quality evidence of very close interfirm cooperative relations based upon long established (often for centuries) but continually developing informal social and economic structures. From artisanal incipience, these districts are now recognized for their innovative capabilities.
oriented, and not (or not yet) subject to standardization and cost only competition. As a result, agglomerative flexibilities are represented in new industrial spaces as both the determinants of, and the reinforced consequence of, the dynamic formation of organizational externalities and of continuous innovation. Scott, describing the way production fragments into a social division of labor, emphasizes the particular role of vertical disintegration as the link between the expansion of demand and the constancy of innovation:

...insofar as extension of the market leads to an expanding social division of labor, we might refer to this as a process of dynamic vertical disintegration, for it concerns something more than a simple institutional breaking apart of a given and invariable set of production activities. What is involved here is a process of disintegration plus innovation, so that, as the whole system expands, it acquires new and independent forms of specialized economic activity, but in a socially divided form (Scott, 1988c: 27).

This conforms well with many other statements concerning organizational externalities of flexible production and the agglomerative forces accompanying it.

It claims that the pivotal characteristic of flexible agglomerations is the extent of the social division of labor, that is, the degree to which the production specializations of firms and plants are
vertically segmented. Further, as great stress is placed upon the dynamic growth that occurs in these locales, it is much more the process of vertical fragmentation that is significant, rather than the existence of vertically disintegrated production per se. Such a process is quantitatively measurable (Scott, 1986, 1988b; Signorini, 1994), and interregional comparisons can be drawn based upon them.

Other aspects of flexibly organized agglomerations are less palpable. Scott says of intra-agglomeration flows:

...many transactions...are composed purely of intangible exchanges of messages and information in which firms make business arrangements, plan future actions, and monitor their economic environment (Scott, 1988c: 31).

And Scott further comments on the milieu within these agglomerations:

...tangled informal networks of useful knowledge about local production methods, business conditions, and employment practices are an intrinsic element of community consciousness and help to keep the whole system functioning smoothly. Personal knowledge of others in the community becomes an essential component of the ways in which the local economy operates...small producers...seem to depend...on the familiarity and trust that are generated in the business community over time (Scott, 1988c: 40).

These are the infrastructural foundations to such agglomerations, a portion of which are the broadly defined advantages of urbanization economies, but others
are barely tangible. While the availability of general urbanization infrastructure is roughly proportional to urban size, the less than tangible elements include cultural and institutional factors that cannot be properly quantified (Hanson, 1990; Storper, 1993; Signorini, 1994).

This is the *milieu* that includes networks of informational flows and personal relationships, the general social informalities that create environments of trust, cooperation and accommodation, allowing for, among other advantages, the localized transfer of knowledge and innovative capabilities. Associated with this, and particularly in the U.S., is the way in which universities and research establishments help to create an innovative intense environment by providing a continual stream of technological spillovers. Though this *milieu* is an important aspect of claims made about agglomerative flexibilities, its characteristics are largely place specific, such that it transcends

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*It has been suggested that only the largest and most prestigious universities can be counted upon to help establish technically innovative environments. But among these, it would be difficult to predict their different levels of external impact. As a factor of high technology growth center development, like all independent factors that relate to economic, creative or business environments, it does not predetermine*
systematic consideration and is typically investigated by case study or comparative method (Scott, 1986; Leslie and Kargon, 1994; Saxenian, 1994).

2.3.5 Conclusion

Of the three broad classes of flexible production, manufacturing technology, labor relations, and organizational externalization, it is the latter that most implicates the role of space. Not only does it indicate that agglomerative growth, rather than balanced interregional growth, is typical, it also suggests that spatially mediated relationships create a further impetus to growth that is, specifically, flexibly organized. In order to empirically verify these notions in systematic cross regional fashion, several indicators are available. These are indicators of plant size, vertical integration (disintegration), and urbanization economies. The first two derive from the supposition that agglomerative growth entails accelerated plant

locational potential as much as it becomes, in time, one of a set of interdependent elements of localized growth. It would require, for instance, an investigation of singular attributes and events to distinguish the reasons for the great local impact of MIT from the negligible one of Princeton.
level fragmentation, the result of increased spin-offs and of subcontracting. The latter captures some of the infrastructural basis of agglomerative growth beyond the strictly localized impact of a single growth industry or of a set of related industrial subsectors.

2.4 Characteristics of Agglomerative Growth

2.4.1 Introduction

The contextual framework investigated in this study entails an accounting of the organizational externalities associated with flexible production. To that end a set of indicators are identified from the literature associated with flexible production systems and spatially oriented growth theory. They include plant size growth, vertical (dis)integration, and urbanization economies. The theoretical meaning of these indicators as they relate to notions of flexible specialization and interregional growth is reviewed in this section. A discussion of their measurement is reserved for section 4.5 (ie. contextual variables).

Interest in the employment and innovation generating role of small firms is very closely
associated with production in smaller plants. The small firm and small plant environments are, however, not fully commensurate. The small plant context is the measurable attribute used in this study. It is argued here, as it is elsewhere (Scott, 1986, 1988b), that it is the most useable and meaningful indicator for cross spatial investigation.

The literatures on small firms and small plants are closely aligned and are not thoroughly separable. The review, in section 2.4.2, of their role in flexible production and regional growth concerns literature that typically examines both contexts. The statistical correlation between firm and plant sizes is addressed in section 4.5.1.

Vertical integration is a major issue in the industrial organization literature, and has been examined from a number of theoretical and policy oriented perspectives. This study (in section 2.4.3) concentrates on several aspects of integration that have become relevant to the geographically oriented discussion of flexible specialization; namely, the technological and the transaction cost incentives to vertically integrate.

In this study, the Verdoorn Law is an empirical
regularity associated with localization economies. However, in much of the literature, it is closely aligned to the more broadly defined agglomeration advantages of urbanization. The role of urbanization economies is examined in and related to the Verdoorn relationship in section 2.4.4.

2.4.2 Plant and Firm Size

Attributes of firms and plants relative to their size have received substantial attention over the last several decades. It has been widely thought that small firms account for a significant amount of product and process innovation (Acs, 1992), and that they have been central to employment growth. These apparent relationships have attracted the attention of policy makers to the extent that development programs at various levels of government (but particularly at the state level) have sought to exploit them (Vaughn and Pollard, 1986; Lambright and Teich, 1989; Osborne, 1989). In fact, it can be supposed that the widespread interest in forms of flexible production is considerably due to their association with smaller firms and plants. It is widely accepted that much new process technology
is assumed to be flexible by nature and is used more productively when adopted by small firms, by which it is purportedly adopted most often (Acs and Audretsch, 1990). Ultimately, it seems, the effect on employment is of paramount interest to policy makers.

Birch (1979, 1987) has provided the seminal research linking employment growth to small firms. This has since been supported by numerous other studies examining not only the U.S., but many other industrialized economies as well (Duche and Savey, 1987; Phillips, 1991; Acs and Audretsch, 1990). More recently, supportive findings relate to the extent to which small firm growth and its generation of employment are associated with the unevenness of economic expansion (Hanson, 1990; Baker, 1993; Phillips, 1993; Dennis, Phillips, and Starr, 1994). While a portion of this literature shows that regional restructuring is abetted by the smaller firms of mature industries (Baker, 1993), much of it indicates that such firms are a significant force in the rapid growth of technology-intensive manufacturing sectors (Phillips, 1991; Asquith and Weston, 1994), and that they have a reportedly broad effect upon small firm formation and employment generation across all economic sectors (Phillips, 1993).
Generally, the empirical record seems to show that, since the mid 1970's, small firms have contributed to a larger proportion of new employment growth than would be expected given their absolute employment magnitudes. And, this contribution is all the greater when the small firms are part of "high-technology" industries (Phillips, 1993; Asquith and Weston, 1994).

The reported influential role of such firms in the growth of employment is paralleled by their purported importance as product (and process) innovators. Some detailed studies of innovation indicate the greater apparent adoptive capabilities of small firms. As well, it is to smaller plants where specifically flexible process technologies have diffused most rapidly (Acs and Audretsch, 1990).

The suspicion that large firms, per dollar of sales, research and development expenditure, or labor cost, are no more innovative than small firms has, for some time, steadily gained acceptance (Scherer, 1965; Kamian and Schwartz, 1982). Recent studies generally qualify this type of finding by suggesting that differences in the relative innovative (research and development) effort and impact of small companies is dependent upon the technological intensity of their
industry and its, often related, market structure (Kamian and Schwartz, 1982). As these stipulations appear to be highly significant, some researchers argue that not only should the role of small firms be considered as they vary across different types of industries at a given time, but their role should preferably be considered with reference to the historical development of their industry (Kaplinsky, 1983). In this way the interrelated dynamics of industries, firms and plants can be examined.

Given the apparent importance of technological intensity and market structure, it seems reasonable to suspect that general life cycle characteristics are closely associated with the innovative propensity of small firms. Kaplinsky (1983) suggests that this has been the case in the computer aided-design industry, where the innovative capability of small firms is greatest during an early growth phase, after initial technical breakthroughs, but before concentration begins to occur.

If, however, industry (and product) life cycles are breaking down in the context of veritably continuous technological advance and product differentiation, as is suggested by the thesis of agglomerative flexibilities,
then it is logical to deduce the further strengthening of the small firm/plant influence. Instead of life cycles advancing to mature phases, they would become attenuated at junctures where product innovation remains critical, and where process standardization is not yet plausible. Networks of firms and plants would deepen and agglomerative tendencies would intensify. In fact, it seems clear that, in studies that indicate a nearly unqualified employment and innovative significance of small firms, the relationship between flexibility and small firms/plants is strongly implied where it is not specified.

Acs and Audretsch specifically come to this conclusion of a close correspondence between flexible production technology and small firm prominence. They show that small firms are at least as innovative as are large firms except in high-technology industries, where they are more innovative (Acs and Audretsch, 1990). They find this particularly significant since small firms normally find themselves at certain disadvantages, such as with capital market imperfections. Acs concludes that small firms make up for existing disadvantages by utilizing favorable conditions of externalization. He says they take greater advantage of
"geographically mediated spillovers from the innovation knowledge base" (Acs, 1992: 41), a notion that has currency for theories of flexible agglomerations as well as for government policies promoting small firm formation in "high-tech" industrial clusters rich with university and research oriented facilities.

With regard to flexible machinery specifically, Acs and Audretsch show that a positive relationship exists between its adoption and the change in the share of industry output and employment accounted for by small firms.\(^{10}\) The relationship is similar between adoption rates and changes to mean plant sizes (Acs and Audretsch, 1990). In sum, their findings are formidable and demonstrate, at least for the 1970's and early 1980's, a very close association between flexible production, agglomeration economies, technological intensity, rapid output and employment growth, and the impact of small firms and production units.

Acs and Audretsch squarely identify both smaller firms and smaller plants as fundamentally related to competitive choices necessitated by underlying changes in global and national economies. Acs says that,\(^{10}\)

\(^{10}\)The correlations are across four digit SIC subsectors (Acs and Audretsch, 1990).
because of market volatility and resulting uncertainty, the firm strategy of choice (in the 1970's) became:

...specializing in a particular business area and building in flexibility... In manufacturing industries this meant using new technologies. The intensified use of automation equipment (numerically controlled machine tools, robotics, flexible manufacturing systems) constitutes a part of firms' strategy to improve production flexibility... (Acs, 1992)

Further, he suggests another element of firm strategy was the building of networks of specialized suppliers, creating a set of "small plants or firms clustered around large enterprises" (Acs, 1992). The combined elements of:

Flexible specialization and the use of networks in production increases the role of small firms. Moreover, the elasticity of substitution between labor and capital is greater than unity for high technology industries, thus offering the possibility of reversing the century-long rise in scale economies (Acs, 1992).

It is worth noting that this general notion is associated with some nascent ideas concerning the crucial role of networks in the development of the space economy. So apparently crucial do networks seem that some observers, closely aligned to the thesis of agglomerative flexibilities, have suggested that firms per se have become unimportant (Walker, 1989).

While the prevailing view has been, and largely continues to be, that small firms are particularly
dynamic elements of the space economy, dissenting views have been advanced. First, in some sectors where growth has been especially rapid, some reconcentration of production has been evidenced. A life cycle of organizational changes appears recognizable, where product and process standardization has led to peripheral branch plant manufacturing by the larger firms of technology intensive sectors (Miller, 1989).

Second, and more damaging yet for the small firm thesis of employment dynamics are reevaluations of the data of the 1970's and 1980's, which show no real increase in the proportion of employment accounted for by either small establishments or small enterprises in the U.S., Germany, or Japan (Davis, Haltiwanger, and Schuh, 1994). Some misinterpretation is also represented by the supposed trends of the 1980's, in that the reduction in average manufacturing firm size, measured by employment, was much less a result of surging small firm growth than a downsizing of the largest firms. Indeed, in the competitive conditions of the period, more workers found themselves employed in subcontracting firms rather than in the larger firms (Harrison, 1994). In short, some disagreement with the figures is in fact a problem of interpretation. In
manufacturing particularly (rather than in services) employment growth is not so much in evidence as are shifts among firms and establishments of different sizes.

A third difficulty relates to the long term viability of small firms/plants as flexible technologies further integrate the production process. The fact that the development of external organizational networks and the adoption of flexible machinery are now closely associated does not mean they will remain so. A qualification made by Acs and Audretsch concerning their study is worth noting in this regard. In essence they say that while the adoption of early generation flexible technologies, such as numerically controlled machinery, has been associated with small firms, future technologies, such as FMS (flexible manufacturing systems) may have a different consequence for plant size (Acs and Audretsch, 1990). It may make the integration of manufacturing processes requisite, favoring larger firms and plants, and reducing the comparative importance of externalized networks and agglomerative forms of flexible specialization.
2.4.3 Vertical Integration

The general conditions for the firm's decision to integrate production vertically have been understood for some time. They can be subsumed into a two way classification. First, production processes may be technologically interrelated to the extent that engineering (and, therefore, cost) considerations make integration competitively requisite. Second, markets may fail to enable firms to exert sufficient control over production where close coordination is deemed necessary. To limit the costs of transactions (including their uncertainty) across external linkages, firms may choose to integrate (Davies, 1987). Both of these conditions are sensitive to the introduction of innovations, or the mere possibility of their being introduced. That is, reflected in the degree of vertical integration are contexts where innovations are adopted as products or processes, and where an industrial sector is subject to uncertainties of rapid technological change. Given this temporal dimension, it should be noted that the decision to vertically integrate is likely to entail both long term strategic as well as shorter term cost considerations.
2.4.3.1 Technological Interrelationships

In terms particularly of plant level activity, technological interrelationships are a significant determinant of vertical integration (Nabseth and Ray, 1974; Sutton, 1980). Because there has been a long term post-war trend toward the further development of continuous process technologies, it is often assumed that, in terms of engineering considerations, there has been substantial pressure for firms to vertically integrate. However, whether or not a general integrating trend has occurred is not clear. Empirical findings are mixed on this point (Laffer 1969; Maddigan, 1981).

A caveat concerning these technological imperatives is crucial. Efforts to combine formerly distinct vertically related processes are likely to proceed further at earlier stages of the production chain, where the resulting (intermediate) products are largely fungible, and where general demand conditions are the basic limitation to continuous processing. However, even with greater amounts of interchangeable parts, downstream products are inherently more differentiated and specified, lending more uncertainty and technical
difficulties to the decision to incorporate new machinery. That would be the case except were the machinery to be flexible enough to produce goods in small batches.

As reviewed in section 2.3, the flexible specialization thesis offers several alternatives to the dilemma of differentiated demand. One is the

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An example from the present study is found in the textile/apparel complex of manufacturing activities. Here capital intensification is possible upstream in more of less standardized textile production, but not possible in downstream apparel manufacturing. In the latter industry, the problem for standardization is the physical nature of the product itself (i.e. the difficulties in its handling), as well as its demand irregularities. It is worth noting that the textile sector has been able to increase labor productivity over the last several decades due to heavy investments in capital machinery, benefitting as well from the accompanying increased returns to internal (plant and firm level) scale. However, its apparel purchasers have remained fragmented in terms of products and process (as its plants and firms have remained comparatively very small as well). For the textile industry, this has meant the scale requirements of efficient production that have accommodated its machinery investments exceed any desired level of individual product demand by apparel manufacturers. (Parsons, 1988; Dertouzos, Lester, and Solow, 1989). As it can be anticipated that apparel manufacturers in industrialized countries will necessarily move toward what is their comparative advantage, supplying the more specialized and demand volatile market segments, it can also be posited that its relative fragmentation will remain. Thus, apparel producers are likely to move yet closer to JIT type production systems which are inconsistent with the apparent "just-in-case" assumption recently made by many textile producers.
observation that machinery is indeed becoming more flexible so that it is (or will become) more practicable to combine processes without enlarging the scale of the production of single products (that do not have sustainable demand). In effect, the suggestion is that machinery will eventually conform to the volatile nature of demand for downstream goods. Yet, at present, the impulse to cost contain through product standardization is not congruent with market proclivities, or attempts by niche producers, to product differentiate.

A second flexibility alternative is for firms to forego integration and align their production to demand niches. In effect, where demand continues to become more variable over time, this implies the actual fragmentation and disintegration of the production process, favoring networks of firms and plants. Firms within such networks are in turn compelled to agglomerate such that their transactions entail very limited costs, below the imputed costs of integration, and the associated costs of investment in continuous process machinery. This process, as a flexible specialization phenomenon, is claimed to have advanced substantially in places (Piore and Sabel, 1984; Scott,
Therefore, while the technological basis for integration has been long understood, the availability of continuous process machinery, or the potential for its development, does not lead unambiguously to its adoption. Rather its potential adoption is mediated by the specific demand conditions, or by existing organizational contexts.

2.4.3.2 Transaction Costs

A second determinant of vertical integration is market failure. Firms integrate to control the costs of transactions with suppliers as well as with distributors. Such costs entail the price, quality, and specification uncertainties of input supplies. This theory of transactions costs has been developed by Williamson (1981, 1985) based upon the earlier writings of Coase (1937).

According to Coase, when the expense of market contracting is sufficiently high that it exceeds the costs of internalizing a function, firms will internalize such a function, thus eliminating a set of (external) transactions. He views the decision to
integrate as one between marginal costs, such that equilibrium levels of vertical integration arise as an efficient combination of firm and market production coordination. The equilibrium level is where:

...the costs of organizing an extra transaction within the firm become equal to the costs of carrying out the same transactions by means of an exchange in the open market or the costs of organizing in another firm (Coase, 1937; 341).

Williamson has extended the argument by examining transactions costs under various conditions. Davies succinctly summarizes these conditions as follows:

Vertical integration is more likely in circumstances where, given bounded rationality and opportunism, the assets required are highly specific to the transaction, there is a high degree of uncertainty involved and, to justify the costs of setting up a system of internal organization, the transaction recurs frequently (Davies, 1987: 87).

Williamson’s arguments have motivated a considerable amount of related work concerning the question of why firms integrate, all under the rubric of transactions cost theory.

There are costs, or potential costs, involved with market transactions particularly in an innovation intensive environment. In fact, such an environment may not have well developed markets at all, in the sense that standard product (and process) specifications are not well established, nor, as a result, are their prices
(Shapiro, 1991). Agreement between linked producers concerning product innovations may be more difficult than when linkages are internalized (Silver, 1984). Cooperation among firms is imperative under such conditions but, unless informal and very intensive systems of cooperative trust have been developed among the firms involved, interfirm relations must be rigidly contracted. Ironically, integration could reduce rigidities in these instances because the uncertainties of sales contracts are transferred to presumably more flexible internalized employment contracts. Again, where the environment is innovation intensive, internalizing functions becomes most apparently crucial, as Shapiro recounts:

Because employment contracts do not blueprint the production they regulate, the production governed by them can be changed in the course of its execution... when tasks can be altered in the light of their performance, they can be adapted to the changing requisites of a new product’s development and production. Employment contracts make possible the task flexibility that innovation requires (Shapiro, 1991: 54).

Further, with transactions between producers, the incentive for opportunism can be significant. Asset specificity, where capital equipment is dedicated toward the production of a particular good and linked to a particular downstream consumer, can aggravate
transaction vulnerability. Asset specificity, in fact, is a major aspect of the technological interrelatedness, reviewed above (section 2.4.3.1), that appears to have encouraged integration (Williamson, 1985).

Generally the higher the transactions costs, all other factors being equal, the greater the incentive to vertically integrate. But from the flexible production perspective, other factors are not equal, and the most important one, market demand, is crucial. The argument forwarded by flexible production theorists is that, as with purely technical considerations, increasing demand irregularities significantly alter the logic of the integration decision (Scott, 1988a, 1988c). Therefore, instead of integrating production in order to substitute internal costs and uncertainties for transaction costs, firms may seek to reduce the costs of transacting externally.

Within the flexible production paradigm, two general conditions, not mutually exclusive, for the reduction of transaction costs are theorized. Both, it should be emphasized, suggest that the existence of agglomeration economies, and some special attributes of industrial district localizations, are necessary for, but not determinative of, transaction cost discounts.
First, there is Scott's particular interpretation of transaction cost theory as it pertains to a post-fordist environment. In essence, he argues that all the notions developed by Williamson concerning the particular contexts of likely vertical integration have become the reverse, they have become the underlying factors of vertical disintegration under systems of flexible production (Scott, 1988a, 1988c).

Once a degree of fragmented agglomeration based production has developed, and the more there exist market instabilities and uncertainties, the more linkages are likely to further develop. Subcontracting relationships will proliferate, particularly where "interlinked production processes have widely varying optimal scales of operation" (Scott, 1988c: 26).

Ultimately networks of firms develop into tightly organized agglomerations of vertically disintegrated production activities. Thus, a system of external relations between firms (and plants) is instituted, the linkages of which become ever more reliable. These linkages, therefore, become more used, and their relative costs decline. In such an environment, transaction costs remain, but they diminish relative to the costs of integrating. Networks of firms and plants,
and agglomeration economies, substitute for firm and plant integration, and very often, sales contracts are preferred to employment contracts. In Scott's words:

...as vertical disintegration...moves forward, so production systems become steadily more externalized and hence, in organizational terms, more flexible. Vertical integration, by contrast, signifies increasing organizational inflexibility for it puts limits on the possibilities for combination and recombination of individual production processes (Scott, 1988c: 25).

Thus, an accumulated locational logic of agglomeration ensues, where uncertainties are associated with integration rather than with disintegration. Firms and plants can remain rigid (and efficient) producers of narrowly specialized goods, but they are part of an externalized system that is distinguished by its organizational flexibility.

The thesis of flexible production also appeals to broader and less tangible notions of the way transactions costs are overcome. This (second condition) underpins, at least by implication, most discussion of flexible production, whether or not Scott's reworking of transaction cost theory is accepted (Storper and Walker, 1989; Storper, 1993).

In short, the degree of trust and cooperation that develops within agglomerations creates manifold advantages for networks of small vertically
disintegrated firms. Informal social and personal relationships promote stable yet flexible contracting between firms. This contributes to interfirm coordination to the degree that it equals or supersedes that which is achievable within firms. The uncertainties that are much of the cost of interfirm transactions, and therefore the motivation for integration, are reduced as a result of these cooperative arrangements. In essence, this is closely related to the _milieu_ argument reviewed in section 2.3.4 (Piore and Sable, 1984; Storper and Walker, 1989; Becattini, 1990).

### 2.4.3.3 Summary

A long standing premise of the industrial organization literature has been that vertical integration generally occurs as a result of the technological interrelatedness of machinery, or because under many conditions markets fail. Far from their being anomalies, however, the instances where vertical disintegration takes place are considered, in the flexible specialization literature, to be a recognizable trend. In fact, vertical disintegration is said to
occur for much the same reasons that transaction cost theory predicts integration.

2.4.4 Urbanization Economies

The flexibility literature generally suggests that in some areas of technologically intensive industrial development, urbanization economies are particularly significant to the growth of agglomerative efficiencies. As an example, the Orange County, California, complex is described by Scott as the locus of intersectoral and generalized infrastructural development. According to Scott, among the "major forces" determining the growth process in Orange County during the 1955 to 1984 period is the development:

...of a whole series of urbanization phenomena (infrastructure, transport networks, housing facilities, educational establishments, etc.) which ensured the successful social and territorial of the entire complex. These intertwined events have come to represent a vigorous process of industrialization and urbanization in Orange County today. The more the complex has expanded, the more it has produced, by its own internal momentum, a wider pool of agglomeration economies, and thus it has expanded wider still. (Scott, 1986, p. 41)

In addition, Scott’s entire analysis and discussion of Orange County can be viewed as a statement of the overlapping and interactively intersectoral nature of
Orange County's growth. This is somewhat different from most of his other case studies which emphasize only specific industries, rather than the larger territorial complex within which the industries function (Scott, 1983, 1984, 1988b, 1988c; Scott and Angel, 1987; Scott and Kwon, 1989).

Scott shows, as have others (Hoover, 1948; Pred, 1977), that the development of a shared infrastructure, the growth of very broadly defined business services, access to a large and varied labor force, and other urbanization advantages, are significant elements of agglomerative dynamics. However, the larger segment of the flexibility literature mostly represents the development of new industrial space as an underlying function of the characteristics of particular industries. It is certainly true that the existence, or the greater possibility, of urbanization economies influence the potential for the development of an industrial complex, but most of the literature on flexible manufacturing suggests that the significant aspects of locationally concentrated production are industry specific. As reviewed in section 2.2, it is the organizational and technological characteristics of
a particular industry, the way they impact and are impacted by their locational development that is the dominant theme of the flexibility thesis in geography.

As a result, the 'new' in new industrial spaces is conceived as indicating sunbelt locations, areas of emerging rather than built (and to be maintained) infrastructure. There are numerous reasons to believe that comparatively untouched locations are more amenable to new systems of production. In short, their labor force, capital equipment, institutional and regulatory environment can be newly fashioned rather than arduously transformed.

On the other hand, some agglomerative attributes

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Formal analysis requires definitional correspondence with data collection categories. In this study, the use of census data dictates defining industries in terms of Standard Industrial Classifications (SICs). Two digit SIC industries are considered to be large enough to include a credible cluster of linked subsectors, but not so broad as to include virtually unrelated industries that might, nonetheless, help to fashion urbanization advantages. Clearly, though, two digit SICs are not discrete; functional interrelationships and material linkages do transcend the classifications. In this study, the most obvious example of this is the relationship between portions of the electronics sector, notably semiconductor, integrated circuit, and microprocessor production, and the machinery sector, notably computer and metalworking machinery production. Also the electronics and instruments industries are combined for the purposes of this study due to the reclassification of some of their subsectors.
must certainly exist to give at least selected older industrial areas efficiency advantages (Leslie and Kargon, 1994). Thus, locations in the old manufacturing belt are not ruled out as sites of new industrial location (egs. Boston's beltways, New Jersey's Route 1), although most of the flexibility literature takes little note. Existing infrastructural advantages may also favor older core regions as the locations of restructured manufacturing. This has been evidenced in the auto and steel complexes of the midwest (Florida and Kenny, 1992), and may influence the machinery industry examined in this study.

In view of this, and considering the fact that even sunbelt output growth is uneven and has tended (in its agglomerative form) to favor already significantly urbanized locations, the impact of existing urbanization economies needs to be assessed. Accordingly, this study employs measures, as detailed in section 4.5, in order to proxy this effect.
2.4.5 Conclusion

Each of the above described characteristics of flexible agglomerative growth, diminishing plant size, vertical disintegration, and existing urbanization economies, can be introduced into the augmented Verdoorn model as contextual effects. Hence, the general equation (3) is expanded to:

\[ p = f(q, a[x_1, \ldots, x_n]; k, b[x_1, \ldots, x_n]), \]  

(4)

where \( a \) and \( b \) are the coefficients of \( q \) and \( k \) respectively, and the \( x_j \)'s denote variables representing these contextual effects. The specific procedure for this, the expansion method (Casetti, 1972, 1982), is detailed in section 4.3.
CHAPTER III - THE INDUSTRIES

3.1 Introduction

The three industries examined in this dissertation are all considered to be impacted by flexibly organized forms of production. Each of these industries has distinguishing organizational and technological characteristics that are likely to condition the way in which flexible production is likely to impact Verdoorn productivity effects.

In light of this, chapter 3 surveys the organizational characteristics of these industries. In particular, it defines each sector, and its major component subsectors, and identifies distinguishing features of their production systems, especially as they relate to each industry's spatial growth characteristics.

The following sections concerning each of the three industries consists of a review of sectoral characteristics followed by a survey of the sector's interregional growth patterns with respect to its
3.2 Electronics/Instruments

The electronics/instruments industry in the present study is defined as the combination of SIC 36 and 38 sectors, respectively electronic and other electrical equipment, and instruments and related products sectors. This is done primarily because of changes to SIC definitions occurring during the study period. The 1987 SIC classifications represent numerous definitional revisions of those for 1972/1977, particularly in rapidly developing (and technologically intensive) sectors. While most of these changes affect classification within two-digit sectors, some cross-sectoral shifting occurs. As will be detailed below, this is most notable between the electronics and instruments sectors. As a redefined sector, however, an electronics/instruments sector represents a large segment of those industries typically, by various but related definitions, characterized as "high-technology". Typical definitions range from very aggregate indicators of the effects of technological intensity, such as the comparative growth of output or employment itself, to detailed assessments of the type and
Among these two larger components of the electronics/instruments sector it is the electronics and electrical equipment portion that has received much more attention. In geographically oriented studies, it has received virtually all of the analytical scrutiny. Generally, this attention is a result of the crucial role the sector provides to broad industrial development. Particular subsectors, notably electronic components and communication equipment,\textsuperscript{1,4} produce goods used in the process innovations of many other industries. Other subsectors, such as consumer electronics, have played a critical role in the export generation of growth for emergent national and regional economies (Dicken, 1992). The electronics and electrical equipment sector has also been of particular technical nature of firm or industry process and product innovations. Standard measurable definitions have included the percentage of output accounted for by research and development expenditures, and the proportion of labor input that is considered to be technical (Markusen, Hall, and Glassmeier, 1986; Hagey and Malecki, 1986). While these two measures can represent the relative importance of technological innovation in a given industry, they do not necessarily indicate the degree to which innovative activity occurs at the site (or localization) of production itself.

\textsuperscript{1}Significant, and especially technically advanced, portions of communications equipment are now classified in SIC 38 (Standard Industrial Classification Manual: 1987).
interest to geographers, as certain of its elements have tended to concentrate in a few clusters of localized activity. Such clustering is strongly associated with, and often considered the spatial underpinning of the technological and organizational requisites of rapid growth (Scott, 1986; Scott and Angel, 1987; Saxenian 1983). The implication is that flexibly organized production has been pivotal to the growth of the electronics industry especially, and that this growth entails increased external economies of scale in innovatively rich agglomerations, the foundation of Verdoorn effects.

3.2.1 Sectoral Characteristics

Electronics and electrical equipment (SIC 36) consists of eight three-digit subsectors, of which communications equipment (SIC 366) and electronic components and accessories (SIC 367) are, in terms of both value added and employment, the largest. In 1977, 28 percent of SIC 36 was accounted for by communications equipment, and 18.3 percent by electronic components.\textsuperscript{15}

\textsuperscript{15}All figures are calculated from the 1977 and 1987 U.S. Census of Manufactures. Producer price indices for
The respective 1977 employment percentages were 26.6 and 21.7, an indication of somewhat higher labor productivity in communications equipment. By 1987, the relative importance of these two most significant subsectors reversed themselves, with communication equipment accounting for 21.8 percent and electronic components for 32.2 percent of output, and respectively, 16.0 and 34.9 percent of employment (US Department of Commerce, 1977, 1987).

A portion of this shift is strictly definitional, relating to the partial removal of radio and television communication equipment from its erstwhile SIC 36 classification (SIC 3662 in 1977) into an instruments category (SIC 3812; search and navigation equipment). Another portion of the former 1977 radio and television communications equipment classification reappears in the newly designated SIC 3663 of the 1987 census (US Department of Commerce, Census of Manufactures, report electrical machinery and equipment as a commodity (available from the BLS) are used. Reported prices are in 1982 prices.

Significantly as a result of this reclassification of SIC 3662, the newly instituted SIC 3812 initially became a large component of instruments and related devices, representing slightly over a third of the output of SIC 38 (US Department of Commerce, 1987).
MC87-1-36D, 1987). Also, however, the relative output and employment shift between electronic components and communications equipment is explained by a more substantive development; a surge in the domestic production of the former, coupled with a comparative contraction of the latter.

Among electronic components, the growth in production of semiconductors and related devices (SIC 3674) and printed circuit boards (newly designated in the 1987 census as SIC 3672) is notably distinctive. Semiconductors and related devices alone accounted for 36.9 percent of electronics component and 6.8 percent of all electronics and electrical equipment output in 1977. By 1987, these percentages increased to 43.6 and 14.0, respectively. It is noteworthy, regarding these percentages, that growth of semiconductor production is rather moderate with respect to the electronic component subsector, as compared to its growth relative to the larger classification of all electronics and electrical equipment. To a substantial extent, this is a consequence of the complementary development, and output growth, of products, many highly innovative, in various product classifications of electronic components, including printed circuit boards and the catch all
category of n.e.c. (i.e., electronic components not elsewhere classified) (US Department of Commerce, 1977, 1987).

The semiconductor, with its derivative integrated circuitry and microprocessor innovations, is the fundamental technological source of this rapidly developing complex of products. The acceleration of innovation with respect to its associated products is pivotal feature of recent developments. As a result, the lives of the industry's products, while they have varied dramatically in length, are marked by a secular tendency to shorten. This has created strategic uncertainties concerning product development, making it increasingly hazardous to attempt to take products entirely through their life cycles. A once viable strategy of profiting from extended product runs, and using the proceeds to finance product innovation is becoming less tenable. In general, it is thought that, while some firms will retain mass production capabilities, the industry as a whole will move toward the production of smaller batch semi-custom products. (Schoenberger, 1986, 1989).

While the U.S. components industry has been composed of producers who have functioned under an
operative strategy of guiding products through extended production runs, it has also been composed of more design intensive firms that have chosen not to compete at the mature end of the product life cycle. By the mid 1980's, the latter segment had begun to proportionally expand, as some larger firms joined those smaller firms who had already been specialized producers (Malecki, 1991). The factor that has keyed this trend, and is said to have the potential to transform the industry entirely, is change to the design phase of production (Schoenberger, 1986, 1989).

Prior to the 1980's, the design expense of integrated circuitry had been such that it had been considered desirable to overdesign them, making them acceptable for multiple purposes, and standardizing their production. Technical advances nevertheless have meant that even these generic products were subject to very short mature phases. However, the possibility of greater standardization of the design phase of production has more recently offered a potential for substantially reducing product development costs. Such impending process technologies make ongoing efforts to standardize products a less feasible firm strategy. They make it cost effective and preferable in terms of
market uncertainties to produce much more highly specified products. This should have the effect of not only allowing for a wider scope of products, but also to ameliorate the tension between product innovation and product standardization that has been building in the industry (Schoenberger, 1989).

However, such flexibilities place more pressure yet upon the quality and service attributes of products. Product life cycles (if they remain a usable concept) and production throughput time shortens much further. As a consequence, the competitive focus moves toward the coordination of different spheres of production rather than simply on design flexibilities. This, in turn, implies a requirement to integrate production, a view that is disputed in the flexible specialization literature (Piore and Sabel, 1984; Scott, 1988a; Sabel, 1989). The entire process is likely also to continue to become more capital intensive (Schoenberger, 1989).

Among other subsectors of the electronics industry, communications equipment also exhibits dynamic attributes. From a global perspective this subsector of the electronics and electrical equipment industry is undoubtedly experiencing rapid growth, but much less so in the U.S. than elsewhere. Many specialized niche and
very recently developed products are retained by U.S.
industry (some now classed in SIC 3812), but some have
been lost (Dertouzos, Lester, and Solow, 1989).

Losses are even more evident in other three-digit
SIC classifications of electronics and electrical
equipment representing large consumer good outputs,
including household audio and video equipment (SIC 365)
and household appliances (SIC 363). The domestic U.S.
market is heavily supplied with many of its consumer
products by foreign transplant establishments, as well
as by imports from Japan, elsewhere in East Asia, and
even from Europe (Staelin, et. al., 1989; Morris, 1992).
In these subsectors, where rapid growth in production
occurs, it is more a function of rapidly growing
consumer markets (such as in East and Southeast Asia)
rather than a result of product and process innovation
per se. That said, future opportunities for growth of
the domestic U.S. electronics and electrical equipment
industry may be curtailed as a consequence of such lost
production in mass consumer markets. Many observers of
the global dynamics of the electronics industry believe
that an erosion of the U.S. domestic electronics
component base is a likely next step to the loss of
consumer markets. (Dertouzas, Lester, and Solow 1989).
This is a prevailing concern of a body of literature pertaining to technology intensive industries, and other industrial sectors that are considered to be propulsive or "strategic" in economic terms. Typically, this literature makes a crucial distinction between the nature of tactical investment signals that are short term and price based (and could, but do not necessarily conform, to optimal current market conditions), and strategic long term decision making that entails planned innovative activity and capital investments for future market developments. The aforementioned loss of consumer electronics markets to U.S. firms, and the potential loss of advanced electronic components, is viewed by this literature as a symptom of structural and institutional deficiencies in the U.S. industry. The early statement of this view is Cohen and Zysman (1987), though a more broadly ranging literature concerned with national (and to a much lesser degree, regional) competitive advantage, and argued along largely institutional lines has developed (Cohen and Zysman, 1989; MIT Commission on Industrial Productivity, 1989; Porter, 1990). Along with transportation (ie. automobiles), metals, and machinery, electronics, particularly semiconductors, integrated
circuits, and microprocessors, are at the center of the dialogue (Strowsky, 1989; Clausing et al., 1989).

Other three digit classes of SIC 36 are electric distribution equipment (SIC 361), electrical industrial apparatus (SIC 362), electric lighting and wiring equipment (SIC 364), and miscellaneous electrical equipment (SIC 369), all of which, in the U.S., experienced either unspectacular growth or moderate losses of output in real terms.

The instruments sector would have experienced high levels of output and employment growth even without the newly designated 3821 classification, as all its major subsectors witnessed high rates of growth. Notably, this includes measuring and controlling devices (SIC 382) and medical instruments and supplies (US Department of Commerce, 1977, 1987).

3.2.2 Patterns of Interregional Growth

The electrical and instruments industries do not have the long history of either the apparel or machinery industries. Their stature as propulsive industrial sectors dates from the second World War, though the radio and telephone were developed earlier. As noted
above, both are associated with high rates of technological advance, the products of which are often significant for process innovation in other industries. They are, therefore key manufacturers of producer goods or of the critical components of such goods. (Dicken, 1992). In the U.S., the industry's major locational shifts since the World War are closely related to a set of fundamental technical changes within the industry, changes which have had a determining influence upon the structure and organization of the sector.

Most notably, the development and manufacture of semiconductors, and of the related innovations, integrated circuits and microprocessors, has had the effect of creating a center of technologically-intensive production activity in Santa Clara county, California ("Silicon Valley"). Other nodes of activity also exist, many as a result of the development of semiconductor based technology. Salient among these are such new growth areas as Phoenix and Dallas-Ft. Worth (now replaced, to a degree, by Austin), Southern California

17Both the machinery industry, which itself manufactures large amounts of capital goods, and, more recently, the apparel industry increasingly rely upon electronic components (i.e., microprocessing technologies) to enhance process efficiencies.
(Orange County and San Diego), Colorado Springs, and Portland, Oregon, among others (Malecki, 1986a, 1991). This overall pattern of sunbelt growth clearly parallels the generalized pattern of shifts in all economic activities away from the northeast and midwest to the U.S. south and west. However, electronics production has expanded more rapidly in the south and west than manufacturing generally since the 1960's, though much of it has not been necessarily associated with these nodes of technical innovation (Harrington, 1985). In fact, production itself is a more diffuse phenomenon than can be suggested by listing the scattered clusters of research activity and the very few centers of intense entrepreneurial activity that are typically associated with the electronics industry.

Several factors appear to have kept production close to research and management locations. Variable specification requirements in the manufacture of some products apparently make necessary the close proximity of research activity and pools of technical and skilled labor. In addition, the yet rapid rate of product innovation in the electronic component subsector sustains rare entrepreneurial clusters of activity, places where spinoffs and access to venture capital are
supportive of organizational fluidity. However, as noted in section 3.2.1, many electronics products have been produced by standardized production processes. Much of this mass production is located diffusely, often in comparatively peripheral parts of the U.S., or, particularly, in third world locations, where consumer electronics have, for a longer period, been produced.

Since many of the claims concerning the rise in importance of flexible production systems use the electronics industry and its industrial clusters for confirmatory empirics, a brief review of the evidence is useful.

As related in the previous chapter, a set of circumstances closely associated with California locales has influenced the direction of research taken by a set of scholars mostly, in fact, based in California. It is little wonder, therefore, that the electronics industry, as it has localized in California (Orange County as well as the Silicon Valley) has become the subject of

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These latter clusters are rare. Arguments have been made that in electronics, only the Silicon Valley has all the necessary conditions of such a cluster (Saxenian, 1993). Whether such conditions are really optimal for innovative and productive activity is not at all clear, and such claims appear to be increasingly dubious (Sayer, 1989, Dertouzos, Lester, and Solow, 1989).
significant research efforts.

The general characteristics of these localizations are well known in the broad literature on economic location and regional development. A set of initially favorable conditions galvanized, through the efforts of a few earnest individuals and the early attraction of several crucial entrepreneurs, into a process of localized and eventually, urbanized growth. This process is richly described by Scott in his numerous studies featuring the industry (Scott, 1983, 1986, 1988a, 1988b). On the industry in the Silicon Valley during the mid to late 1960's he writes:

...once the process of growth had begun, the region acquired a very significant and potent stock of agglomeration economies that reinforced its increasing locational dominance. It soon began to draw into its spatial orbit specialized service and input industries, and it also developed a burgeoning specialized labor-market for semiconductor engineers and other technical personnel (Scott, 1988c: 84).

He contrasts this outcome with that of other centers of comparatively early semiconductor manufacturing where significant agglomeration conditions did not prevail:

Neither Motorola in Phoenix, nor Texas Instruments in Dallas, generated...a series of local spin-off ventures. Nor did the specialized disintegrated input suppliers or ancillary subcontractors, so characteristic of Silicon Valley, appear in a major way in Phoenix or Dallas. At the same time, most of the vertically-integrated electronics firms manufacturing discrete semiconductor devices in the Northeast failed signally to make an
effective transition into the production of integrated circuits. (Scott, 1988c: 84).

Therefore, the lesson of Silicon Valley is said to be that large firms, their large and vertically integrated plants, and the resulting lack of economic synergies tend to limit agglomerative potential. The point is also made that because such agglomeration is highly correlated with the most rapid technological advancements, it is inevitably associated with the greatest amount of output growth. By extension, as Scott, in fact, cites it as a Verdoorn process, this means the greatest amount of productivity growth as well (Scott, 1988c: 29).

While Silicon Valley has often been considered a model of regional economic development (Malecki, 1986a), it is clearly a singular occurrence. However, as many observers have noted, it is not likely to be a model of regional development duplicated elsewhere (Malecki, 1986a; Leslie and Kargon, 1994). The Silicon Valley of the last several decades represents a nearly singular circumstance that has little meaning in other contexts. In fact, even given all its dynamism, it may not represent the most efficient of all possibilities (Finan and LaMond, 1985; Clausing, et al., 1989; Stowsky, 1989). Within the institutional and organizational structures of the U.S. (or the Anglo-American world), perhaps it represents this, but a comparison with Japanese production systems might leave doubts (this general point is more convincing in terms of the machinery and apparel industries). In any case, it is difficult to envision
observations concerning the changing organizational and technological relationships within the industry, as noted in section 3.2.1, suggest that significant new patterns of growth have been underway for some time. Given the development of more flexible process technologies, and the cost implications of mass production with attenuated product life cycles, and significantly shorter throughput times, it can be anticipated that the role of agglomerative complexes of production activity within the industry will further strengthen. Where the industry's spatial organization (particularly that which is U.S. based) could be identified as locationally differentiated along functional lines characteristic of product life cycles and divisions of labor, this is increasingly less the case. It is said that the industry is reorienting, as a consequence of production (including a closer and more detailed association with its consumers) toward more spatially concentrated activity, specifically, in industrially mature economies. Here, functions are becoming increasingly more integrated (not necessarily manufacturing everywhere in vertically disintegrated flexibly organized complexes.)
within firms, but within agglomerations), and the spatial separation of activities has more to do with specific (notably first world) markets than with factor cost considerations *per se* (Schoenberger, 1986, 1989).

The general picture seems clear. A reconcentration of activity to developed economies means that the industry can anticipate further growth. Since the growth is subject to flexible processes, it should further exhibit agglomerative traits and Verdoorn effects. However, a considerable amount of integration internal to firms and plants could occur because of the apparent requirements of flexible process technology. As well, a shift in the location of the most dynamic growth has been suggested, where the advantages of Silicon Valley have now past, and other centers, such as the Dallas area, and Route 1 in New Jersey, among others, are potential successors (Leslie and Kargon, 1994). In fact, more centers of activity (again within industrial economies) are likely to arise in a pattern that has been termed "deconcentrated concentrations" (Schoenberger, 1989).

By contrast to electronics, the instruments sector has been subject to relatively little product standardization. As a result, and because of its
research and development intensity (Malecki, 1991), the industry's production structure tends to inherently conform closely to the characteristics associated with flexible specialization. Production in the industry, generally, is likely to benefit from the further development of flexible process technologies.

3.3 Machinery

The non-electrical industrial machinery and equipment industry includes all subsectors of SIC 35 (referred to simply as the machinery industry). These subsectors form a fairly diverse group, and have some significant and tightening relationships with portions of the electronics/instruments industry. This is particularly true as electronic inputs into both machinery manufacturing processes and its products become increasingly important.

A general characterization of the machinery industry is that it produces a critical array of capital goods. In fact, many of its subsectors (metalworking machinery, special industry machinery, and general industrial machinery among them) are virtually exclusive manufactures of producer goods. From the perspective of
the competitive global economy, the strength and technical capabilities of a national machinery industry is typically considered to be a crucial measure of industrial development, and a portend of long-term competitiveness (Graham, 1993).

3.3.1 Sectoral Characteristics

The industrial machinery and equipment industry consists of nine three-digit subsectors. Most of these subsectors have experienced considerable restructuring since the mid-1960's, a consequence of numerous interrelated factors, namely firm consolidation, import penetration, and the effect of two notably severe recessions (Dertouzos, Lester, and Solow, 1989). For the sector as a whole, very little price adjusted growth occurred over the 1977-1987 period in real terms. However, among the three-digit subsectors, rates of growth and decline have varied considerably (US Department of Commerce, 1977, 1987). The result has been a substantial shifting of subsector output and employment rankings as relative demands by manufacturers and competition from imports have disproportional subsectoral impact.
Most of the subsectors experienced relative and price adjusted absolute contraction over the 1977-1987 period. The enormous expansion in output achieved by computers and office equipment (SIC 357), from 14.8 percent to 27.4 percent of machinery output, assures, by definition, the relative decline of other subsectors. Such an output increase constitutes an absolute doubling in real output of computers and office equipment over the decade (US Department of Commerce, 1977, 1987).

Exceptional sectors that nonetheless experience increased output represent a large grouping of specialized products, and include refrigeration and service machinery (SIC 352), special industry machinery (SIC 355) and miscellaneous industrial machinery (i.e., not elsewhere classified; SIC 359). The latter two are large, but generally catch-all categories that include the often custom and virtually one-of-a-kind products of very small firms and plants (US Department of Commerce, 1977, 1987). Although such products are not necessarily highly technically sophisticated, they are products that are not produced by, and may not be amenable to, standardized processes.

From 1977 to 1987 substantial losses of machinery output shares occurred in engines and turbines (SIC
351), farm and garden machinery (SIC 352), and construction and related equipment (SIC 353). Lesser, but nevertheless considerable declines were recorded in metalworking machinery (SIC 354) and general industrial machinery (SIC 356) (US Department of Commerce, 1977, 1987).

Two particular subsectors of machinery have been drawing most scholarly (and popular, and polemical) attention. The metalworking machinery and computer subsectors receive such interest because they are, even within a core industrial sector, of particular importance as propulsive subsectors, and are of special significance in the competitive long-term.

The decline of the U.S. domestic metalworking machinery is manifest. Its output has declined at a rate of slightly less than 1 percent per annum over the 1977-1987 period, and has been reduced, in terms of value added, to a 11.6 percent segment of the machinery sector by 1987, down from 13.0 percent in 1977 (US Department of Commerce, 1977, 1987). This is, however, a symptom of problems in the industry that date at least from the mid-1960’s and have not yet been obviated (Graham, 1994). It is generally agreed that the industry’s fragmented structure has limited adoption of
process technologies (March, 1989; Rees, Briggs, and Oakey, 1986). Where consolidation has occurred, the larger purchasing firms and conglomerates, as often as not, have extracted profits without substantial reinvestment in plants. When they have invested, they have tended to emphasize only high volume standardized products. New process technologies have been only slowly and haphazardly introduced, a trend that became exacerbated by the severe downturns of the early/mid-1970’s and early 1980’s (March, 1989). Limited overall gains in productivity and reduced capacity has meant that users of metalworking machinery now purchase amply from foreign producers who have increasingly provided higher levels of service, faster delivery, and higher quality products (March, 1989; Graham, 1994).

As with electronic components, much of the most active interest in the metalworking machinery industry generally (ie., in the U.S. and elsewhere, typically in comparative perspective) is represented by concerns about the subsector’s strategic influence. And, as with the electronic components industry, such analyses generally trace the underlying difficulties to the structure of the industry as it relates to the larger institutional framework of national economies (March,
1989; Graham, 1994). The conclusions of these studies assert the value of policies that promote long-term perspectives. In short, the experience of the last several decades show that the possibility of long-term competitive enhancing strategies for the U.S. metalworking machinery industry, particularly concerning machine tools, have been sacrificed to the short-term expediencies of firm and conglomerate profit making.

The inclusion of computer and office equipment within SIC 35 is a relict of the time before the office use of computers. Of course, much of the upstream input into computers originates in SIC 36, and often, in casual discussion, computers are categorized as electronic products. Also, the growth characteristics of the computer industry are similar to electronic components, each sector presumably impelling growth in the other.

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20 This means that, for the present study, full vertical integration is not even a theoretical possibility. It illustrates the limitations imposed by categories imposed upon products in an originally systematic manner, but for which technological change and economic growth have created less coherent classifications over time.

21 However, apparent discontinuities in the domestic production of computers and electronic inputs, such as semiconductors and microprocessors, have arisen. The problem is the focus of substantial literature (Finan
By 1987, computers, including storage devices, terminals and peripheral equipment constitute over 91 percent of the three-digit computer and office equipment classification, which itself accounts for more than a quarter of industrial machinery output (US Department of Commerce, 1987). In terms of the rate of growth, the computer and office equipment sector output has exceeded a 7 percent per annum increase over the 1977-1987 period, making it the only subsector of the machinery industry with particularly rapid growth.22

This specious evidence would suggest that computer production is the only really dynamic subsector of an otherwise contracting machinery industry. But again, as with electronics, the global context offers an alternative, and more realistic, perspective. From such a vantage, it is evident that most subsectors of machinery have dynamic properties, given their pace of technological advance into both process and product innovations, and also given the global development of

\[ \text{and LaMond, 1985; Clausing et al., 1989; Stowsky, 1989).} \]

\[ \text{22This subsectoral growth is not spatially uniform, and does, therefore, have an uncontrolled for shift impact upon the interregional growth characteristics of the machinery industry.} \]
rapidly industrializing, machinery using, economies. However, the adoption of these technologies has occurred more rapidly in Japanese and (West) German firms that have, as a result, captured ever increasing portions of the U.S. market. From a global perspective, machinery, with or without computers included among its products, continues to experience dynamic growth, with nascent but competitive producers arising even in such countries as South Korea, Taiwan and Brazil (Dertouzos, Lester, and Solow, 1989). The problem for the U.S. is that this growth of production has occurred elsewhere and is exported to American users.

3.3.2 Patterns of Interregional Growth

Despite overall output stagnation in the machinery sector, the fact that interregional variations are evidenced suggests that a Verdoorn response over the period in question may be discernible. Regions with output growth may experience Verdoorn effects particularly given the technological intensity of the sector. The productivity response to output growth may be negative as well, after allowing for some underlying neutral technological advancement. An estimated
Verdoorn relationship in the machinery industry with significant interregional growth variability, but overall stagnation, implies less productivity growth in regions with output contractions.

As a supplier of capital goods, the machinery industry's development has reflected the spatial growth patterns of manufacturing generally. Therefore, through most of the last nearly two centuries, the machinery industry has grown to prominence in the manufacturing belt of the U.S. in close, market oriented, proximity to its industrial users (Miller, 1977; Hounshell, 1984). Significantly, the historically low value to weight ratios of many machinery products, and the once considerably high cost of transportation, made proximity important. Even today, such transferral cost considerations remain, and may have recently heightened, given the increased emphasis placed upon the speed and quality of service associated with lean manufacturing and, particularly, with just-in-time delivery systems (Klier, 1993; Estall, 1985). Only recently has the industry grown at faster rates in regions beyond the manufacturing belt, following, once again, the spatial trends of manufacturing as a whole.

However, as has been noted in the previous section,
with the exception of several subsectors, the industry has ceased to grow in terms of output, and has contracted in employment terms. Growth in one region of the country over the last several decades is nearly tantamount to absolute contraction in others. While, by some measures, the machinery industry of the country’s old industrial core has been capable of maintaining a comparatively strong competitive presence due to the more widespread adoption of new process technologies (Rees, Briggs, and Hicks, 1985), it has demonstrably lost productive output in real terms (figure 5.2) (US Department of Commerce, 1977, 1987). It is certainly possible that the loss of output would have been greater than it has been if firms in the northeast and midwest had not been as (moderately) successful as they have been with process innovations. The evidenced lower innovative propensity of firms in the south and west may have contributed to lower gains in output in these regions than would have otherwise been the case. It is possible to suppose, then, that although a noticeable interregional shift in output has occurred over the last several decades, it may not have been as great as it would have been had all firms in all parts of the country innovated at the same rate and to the same
Alternatively, however, high rates of process innovation adoption in the midwest and northeast is interpretable as a function of consolidation, where productive capacity is concentrated in selected plants, and those surviving rationalization during restructuring are technologically updated. Up to the early 1980’s, at least, this latter interpretation does not seem to be empirically warranted, as new plants are built in the region at rates comparable to other parts of the country (Rees, Briggs, and Hicks, 1985).

Evaluating the interregional circumstances in the U.S. as of the mid-1980’s, Rees, Briggs and Hicks, who have closely analyzed technical innovation in the machinery industry, make the following assessment:

...the industrial heartland appears to have more than held its own in terms of the revitalization of the metalworking industry through new plant growth...there is little to support the common belief that the older industrial regions are less susceptible to renewal and rejuvenation through new industrial growth and expansion. An industrial rejuvenation has indeed altered the structure of the metalworking industry...but it has largely done so within its original seedbed (Rees, Briggs and Hicks, 1985: 170)

In retrospect, such an assessment regarding the industry’s revival in the old manufacturing belt is probably excessively optimistic. Actually, data
gathered by these authors does, in fact, suggest a comparative erosion of output capability in the East North Central and Middle Atlantic regions. They find, over the three decade period beginning with the 1950's and ending with the 1970's, that these two regions were the location of a reduced percentage of new metalworking machinery plants relative to the national total, from 57 percent down to 43 percent. That the 43 percent is yet substantial nevertheless means that it entails comparative decline.23

Coupled with the recent lack of absolute output growth for the industry nationally, this finding begins to make the situation in these regions appear seriously problematic. Census value added data for the 1977 to 1987 period shows that, by this time, the only output growth of machinery goods occurs in parts of the west and south (figure 5.2), and overall growth, as reviewed above, is minimal. Further, if the Verdoorn effect holds, scale induced productivity enhancements will favor the competitive posture of only selected parts of

23They note that by the early 1980's the East North Central was alone responsible for 43 percent of new plants, a result that suggests a surge in that particular subregion of the old manufacturing belt (Rees, Briggs, and Hicks, 1985)
the west and south. Misplaced optimism concerning the midwest machinery industry can be viewed as another example (in addition to the ambiguity of localized dynamics, especially relating to Silicon Valley, in the electronics industry) where it is important to consider the overall condition of the industry when making interregional comparisons. Models of regional economic dynamics entailing different purported models of success (spontaneous high tech growth in the Silicon Valley, or unexpected industrial renewal in the Midwest, among them) may be more specious than real when considered by international comparison.

Even given the output (and labor productivity) problems of the U.S. machinery industry as a whole, empirical evidence that shows higher rates of technological innovation among firms in the old manufacturing belt is significant. The innovation question is, while not independent of those concerning output and productivity growth, at least partly distinguishable from them. Regarding innovation, Rees, Briggs, and Hicks arrive at some prescient conclusions in their 1985 paper concerning adoption rates by machinery firms:

Our finding that older plants are more likely users
of...new production technologies than newer plants is testimony to the technological change occurring in the more established industrial areas of the country. This rejuvenation process has been 'glossed over' by many recent studies of industrial change in the United States...the overall pattern of results indicates a correlation between capital and labor by region. This relationship suggests that the more advanced production technologies are introduced in the higher skill, higher wage areas of the industrial Mid-West to yield cost savings, while a lower incidence of these technologies (or less advanced versions) are found in the lower wage, lower skill labour markets of the South and West (Rees, Briggs and Hicks, 1985: 192)

Viewed in isolation from the fact that the migratory trends of both labor and capital (ie., in the aggregate, without considering skill levels or of capital/labor ratios) are toward sunbelt regions, this is a squarely neo-classical conclusion. In addition, as the authors suggest, it accords well with product cycle theories of industrial restructuring (Rees, Briggs, and Hicks, 1985). Newer products and processes develop in an industry's core region earlier than elsewhere because of existing broadly defined infrastructural advantages, including the specialized technical skills of labor, and the agglomerated presence of user firms. This is particularly the case in machinery since the process technologies in question are of the type that, when instituted, allow for small batch production at
comparatively large scale. Evidence that the northeast and midwest are sites of reinvestment and structural renewal is significant as it conflicts with often held assumptions about the possibilities of restructuring in place rather than necessarily at greenfield locations, in as yet industrially underdeveloped regions. Recently, more abundant evidence has confirmed the innovative resilience of manufacturing belt industries, although the relative loss of productive capacity in many of the region’s industries is equally evident (Florida and Kenny, 1992; Gertler, 1992). Naturally, studies that substantiate a manufacturing renewal in the midwest and northeast along technological lines typically conclude that industrial dynamism is not representative of only newly industrialized regions. Further, they either assert that flexibly specialized production is possible in older manufacturing regions through a process of technological succession, or that

24Reference here is to the NC (numerical machine control devices) and CNC (computerized numerical control devices) technology, as well programmable handling systems. Typically the product cycle has been envisioned along stages which distinguish between the earlier importance of product innovations, and the mid-cycle prominence of process innovations. It has been normally supposed that the drive toward product standardization induces process innovations which reduce labor costs and produce capital efficiencies (Utterback, 1979).
flexibility, in and of itself, is either misidentified as a fundamental characteristic of renewal, or not of determining significance (Sayer, 1989; Gertler, 1988, 1992).

Finally, concerning the machinery industry and its product and industry cycles, the experience of New England as a region should be noted. The notion that New England has, perhaps uniquely, undergone a full cycle of industrial growth, maturation, and decline is well known (Thompson, 1966). Regarding machinery specifically, it was, for perhaps a century, the center of production, originally in service of the textile and apparel firms dominant in the region. In fact, these sectors constituted a first agglomeration of industrial synergies to be identified in the U.S. (Hekman, 1980b). The engineering success in standardizing textile production lent impetus to the southward migration of that industry (Hekman, 1980b). In time a larger machinery industry developed in the midwest around the larger scale metals and assembly sectors that emerged there. Yet certain machinery producing capabilities remained in New England, partly a testament to this past engineering legacy, maintained through a lean first half of the twentieth century by wartime defense contracts.
Growth, sporadic during the 1950's and 1960's, continued to be aided by defense contracts to machinery and instruments firms, a base that ultimately led to the spectacular development of the computer industry (a subsector of machinery) in eastern Massachusetts (Dorfman, 1983). This, in turn, created the impetus for growth in selected subsectors of electronics, and the entire complex spilled over into the adjoining states of New Hampshire and Rhode Island.

Major credit for the revival of machinery (in high tech clothing) as well as for the rise of related subsectors of electronics and instruments is typically given to the region's skilled labor force, the role of its major (and applied oriented) universities, the growth, interaction and spin-off generation of a set of small firms, all complementing the rapid technological change to which their products were subject (Hekman, 1980a; Dorfman, 1983). Despite purported flaws in the region's organizational and entrepreneurial environment (Saxenian, 1994), New England could probably expect to be a center of product and process innovation in high technology industries for some time. As long as product innovations develop rapidly, the region could also maintain much of its production capacity as well.
However, constant pressure toward standardization exists. As Hekman states it:

As long as new computer models and generations of models are introduced quite regularly, companies will not want to separate design and manufacture, because the manufacturing facilities must be readapted each time and because there is much testing and learning by doing in production. But more and more sub-assemblies which are not radically redesigned can be produced elsewhere. This means that employment outside the primary centers should grow more rapidly in the future (Hekman, 1980a).

There exists, then, a tension between the impulse to standardize production, and the dilemma of product innovation. In terms of maintaining growth in existing agglomerations, the prospect of necessarily continuous product innovation reduces such tension by making product standardization unwarranted and flexibility requisite.

3.4 Apparel

That flexible production systems could diffuse more broadly across manufacturing generally than merely in certain high technology sectors is said to be supported by evidence from the apparel sector (Piore and Sabel, 1984; Scott, 1984, 1988b; Gibbs, 1987; Mather, 1993). Instead of merely being an attribute of rapidly innovating industries in early stages of their industry
cycle, flexible specialization could occur in mature industries as well.

The argument with apparel is, however, dependent on the fact that the industry is labor intensive. Labor intensity appears to reduce impediments to flexible adaptations for two reasons. First, in the labor intensive environment, the underlying organizational and institutional conditions are likely to be less rigid than is the case where capital/labor ratios are high. The premise here is that "craft" type production systems are still at least partly intact (ie., the first industrial divide engendering mass production was not breached), and favorable to some forms of labor flexibilities (ie. pay flexibility)(Piore and Sabel, 1984). In terms of locales, such an institutional environment may already exist in places where the industry in question has long prospered, such as in New York City’s apparel districts, but may also be created in newer localizations, such as in the Los Angeles district (Scott, 1988b). The difference is that now specialization will be far greater than in the past, as the market will be potentially global, and competitiveness will be in terms of quality, delivery, and specification capabilities.
A second flexibility adaptation advantage of labor intensity is that large amounts of machinery do not have to be discarded (or converted) in the process. The source of flexibility, then, is not that the sector is adopting large amounts of new flexible production technologies, but that it is not greatly encumbered by the difficulties of incorporating flexible capital into its existing stock of equipment. This may have the effect, however, of placing yet more pressure on the flexibility requirements of both labor and the organizational structures of firm/plant networks than would be the case in more capitalized production processes.

In fact, the evidence is ambiguous, but it serves as something of a counterpoint to the flexibility skeptics. The idea that labor intensive industries could be rejuvenated by producing flexibly for variable demand in small highly specified batches had been a conviction of the earliest descriptions of flexible specialization (Brusco, 1986; Becattini, 1990). This has clearly appeared to be the case in the Emilia-Romagna districts if the Third Italy (Piore and Sabel, 1984). The purported efficiencies discerned there have been generalized as optimal production systems,
particularly in the context of industrially developed high labor cost economies. The logic of such claims has been lent support by the type of changes that have undoubtedly emerging in a number of assembly industries, namely that competitive stature has begun to require much more cooperation between vertically positioned firms (Rubenstein, 1988; Ettlinger, 1992). As demand has become more niched, while product life cycles and product throughputs have temporally condensed, the opportunity for long periods of standardized assemblies has diminished, creating a competitive environment more exacting of quality and delivery standards than of price per se. To bolster the argument, the theoretical notion of transaction cost minimization has been employed, lending more credibility to the localization implications of flexible specialization (Scott, 1988b, 1988c).

Together, these empirical suggestives and theoretical proposals seem to have significantly broadened the conceivable possibilities of flexible production methods, and have directed particular attention to such existing or imaginable systems within the apparel sector.
3.4.1 Sectoral Characteristics

Of what is typically referred to as the textile complex, the apparel industry, SIC 23, is substantially the largest segment in terms of both employment and output. Three of the four industries in the complex can be defined by their relationships within the chain of production. Simply, fiber (natural, or, more often, artificial) is produced in the fiber sector and converted to fabric in the textile sector (SIC 22). The apparel industry produces mostly finished garments to be marketed and distributed by retailers. A fourth sector consists of associated material inputs and capital goods producers. The textile machinery industry is the most prominent of these (classified in special industry machinery; SIC 355), but, subject to severe import competition, has been in precipitous decline through the 1970's and 1980's (Berger et al., 1989)

The apparel industry in the U.S. has been, as it remains, a labor intensive sector of many small firms and plants. In 1987, only 40 percent of apparel plants employ more than 20 people (US Department of Commerce, 1987). While the textile sector is also considered to be labor intensive, it averages much larger plant sizes
and has invested heavily in labor saving machinery over the last several decades in an effort to become more globally competitive. This has required levels of product standardization that, while potentially creating future problems for the textile industry, has not been an option in apparel manufacturing. At least in some of apparel’s most significant subsectors, the production process is not subject to widespread standardization and has not up to now, as a result, been amenable to capitalization (Dickerson, 1991).

It is, however, a large and significant domestic industry. As of 1987 it is a 32.5 billion dollar industry employing 1.1 million people. Due partly to import penetration and partly to productivity gains (which have been among the highest in U.S. manufacturing), employment losses from 1977 to 1987 total nearly a quarter million workers. Despite some lost domestic markets, however, the industry expanded modestly in real output terms.

However, pessimism concerning the industry’s future is widespread, and even the few optimists suggest that only major revisions to its structure and its policy environment can salvage it. Concern is directed toward the organization of the industry, as it is feared that
the many small firms might not be able to make appropriate capital investments in the forthcoming years. Further, it is believed by some observers (Glassmeier, Thompson, and Kays, 1993) that the industry is not suitably structured to compete in the appropriate market segments.

Both the smaller apparel firms, and the, on average, larger textile firms have competed with one another and with imports much more on the basis of price rather than in terms of product quality and specification. This has meant that U.S. domestic producers have become increasing structured to compete with the low cost importers of low value added, high volume fabrics and garments. As a result, apparel producers have become less able to respond to the higher value imports of producers from some developed and newly industrialized countries, while they must continue to find cost savings to compete with manufacturers from developing countries (Berger, et al., 1989). Producers from developing countries can much more easily find cost savings in low labor costs, and could probably maintain a factor cost advantage even were the U.S. industry to appreciably capitalize. In fact, many producers in the small firm segment of the U.S. industry would probably
find it more difficult to invest in labor saving machinery than larger foreign producers. Clearly the price terms of competition have become daunting.

It is generally conceded that within the industry capital and labor are particularly substitutable (Glassmeier, Thompson, and Kays, 1993) and different levels of technology are available to new industry entrants. Apparel is, therefore, producible in a great variety of locations with variable factor input combinations. Producers in industrialized countries can compete by shifting their capital/labor ratios, but only to the extent of available technology. At some point, cost competition is not likely to remain credible, particularly if labor saving machinery in garment production remains technologically limited. The only option for producers in industrially developed countries would be to compete along quality and specification fronts in high value added and specialized markets. This has been the opinion of some analysts during the

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25 U.S. domestic producers would have more incentive to do this, however, because of their much higher labor costs. The importer group includes some large U.S. producers who have long since sought low labor costs in developing countries and are likely to be the more capital intensive producers in these countries despite these much lower labor costs (Berger, et. al., 1989).
1980's (Berger, et al., 1989), but some observers now believe that the opportunity to restructure along these lines has now past (Glassmeier, Thompson and Kays, 1993). There is, as well, recent evidence indicating that high value added market segments dominated by the high cost producers of Europe have become increasingly competitive due to the ability of somewhat lower cost East Asian producers to penetrate their markets (Glassmeier, Thompson, and Kays, 1993).

While the U.S. industry has long sought relief from import pressure, and as with producers in developed economies receives it in the form of the trade managing quota based multifiber agreements, much of this may have actually damaged the industry. In fact, vertical segmentation of the textile complex has tended to disadvantage apparel in particular. Trade restrictions tend to target fabrics which are needed as material inputs into apparel production, as they are often simply not supplied in the correct quantity and by correct specification by textile firms. Such incongruity in the product chain has resulted from the trend toward capitalization and standardization in the textile sector; but it leaves the apparel industry without domestic sources of some inputs. The textile industry
has become attuned to the volume requirements of its capitalization program, and has shifted more of its downstream attention to supplying home furnishing and industrial markets. As a result, the smaller batch requirements of many apparel producers have become less tenable within the domestic market, leaving these producers few options. Those with the most difficulties are likely to be the producers that would find it more difficult to relocate overseas, or to pay tariff costs on imported fabric.

The industry has, to some degree, recognized its particular domestic problem. It is vertically wedged between two much more concentrated sectors, the textile producers on one hand, and the apparel retailers on the other, that can approach their relationship with apparel producers as oligopolists and oligopsonists, respectively. To rectify this, and to address production and coordination problems as well, a 'quick response' system has been developed, although not fully implemented (Office of Technological Assessment, 1987). Its objective is to improve the cooperative environment and speed of transactions between textile producers, apparel manufacturers, and retailers. The system entails closer transaction relationships between apparel
manufacturers and their subcontractors (i.e., coordination between vertically disintegrated levels of garment production). Its success has been viewed as critical for the long-term survival of the apparel industry, mostly because its quick response would require an efficient apparel industry, domestically located. The level of cooperation necessary to effect such a system is substantial, particularly for the relatively small apparel producers. It requires entering into a type of just-in-time computer controlled delivery system, where retailers' sales accounts are rapidly fed to manufacturers who, in theory, can immediately move to produce certain specified garments for very fast delivery. This entails, as well, breakneck coordination of subcontractors, and, ultimately, the integration of computers into manufacturing itself (Office of Technology Assessment, 1987; Dickerson, 1991).

In addition to specializing in highly specified and high-value end products, a systematic coordination of apparel and its linked industries through quick response and computer-integrated manufacturing is undoubtedly the best of all possible responses for the industry in industrialized countries. If not complete fantasy, the reality is that in view of the structure of the U.S.
domestic industry it hardly seems plausible. The QR system has not as yet had an apparent impact (Glassmeier, Thompson, and Kays, 1993). At a time when East Asian and some European (ie. mostly Italian) producers have moved rapidly toward such a system within their own expanding regional markets (and are responding quickly to U.S market demands, albeit without the possibility of a U.S. QR presence) it appears that the U.S. industry could be left behind.26

Nonetheless, the good news is that recent evidence shows the industry to be seriously investing in some capital equipment, as more process technology is beginning to appear (Cline, 1987). The design and pre-assembly phases of manufacturing are increasingly subject to automation, which has had the effect of reducing the length of the apparel "pipeline", and speeding production response time (Dickerson, 1991). In addition, this machinery is flexible in the sense that it is typically computer aided and controlled. The

26The alternative, at least for large and medium sized firms, is to move to a place of low cost labor and to mass produce in standardized items. Such a decision is tantamount to accepting only a price competitive posture, incurring higher inventory costs and taking markdown and stockout losses at the retail end, but which frankly looks more reasonable with the passage of the North American Free Trade Agreement (NAFTA).
dilemma is the expense; much too costly for the mostly small firms of the industry (Gibbs, 1987; Mather, 1993). As a result, this machinery may technically allow for flexibility, but not in the manner envisioned by some observers. Rather than occurring in an agglomerative environment of accelerated subcontracting and reductions to plant size, it may well result in process integration and the concentration of production in fewer firms and plants. The irony could be that the introduction of flexible machinery creates some internal economies of scale that have not before been evidenced in the industry (Arpan et al., 1982).

The impact of capital investment upon a historically labor intensive sector such as apparel can be substantial. The organizational imperatives will likely necessitate an industry shakeout, ultimately creating greater productive efficiencies. The potential marginal returns to the increased adoption of only selected machinery are considerable (Gibbs, 1987). As a result, the rate of labor productivity growth is likely to be highly sensitive to small increases in capital intensity.
3.4.2 Patterns of Interregional Growth

Generally, the apparel industry has a long history of development, having been part of what is typically considered the first set of agglomerated manufacturing districts in the U.S. Together with the early textile and machinery industries, it developed in and around several New England (and to a lesser extent in Middle Atlantic) nodes of activity in the late 1700's and early 1800's (Hekman, 1980b). Since then it has remained an industry of the eastern U.S., its major geographic shift entailing a relocation of many facilities to the southeast U.S. beginning at the turn of the twentieth century. It has, however, continued to be of major importance in the northeastern U.S. This is in contrast to the textile industry that virtually abandoned its erstwhile northeastern locations to reestablish itself in several southeast localizations during the first half of the century. Even as late as the 1960's employment in textile manufacturing expanded (to say nothing of output which expanded very quickly given the then rapid capitalization of the industry) in the southeast while its northeast remnants further contracted. The apparel industry also has tended to diffuse to locations in the
west, particularly the southwest and California, during the mid century to a much greater extent than the textile sector.

The migration of the textile industry is perhaps the best, most thoroughly understood and documented, example of the domestic relocation of any U.S. manufacturing sector (Hekman, 1980b; Johnson, 1985). Apparel manufacturing has often been characterized as attracted to the same set of conditions offered by southeast locations, with the additional inducement of its upstream textile linkages having already migrated. But apparel is internally differentiated to a much greater extent by the manifold distinctions of its products, and this degree of specialization has tended to keep the industry intact in northeastern metropolitan areas and has attracted it to larger western, particularly west coast, urbanized areas. The apparel sector, then, can be characterized as having gravitated toward two types of localities: large metropolitan areas with agglomeration economies, and rural low wage peripheries. Broadly, this is so at various spatial resolutions, as valid globally as it is interregionally within in the U.S.

This dual locational tendency is at least partly a
function of the labor intensity of the industry. This labor intensity is, in turn, necessitated by the technological limitations imposed by the underlying production framework of the industry. Unstandardized product lines, where specifications are often altered on very short notice, have made it very difficult to advance labor saving process innovations. The variability of demand, without technical product innovation per se, but with rapid changes to product design and specification, contributes crucially to the industry’s low capital to labor ratio and resultant low level of labor productivity. It thwarts attempts to develop process innovations, not allowing the industry through anything resembling a product life cycle.

The underlying tenet of the industry life cycle thesis is that an industry’s process technology is the single most critical determinant of its prevailing locational requisites (Vernon, 1966; Abernathy and Utterback, 1978; Hekman, 1980a, 1980b). Without significant process innovations, the apparel industry does not obviously fit into a pattern of industrial (or product level) development. Actually, if it were not for the fact that wages almost inevitably rise in urban agglomerations, little incentive would presumably exist
for the peripheral diffusion of the industry. Indeed, through growth, subdivision, and vertical disintegration, sufficient specialization may increase efficiencies to the extent of offsetting higher wages, thus maintaining or even enhancing urbanized production.\textsuperscript{27} Or relocation may be possible, and deemed necessary, in order to lower the total cost of labor, but not, in the case of apparel, to diminish the labor content of output. In fact, the industry has tended to choose comparatively isolated locations of the southeast, in a much more diffuse pattern than the localization clusters more characteristic of the textile industry (Johnson, 1985; Falk and Tyson, 1988).

So while the textile industry has come to rely on the increased use of dedicated capital equipment in producing large volume runs of standardized goods, the apparel industry has had no such opportunity for obtaining internal (of plant) scale economies. In fact, negligible returns to scale have been identified by production studies of the industry (de la Torre, et al., 1978; Arpan, et al., 1982). While a trend toward larger plant sizes has been observed in the apparel industry

\textsuperscript{27}This is an argument use by flexible specialization theorists (Scott, 1988b).
(where average plant sizes are relatively very small),
economies of scale do not accompany such changes. The
organization of apparel production in the rural south is
not radically dissimilar to the disintegrated form of
production characterizing the urbanized industry. The
only returns to scale are found in the coordination
activities, and in engineering and cutting to a very
limited extent. Sewing, along with design and cutting,
a central activity, shows decreasing returns to plant
sizes greater than twenty employees. When averaging out
the variable influences of scale, plant size
consolidation has the effect of lowering, on average,
output per worker hour (de la Torre, et al., 1978;
Arpan, et al., 1982). The major caveat of studies
showing such results is that the plants, regardless of
size, of larger firms benefit more from the capital
investment (Arpan, et al, 1982). Larger plants, though,
tend to be associated with larger firms.

The most efficient physical arrangement of
operations in southeast locations is purported to be a
"spoke and wheel" system, where small establishments
produce in relatively isolated locations, but close to a
common administrative office. Except for the fact that
that this system may be more typically internalized into
a single firm in rural locations than in urban agglomerations, it is certainly akin to the subcontracting and outsourcing that presumably prevails in vertically disintegrated urban complexes. However, the products of peripherally located plants are more likely to be less specialized, lower priced, requiring for their production the application of fewer skills for which lower wages are paid.

While this is the standard characterization of the rural apparel industry, urban centers are more differentiated. Typically, even the apparel industry of the urban agglomerations has relied upon low skilled and low paid laborers. The firms here can be among the smallest, tending to lack access to financial capital, hiring the most marginal (often immigrant) labor, sometimes owned and operated as well by immigrants. But the small firms of urban areas may be distinguished from one another according to the quality of their product. Those firms producing lower quality garments do substantial subcontracting (or they may be the subcontractors), while high quality, high specialty items are produced by higher skill, higher wage labor in a more integrated process. These latter items are often produced in very small batch quantities, or are
virtually custom made. The internalization of their production is a function of necessary quality control, the producer finding it necessary to exert more supervision over the entire process (Scott, 1984). In analyzing the Los Angeles dress industry, Scott makes the following contrasts between types of producers:

...producers of high-quality dresses in short runs generally organize the manufacturing process on making through principles. This, by, definition, reintegrates the labor process and reduces the opportunities for subcontracting activity...more capital-intensive plants producing relatively low-quality, low-cost dresses in long production runs require much less control over the details of the labor process as such. These plants are relatively less sensitive to the need for high standards of craftsmanship. They are, however, very much concerned with cost-effectiveness... (Scott, 1988b: 102)

Producers of both high and low quality apparel goods, then, are found in metropolitan centers, but with different organizational features. As Scott shows, these small producers of women’s dresses in Los Angeles tend to cluster in the city center, while toward the city’s periphery larger manufacturers (producing in larger plants) tend to produce lower quality dresses. To extend Scott’s spatial notions, it can be broadly suggested that the most peripherally located apparel manufacturing, such as that of the Southeast U.S., tends to emphasize yet lower quality and larger batches,
exhibiting some degree of disintegration at the plant level, but horizontally large numbers of pieces.\textsuperscript{28}

Note, also, in the above quote of Scott's, that the notion of a tradeoff between producing quality and quantity is forwarded; that is, producers either raise labor productivity by producing high value items or keep the cost of labor low (without increasing labor productivity) through layers of subcontracting and a "detailed division of labor" (Scott, 1980b: 102) that controls costs. In fact, the suggestion in the quote is that capital intensity and product standardization raise labor productivity in the case of low quality production. However this has been, as reviewed in this section, difficult to document in plant level studies. In apparel manufacturing generally, if not in women's dresses specifically, productivity increases have not been the result of applying capital and internal scale to production. Further, little growth in the capital component of production can be evidenced up until

\textsuperscript{28}In both 1977 and 1987, the average plant size is much larger in the southeastern states than in the rest of the U.S. For 1977, in terms of employees, the average of state mean plant size is 50.3 workers. The average in Mississippi is 176.5, in California, 23.6 (computed from US Census data; US Department of Manufactures, 1977, 1987).
recently, mostly because of the very difficult to standardize processes inherent to the industry. Moreover, capital investments taking place recently may well be geared to flexible small batch type production (not necessarily in small plants), and flexibility may, perhaps ironically, be achieved through capital intensification. However, it is certainly likely that even small absolute increases in the capital/labor ratio are likely to have significant labor productivity effects.

3.5 Summary

These three industries are among those whose production systems are identified as particularly impacted by the diffusion of flexible systems of production. Their spatial dynamics of the recent past, monitored in various literatures, have been associated closely with the development of the technological and organizational characteristics of flexible specialization. The locational behavior of the electronics/instruments and the apparel industries are said to be have been especially attributable to the rising significance of such production systems, as well
as to the recrudescent importance of agglomerative clustering. Machinery is characterized somewhat differently, and is not as typically associated with flexible specialization, though many of its products are inherently custom or semi-custom.

The argument put forth in the literature concerning flexible specialization is that the locational patterns associated with product life cycles and spatial divisions of labor are of diminishing importance in these industries. How limited these become is roughly correlative to the production significance of flexibility. In a universalist type variant of the flexibility thesis, it is thought that flexible specialization will become the dominant form of production, thus eliminating product life cycles and, at least, extended interregional labor divisions. Each of these industries, for different reasons, seems to show evidence of such a possible trend, but certainly nothing "ruptures" the significance of mass production and economies of scale. In fact economies of scale appear to be of continuing importance, albeit with large-scale production able to accommodate expanded product scope.

The tendency for growth to be spatially concentrated, and for these concentrations to be centers
of innovative activity, suggests that the Verdoorn relationship remains significant, possibly of growing importance. Up to now, the dominant geographical perspective on flexibility holds that Verdoorn effects are tending to strengthen as a result of the increasing importance of interfirrm organizational externalities, manifested in vertical disintegration (Scott, 1988b, 1980c). There is reason to question the continued, or increasing, significance of such externalized organizational factors, however, particularly in view of developments in flexible process technologies (Shoenberger, 1989; Gertler, 1992). Regardless, though, the reconcentration of production activity in these industries appears to be largely ongoing whatever its organizational form, and this is likely to create continued Verdoorn effects.
CHAPTER IV - MODEL, METHOD, VARIABLES

4.1 Introduction

A model incorporating both the Verdoorn effect and the capital component of productivity growth is developed in this chapter. This model is hereafter referred to as the augmented Verdoorn model (AVM). In order to incorporate the influence of the external organizational environment upon the model, the AVM is expanded so as to redefine the initial parameters in terms of such influence. The development of the AVM and the expansion of the resulting parameters relies upon methodological approaches developed by Casetti (1972, 1982, 1984b).

The chapter concludes by reviewing issues of empirical measurement, including the construction of variables used in the forthcoming analysis. Particular attention is given to the indicators of organizational flexibilities that theoretically subject the AVM to parametric variability.
4.2 Augmented Verdoorn Model

Kaldor's initial specification of the Verdoorn Law is a simple linear specification of Equation (2):

\[ p_j = n + vq_j \]  

(5)

where \( p_j \) and \( q_j \) are the respective rates of growth of labor productivity and output in the \( j \)th spatial unit (state), \( v \) is the Verdoorn coefficient, and \( n \) represents the rate of autonomous productivity growth (in the absence of output growth). The relationship suggests that beyond variations in the rate of output growth, there is an intrinsic rate of productivity growth that is common to all \( j \) observations. As reviewed in chapter 2, this may not be appropriate if there are underlying technological differences among states. In a competitive economy, variations in the capital component of output are tantamount to differences in the capital elasticity of output. Where technological advancements are capital embodied (and labor saving) labor productivity growth is

\[ \text{As noted in chapter 2, Kaldor's initial test, and the majority of subsequent, and respecified, tests have drawn upon cross-national variations in productivity growth, rather than interregional variations.} \]
systematically related to such differences. However, because of differences in growth environments the marginal product of capital may increase (rather than more predictably decrease) even with higher capital intensities. Further, in a space economy that is discontinuous with respect to systems of manufacturing production, an assumption of the agglomerative flexibility thesis, we would expect the opportunities for capital investment in these different production (and technological) contexts to be similarly uneven. It is therefore necessary to account for the productivity effect of capital intensification as a component of technical progress that is not autonomous. Rather than estimating a coefficient that relates the growth in labor productivity to a change in the capital/labor ratio (ie. the capital elasticity), this study, premised on the assumption that different production (and technological) systems are established interregionally, assumes variable capital elasticities (ie. and variable marginal capital productivities). Then, the coefficient relating labor productivity growth to the capital share of output is a systematic measure of capital deepening.

A method for evaluating this type of relationship has been developed by Casetti (1984b). Casetti’s method
is especially useful because it allows for the estimation of the AVM without the use of capital data, which is unavailable at the state level in two-digit SIC sectors for the years in question.

Following Casetti (1984b), a production function for a particular manufacturing sector can be written:

\[ Y = e^{ht}L^aK^b \]  

where \( Y \) is the sector's output, and \( L \) and \( K \) are labor and capital inputs respectively. With \( ' \) denoting continuous change,\(^3\) the logarithmic derivative of (6) is written:

\[ Y' = h + aL' + bK' \]  

Neutral technological progress is indicated by \( h \); partial labor and capital elasticities of output are \( a \) and \( b \) respectively. The value of \( a \) and \( b \) combined is a measure of returns to scale. Accordingly, define the parameter \( E \) as:

\[ E = a + b \]  

In order to show that \( E \) is a scale parameter consider

\(^3\)ie., the logarithmic derivative with respect to time, for instance: \( Y' = 1/Y(dY/dt) \)
the following. Suppose that $K'$ and $L'$ are, say, .02 per year. Then $Y'-h=E(.02)$. Namely, $Y'-h$, which denotes the output growth in excess of neutral technological progress, is greater than, equal to, or less than .02 if $E$ is respectively greater than, equal to, or less than 1.

Especially significant to this study is the interpretation of $E$ with respect to the underlying sources of external economies. In characterizing $E$ as a returns to scale parameter, Casetti describes its broad interpretation:

...the growth of labor and capital inputs in a region can be both realized through increases in the sizes of productive units and through increases in their numbers and areal density. This suggests that whereas $E$ is an economies of scale parameter at the plant level of resolution, it reflects both economies of scale and external economies when the analysis focuses upon regional aggregates. (Casetti and Tanaka, 1992: 3)

As such, $E$ captures the effect of the organizational externalities that are at the core of the agglomerative flexibility thesis.

Given that $(Y/L)'=Y'-L'$ and $(K/L)'=K'-L'$, equation (7) can be rearranged as:

$$(Y/L)'=h/(a+b)+[(a+b-1)/(a+b)]Y'+(b/a+b)(K/L)'$$  (9).

Define labor productivity growth as the change in output
per labor unit, $p=(Y/L)'$, and capital deepening as the growth in capital per labor unit, $k=(K/L)'$. Using these definitions, and substituting (8) into (9), the following is obtained:

$$p = \frac{h}{E} + \frac{(E-1)}{E}Y' + \frac{b}{E}k$$  \hspace{1cm} (10). 

This result is an interpretation of the Verdoorn relationship that also controls for the labor productivity effect of capital intensification. Accordingly, the three elements of labor productivity growth are represented as $\frac{h}{E}$, neutral technological progress, $\frac{(E-1)}{E}Y'$, the Verdoorn effect, and $\frac{b}{E}k$, capital intensification (Casetti, 1984b, Casetti and Tanaka, 1992).

In following upon the discussion of the introductory portion of this section, by empirical necessity, but also on grounds that conform to theory, the augmented Verdoorn model is developed so that it can be estimated without capital data. Such a procedure demands two further simplifying, but generally supportable, assumptions. The first is the existence of a competitive cost minimizing interregional U.S. economy; the second, that all product is distributed to the products (Casetti, 1984b). If the first assumption
holds, then the distribution of returns is in proportional share to factor productivities.

In addition to its being a foundation of growth accounting (Denison, 1967; Casetti, 1984b), the assumption of cost minimization conforms as well to the new growth theoretic literature. While this literature diverges from growth accounting in suggesting that interdependencies among infrastructural externalities are an underlying foundation of increasing returns to scale, the aggregate level at which these returns occur allows for retaining the assumption of perfect competition (Romer, 1986; Fagerberg, 1994).

The object then is to establish the cost minimizing relationship between the parameters of (9) and (10), and the factor proportions. To that end, the combined labor and capital costs of production are minimized subject the output function, equation (6) (Casetti, 1984b). Formally, minimize: \( wL + rK \), subject to: \( Y = e^{\alpha L^a K^b} \), where \( w \) and \( r \) are the wage and capital rental rates, respectively, and the labor and capital share of product are defined respectively as: \( LS = (wL)/Y \) and \( KS = (rK)/Y \). Thus, with \( G \) representing the Lagrangian multiplier, an augmented objective function is established: 

\[
F = wL + rK - G(e^{\alpha L^a K^b} - Y),
\]

the first order partial derivatives with
respect to labor and capital of which are set to 0 and solved, yielding: \( L = (GaY) / w \), and \( K = (GbY) / r \). As costs are minimized and \( Y \) is allocated to the factors, that is \( Y = wL + rK \), then \( Y = GaY + GbY \), and \( G = 1 / (a + b) = 1 / E \). The respective labor and capital shares are:

\[
\begin{align*}
LS &= a / E, \text{ and } \\
KS &= b / E.
\end{align*}
\]

Therefore, under the cost minimizing assumption, the capital share is the equivalent of the capital elasticity of output. Substituting (12) into (10) results in:

\[
p = h / E + [(E - 1) / E]Y' + kKS
\]

In a simplified regression form this can be restated as:

\[
p = n + vY' + kKS
\]

where \( n = h / E \), \( v = (E - 1) / E \), and \( k = [d\ln(K / L)] / dt \). This is the basic equation (14), the augmented Verdoorn model (AVM), upon which the subsequent analyses are based.

The \( n \), \( v \), and \( k \) parameters are, respectively, the constant representing neutral technological progress, the Verdoorn coefficient, and the rate of capital
deepening. Recall as well, that $E$ is the structural parameter indicating returns to scale.

The intercept constant, $n$, indicates neutral technological progress, and depends upon $E$. The actual rate of autonomous growth requires the removal of the $E$ effects, such that the value of the structural parameter $h$ is obtained. The resulting $h$ value is the rate of productivity growth in the absence of capital deepening and scale economies (i.e. with the Verdoorn effect removed from the model). While the value of $n$ could approach zero if all factors impacting variable rates of productivity growth were accounted for, it would not normally be less than zero.

The Verdoorn coefficient is $v$. If $E=1$, then $v=0$, and the estimated model collapses to one of technical progress with capital deepening, but with constant returns to scale:

$$p = n + kKS$$  \hspace{1cm} (15)

A Verdoorn coefficient greater than 0 occurs when $E>1$, and indicates increasing returns to scale. Alternatively, decreasing returns occur when the Verdoorn coefficient is less than 0, and $E<1$. An inspection of (13) demonstrates that $v$ cannot be equal
to or greater than 1, as E is not capable of producing such a value of v. It should also be noted that, in terms of empirical analytics, the Verdoorn effect potentially works in reverse, in the sense that declining output could create a negative impact upon productivity growth. In the case where an individual observation, i, is negative (Y_i<0), the greater the value of v, the more detrimental is the labor productivity growth effect of negative output growth (Michl, 1985). In essence, cumulative growth processes can be either negative or positive in their effects.

The capital deepening parameter, k, indicates the rate at which capital per unit of labor is increasing (k>0) or decreasing (k<0). If k=0, no systematic change in the existing spatial variability of marginal capital productivities is evidenced.

As it is likely that both v and k may not be invariant across space and with respect to certain external organizational contexts, such sources of variability need to be explored.
4.3 Expanded Model

4.3.1 Expansion Method

The expansion method provides a systematic approach for incorporating empirical complexities into established theoretical relationships (Casetti, 1972, 1982). The Verdoorn Law represents such a relationship, of which the augmented Verdoorn model (13) is one possible specification.

The significance of Verdoorn effects have been recognized for a considerable period of time, and they have generated a substantial body of literature (Bairam, 1987). More recently, nascent ideas about a general reorganization of production have arisen (Scott, 1988a). The characteristics of this reorganization, if they are empirically significant, are likely to impact the production relationship denoted by the Verdoorn Law. The manner in which output growth accounts for productivity growth is, therefore, potentially subject to contexts of flexible production.

In order to examine this contextual impact, the expansion method is employed. With it, empirical characteristics associated with flexible production are
integrated into the augmented Verdoorn model (AVM). The method offers a systematic format for the development of an "expanded" terminal model from an initial model.

The method consists of three logical phases (Casetti, 1972, 1982). First, an initial function is determined, typically by reference to fundamental theoretical underpinnings. In the present case the AVM is identified as such. Second, the contextual characteristics are examined as to their potential impact upon relevant parameters of the model. The parameters are then redefined in terms of the contexts; in the present study this includes: the change in mean plant size, the rate of vertical integration/disintegration, and existing urbanization economies. Finally, a terminal model is obtained by replacing the model's parameters with their contextual redefinitions.

4.3.2 An Estimable Expanded Model

The expansion of the AVM is illustrated with respect to a single context, the change in mean plant size, PS'. Diminishing plant size, as reviewed in chapter 2, reportedly characterizes agglomerative production flexibilites. It therefore can be
hypothesized that PS' influences the Verdoorn and capital intensification components of productivity growth, that the parameters of the AVM vary significantly with respect to changes in plant size. Taking the initial AVM as represented in (14),

\[ p = n + vY' + kKS, \]  

(14)

the \( v \) and \( k \) parameters are defined in terms of plant size growth, such that:

\[ v = v_o + v_iPS', \]  

(16)

\[ k = k_o + k_iPS'. \]  

(17)

The Verdoorn coefficient is now defined as a function of its own exogenous effect \( (v_o) \) and of the effect of a change in plant size \( (v_iPS') \). Similarly, capital deepening is a function of an exogenous effect \( (k_o) \) and the impact of plant size change. By substituting the right sides of the expansion equations, (16) and (17), into (14), the following is obtained:

\[ p = n + (v_o+v_iPS')Y' + (k_o+k_iPS')KS, \]  

(18)

which, as the terminal model, can be expressed as:

\[ p = n + v_oY' + v_iPS'Y' + k_oKS + k_iPS'KS. \]  

(19)
This terminal model retains the parametric integrity of the initial AVM, the independent effects of which are denoted by the (0) subscripts. Yet, this expanded AVM also specifies parametric drift, as represented in the expanded parameters, denoted by the (1) subscripts.

Statistically testing the significance of $v_1$ and $k_1$ is tantamount to verifying the existence of such parametric drift. If $v_1=0$ and $k_1=0$, then the expanded AVM collapses into the initial model, and it is concluded that $v$ and $k$ are invariant with respect to plant size change. If $v_1$ is found to be significantly different from zero, than variation in the Verdoorn effect is associated with changes in the size of manufacturing plants. Similarly, variation in capital deepening occurs in association with changes in plant size if $v_2$ is found to be significantly different from zero.

By substituting numerical estimates of the terminal model parameters into the expansion equations, (16) and (17), the Verdoorn coefficient and the rate of capital deepening, respectively, are established for any given rate of plant size growth. Hence, each observation is represented by particular $v$ and $k$ coefficients.

Following the arguments made in the literature
pertaining to flexible specialization we would expect PS' to augment the Verdoorn effect, thus systematically altering the value of v across the domain of PS' values. Specifically, reduced plant sizes have been associated with the rapid growth of flexibly induced productive efficiencies, such that v is likely to have a negative sign. Similarly, the k parameter may be systematically a function of changes in plant size. We would suppose, based upon the literature concerning plant and firm sizes (Acs and Audretsch, 1990), that capital deepening is associated with diminishing plant sizes. Therefore, it would be hypothesized that the direction of influence is negative as well, and the k parameter is also negative.

31Of course, in view of the literature examined in chapters 2 and 3, this point is little more than conjecture. In some industries the possibilities for adopting capital equipment may impel a higher degree of operational scale, greatly increasing the minimally efficient level of output. Therefore, in certain instances, average plant size increases, rather than contractions, may be associated with capital intensification.
4.4 Empirical Measurement

In the analyses of chapters 6 and 7, the AVM, (14), is estimated by OLS and by a non-linear iterative algorithm. This latter procedure is adopted in order to constrain the neutral technological progress constant (n) to a non-negative value. Because of the credible estimates that result, the non-linear procedure is used for all subsequent expanded AVM estimations.

In addition to the PS' expansion of the AVM, estimations of expanded AVM equations with respect to the rate of vertical integration/disintegration and to existing urbanization economies are run. The same procedure exemplified by the PS' example is used to develop these expansions. Urbanization economies are proxied by two different measures which are reviewed in section 4.5.3.

In order to develop a thorough parametric portrayal of each of the three industries, to control for the effects of each of the expansion contexts, and to construct an interregional portrait of parameter variation, "industry" expansion models are estimated. These include expansions of the AVM by the three contextual variables (plant size change, rate of
vertical integration, and urbanization economies) for each of the three industries.

Following, generally, the procedures set forth in section 4.3, and adapting these for the case of \( n+1 \) expansion variables, the parameters, \( v \) and \( k \), of the initial AVM (14) are expanded such that:

\[
v = v_0 + v_1 Z_1 + \ldots + v_n Z_n, \tag{20}
\]

\[
k = k_0 + k_1 Z_1 + \ldots + k_n Z_n, \tag{21}
\]

where \( Z_n \) represents the \( n \)th expansion variable.

Replacing the initial AVM (14) parameters with the right side of (20) and (21) results in:

\[
p = n + (v_0 + v_1 Z_1 + \ldots + v_n Z_n)Y' + (k_0 + k_1 Z_1 + \ldots + k_n Z_n)KS. \tag{22}
\]

In this manner industry expansion models are developed and estimated. Details and results are reviewed in section 6.2.2.

Except for the proxies of urbanization economies, all variables are constructed from the U.S. Census of Manufactures (US Department of Commerce, 1977, 1987). Data for the variables indicating existing urbanization economies are drawn from the U.S. Census of Population for 1980 (US Department of Commerce, 1980).
Output is defined as manufacturing value added, and labor productivity as value added per labor hour. While the Census reports hours only for production workers, a standard computation of non-production worker hours is a multiplication of the non-production workforce by an estimated 2040 hours of annual work. This standard is used here. The variables employed in the AVM indicate change over the time period. This is operationalized by representing the change in values over the period as annual rates. Therefore, output change, $Y'$, is computed as:

$$Y' = \frac{[\ln(Y_{87}/Y_{77})]/10,}{\text{(23)}}$$

and labor productivity growth as:

$$p = \frac{\ln[(Y_{87}/LH_{87})/(Y_{77}/LH_{77})]]/10,}{\text{(24)}}$$

where LH denotes labor hours.

The average capital share is obtained by taking the ratio of labor compensation to value added for 1977 and 1987, obtaining its geometric mean as a measure of the average labor share of output over the 1977-1987 period, and subtracting it from 1, such that:

$$KS = 1 - \text{SQR}(LS_{87} \times LS_{77}).$$

$$\text{(25)}$$
The commodity price index (PPI) of the Bureau of Labor Statistics that most closely conforms to the SIC in question is used to index all values to constant 1982 dollars. Instruments, a portion of the electronics/instruments industry as defined in this study, is not represented by a usable commodity category, and consequently the more general PPI for manufacturing durables is used for this subsector.

4.5 Contextual Variables

The underlying significance of various indicators of externalized flexibilities are reviewed in chapter 2. What follows is a brief explanation of the way they are measured for the purposes of this study.

4.5.1 Plant Size

Plant size categories and mean plant sizes have been used as measures of flexible production, and as indicators of the urban and regional spatial arrangement of forms of production (Scott, 1986, 1988b). Plant size is often used to proxy for firm size, although the two are not the same where multiplant firms exist. However,
plant size variation by itself is a measure of the degree of internal/external organization, indicating the relative level of production unit fragmentation.

Most of the literature pertaining to questions of internalizing and externalizing production measures such activity at the level of the firm. This parallels the industrial organization literature, which is primarily concerned with the concentration of production activities within firms. When approaching the question of spatial agglomeration, plant size is a more viable measure, as plants are discrete, they and their values (employment or output) can be added up, and average sizes obtained.

In fact, very strong correlations between plant and firm sizes, as well as between changes over time to average plant and firm sizes, are typical (Carlson, 1989; Acs and Audretsh, 1990). As an example, across four digit SIC engineering industries (ie. electrical and non-electrical machinery, instruments and aerospace) the correlation between the change in average firm size and average plant size is r=.94 during the 1972-1982 decade (Carlson, 1989). Therefore, though they do not measure precisely the same phenomenon, the two measures are intimately related to the extent that recent
discussion concerning the role of different sized firms in the economy essentially holds for the role of plant size. As well, plant size is particularly meaningful when considering agglomerative flexibilities, where distinctions across space are most significant.\textsuperscript{32}

In this study, average plant size is measured in terms of employees per plant. With subscripts indicating industry (i) and state (j), average plant size (PS) is calculated as:

$$PS_{ij} = EM_{ij}/PT_{ij}$$  \hspace{1cm} (26)

where EM indicates total employment, and PT, the number of plants. Annual change on plant size over the 1977-1987 study period is:

$$PS'_{ij} = (1/10)[\ln(PS_{1987}/PS_{1977})]$$  \hspace{1cm} (27)

A potential difficulty with using an employment rather than a shipments (or sales) basis for determining mean plant sizes is that the measure could be associated with changes in the capital to labor ratio (Scherer, 1980). As such, it would also be related to capital

\textsuperscript{32}Scott discusses theory in terms of firms, but tests for new industrial spaces by using plant size data (Scott, 1988).
intensification as a source of labor productivity growth. However, empirical evidence in the present study shows insignificant zero order correlations existing between PS and KS. Also, the reported employment generating and innovative features of small size have pertained mostly to the employment criterion (Acs and Audretsch, 1990). Theoretically speaking, the flexibility literature tends to place great emphasis upon the way organizationally defined flexible specialization has entailed an intensified social division of labor. This is said to be the basic element of flexibly conditioned external economies of scale (Scott, 1988a, 1988c). Therefore, both for practical and theoretical considerations, the employment criterion is used.

4.5.2 Vertical Integration

Vertical integration is measured as the ratio of output (value added) to shipments, where shipments are equivalent to the combined price of production output and materials input. With shipments indicated by S, value added by VA, and materials costs by MC, the subscripts indexing industry (i) and state (j),
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Shipments are computed as:

\[ S_{ij} = VA_{ij} + MC_{ij}, \]  \hspace{1cm} (28)

and the ratio is:

\[ VS_{ij} = \frac{VA_{ij}}{S_{ij}}. \]  \hspace{1cm} (29)

\[ VS_{ij}, \] \ the value added to shipments ratio, ranges from 0 to 1, depending upon the proportion of \( S_{ij} \) accounted for by \( MC_{ij} \). When \( VS_{ij} = 1, MC_{ij} = 0 \), and the industry is fully integrated as all plants process all their products completely from their production chain origins through final product. When \( VS_{ij} \) approaches 0, \( MC_{ij} \) becomes a large proportion of \( S_{ij} \), indicating the industry is highly disintegrated. As an index of vertical integration, it indicates the degree to which production is internalized or externalized. Accordingly, the index is lower, or declining over time, where organizational flexibilities associated with agglomeration economies are present, or emergent. On the other hand, where returns to scale are achieved by internalizing processes, and a resynthesis of production has occurred, or is occurring, the index is higher, or is increasing.

The \( VS \) ratio is, however, subject to several problems. Among these are its sensitivity to sectoral
positioning along the production chain, to material input price changes, to increasing efficiencies in intermediate goods processing, and the inappropriate use of Census data with which to compute its value. Let us consider these in turn.

The measure is sensitive to an industry's position on the production chain, and cannot be used, therefore, for interindustry comparisons. The ratio, all other factors being equal, is higher for industries that process raw materials than for those that produce consumer products (Tucker and Wilder, 1977). Comparing a specific industry across regions is justifiable if it can be assumed that the industry in question does not vary spatially with regard to vertical positioning. This is an increasingly more reasonable assumption the smaller, more discrete and internally consistent an industry. Of course by definition, the more strictly the industry is defined, the less absolute vertical disintegration there will be. Generally, any comparison of the index across regions, because of its sensitivity to the vertical position of production, must concentrate on trends to the index rather than to absolute values of the index.

However, price changes can bias intertemporal
comparisons. Laffer has speculated that relatively greater price increases for intermediate and finished products over the 1948 to 1965 period upwardly biased the ratio. Since his measurements indicate little nominal change for firms in manufacturing sectors over the period, he concludes that, given this price bias, levels of vertical integration actually declined (Laffer, 1965). If it is assumed that such price changes do not vary significantly by region, then cross-regional comparisons of changes to the index will not be biased by price fluctuations.

A secular decline in the relative price of upstream inputs is specifically influenced by increasing efficiencies of intermediate and finished goods processing. Other prices being unchanged, a more efficient and less wasteful use of material inputs lowers the MC \(_i\), component of S \(_{i3}\), and increases the VS \(_i\), ratio. Furthermore, efficiencies in material use is one of the supposed features of agglomerative flexibilities, and so should be expected especially where these occur. Signorini suggests that because of this potential upward bias in the index, a high value is not unambiguous evidence of integration, but a lower value is straightforward evidence vertical disintegration.
Yet, in the context of agglomerations, as vertical disintegration reinforces itself through successive process fragmentations, more subcontracting occurs resulting in more intermediate linkages. Material inputs \((MC_{ij})\) become a greater proportion of shipments \((S_{ij})\) because there are more such intermediate links. And, theoretically speaking, these links are subject to increasing efficiencies as well, as they are part of an agglomerated complex of plants. Firms are able to economize on their material purchases, though they are purchasing more of them relative to their shipments. This should tend to even out the upward pressure on the index. In short, once agglomeration growth has established itself, the index should decline if vertical disintegration is occurring.

In this study, the change in VS is used as a contextual variable, influencing the Verdoorn and capital deepening effects upon labor productivity. As such it is a measure of changing relative spatial variation in the extent of vertical integration within two-digit SIC industries. In this study, these relative changes across U.S. states, but within industries, are accepted as valid measures of changes to levels of
vertical integration.

The inappropriate use of Census data with which to compute the value of VS is a difficulty relating to the asymmetry between plant and firm level data. Multiplant firms, particularly when their products cross industry definitions, may confound attempts to systematically measure vertical integration with the use of this ratio (Eckard, 1979). However, this is only the case when integration is defined at the aspatial firm level. Plants are the important level of measurement when examining locationally defined integration and disintegration in the context of agglomerative flexibilities. Scott, who uses the index, suggests that establishment (plant) level data is more useful in a spatial context, where the physical location of activity is of significance (Scott, 1986: 30). This Census data difficulty, then, is considered largely inapplicable to the current study, though it is a significant problem for numerous empirical studies of firm integration (Eckard, 1979).

It is the change in the VS ratio that is of interest. As a context of a Verdoorn process of localization, a dynamic effect, only, is assumed. Consider briefly the possibility of a state having a
preponderance of large branch plants producing mostly downstream items. The VS ratio, in such an instance, could be moderately low, as the plants import in bulk their material inputs which are already semiprocessed. A small portion of value is added, and the goods are reshipped. Yet, changes toward vertical disintegration are not likely to be forthcoming without agglomerative dynamics. However, if they develop, then abbreviated phases of vertical processing multiply and subcontracting expands. The industry in the state increases its total value added, but even more, it experiences increases in the value of material inputs, lowering further the VS ratio. If agglomeration dynamics do not develop, but expansion occurs as a result of the continued attraction of branch plants, then the moderately low VS ratio does not tend to decrease further. If larger integrated plants are located in the state, the VS ratio is liable to increase. Thus it is the change in the ratio over the study period that is most significant and interpretable.

In this study, it is the change to the VS ratio that is used. The annual rate of vertical integration/disintegration for the 1977 to 1987 study period is:

\[ VS'_{17} = \frac{1}{10} \ln\left( \frac{VS_{1987}}{VS_{1977}} \right) \]  

(30)
4.5.3 Urbanization Economies

Because of evidence concerning the advantages to productivity growth of existing urbanization economies (Carlino, 1978, 1979; Moomaw, 1988), its influence is controlled for in this study. The productivity effects of both the Verdoorn relationship and capital intensification are quite possibly augmented by such urbanization economies.

Two 1980 measures are used: a) state population density, and b) the proportion of a state's population that is urbanized. In the U.S. context, the two measure somewhat different phenomena.

State population density is an often used proxy for the existence of an urban to rural continuum of infrastructural externalities. Generally, it is assumed that states with higher population densities have greater densities of infrastructure as well. Highest population densities are associated with the greatest complex of human and capital resources.

However, state variations in population density do not fully correlate with the spatial arrangement of urbanized areas. For example, while interior western states have the lowest population densities, they are
often among the most urbanized states, as most of their admittedly sparse populations live in cities. In terms of the urbanization economies that are of importance to particularly newer and technology intensive industries (producing low weight, high value added products), these types of places may be prominent, despite low overall population densities. Elsewhere, southeastern states are less urbanized though their population densities are higher than western states, owing to higher rural densities. California has a population density similar to many southeastern states, but is far more urbanized than any of the latter. In view of these considerations, the proportion of a state's population that is urbanized is used an alternative proxy for urbanization economies.

The variable used for population density, \( D \), is computed as a natural logarithm:

\[
D = \ln(\frac{POP}{AREA}), \tag{31}
\]

where \( POP \) indicates a state's population, and \( AREA \), its land surface in square miles.

For a state's proportion of urbanized population, \( MT \), the measure used is:
\[ MT = \frac{\text{METPOP}}{\text{POP}}, \]  

where \text{METPOP} is the population of a state resident in a Census designated standard metropolitan statistical area (US Department of Commerce, 1980).

4.6 Summary

An augmented Verdoorn model is developed, and its parameters are subjected to an examination of the extent and manner of their variability with respect to indicators of forms of agglomerative flexibilities. This chapter has reviewed a method for evaluating such parametric drift. Chapters 6 and 7 survey and interpret the results of such an analysis.
CHAPTER V - DESCRIPTIVE EMPIRICS

5.1 Introduction

Before proceeding to a consideration of the estimated results of this study, it is helpful to first characterize the interregional conditions in 1977, at the outset of the study period, and to describe the empirics of change over the 1977 to 1987 period as they relate to the three manufacturing sectors. The purpose of this chapter, then, is to provide a description of the interregional production environment as a preface to a review and discussion of the systematic production relationships in chapters 6 and 7. Manifest

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interregional patterns are commented upon, and are very generally related to regional theory.34

5.2 Electronics/Instruments

By 1977, many of the sunbelt clusters of activity, as reviewed in chapter 3, are well established, as is a general diffusion of production activity away from some older agglomerated centers, mostly in the northeast, to more peripheral locations, mostly in the south. While no regional pattern of labor productivity is clearly evidenced (figure 1), numerous states in the northeast quadrant of the U.S. display moderate to high levels of output per labor hour. Other states with comparatively high levels of labor productivity are, however, scattered across the country. If a cluster of low productivity states exists, it is in the U.S. South, and, to a lesser degree, in the central midwest. It should be noted that states where new centers of innovative product development and increased electronics/instruments manufacturing arise prior to 1977 exhibit only moderate labor productivity levels,

3All values referenced in this chapter, unless otherwise noted, are computed from the U.S. Census of Manufactures (US Department of Commerce, 1977, 1987).
Figure 1: Labor Productivity: Electronics/Instruments – 1977
such as California, Texas, and Massachusetts, or actually rather low levels, as in Arizona. A clear pattern of interregional labor productivities is not in evidence.

A marked regionalization, however, characterizes the industry's growth in the subsequent decade. This is one that closely corresponds to the popularly recognized snowbelt to sunbelt shift of manufacturing activity generally (figure 2). Most of the sunbelt, with the exception of several states in the central southeast and of Nevada in the west, exhibit rates of output growth higher than the U.S. annual rate of 3.8 percent. Some of these states have particularly high rates of growth. Annual increases in output are above 9 percent in Arizona, Florida, Georgia, and Washington. Although already among the lead producing states in 1977, both Texas and California grow at an annual 7.3 percent over the period.

Conversely, in the older manufacturing regions, output growth is typically limited, and often negative. The snowbelt does exhibit, however, recognizable internal differentiation. A cluster of states with declining output are found along the Great Lakes and the Ohio River. Generally, absolute losses are not extreme. However, this area is clearly distinct from surrounding
Figure 2: Output Growth: Electronics/Instruments – 1977/1987
states where moderate and even high rates of growth are evidenced. Along the northeast coast in particular a number of states have rates well above the U.S. rate, while others have more moderate, but nonetheless substantial, growth rates. As reviewed in chapter 3, Massachusetts is well known as a center of expansion in both electronics and instruments production during the period, and this tends to diffuse to surrounding states. New Hampshire benefits particularly, albeit having a low 1977 output base, with growth comparable to the fastest growing areas of the sunbelt. Massachusetts itself grows at an annual rate just over 5 percent.

In very broad fashion, labor productivity growth during the 1977 to 1987 period appears to follow this pattern (figure 3). Low rates of productivity growth occur in those parts of the old manufacturing belt that have negative or very low increases in output. Higher productivity growth is evidenced along the northeast coast, and, as might be expected, in much of the sunbelt. Yet, in the sunbelt, some of the states among those with the most rapid output expansion, do not have the highest rates of productivity growth. The increase in Texas is the same as it is nationally (2.55 percent per annum) and California is only moderately higher (3 percent per annum). Many southeast states and northeast
Figure 3: Labor Productivity Growth: Electronics/Instruments – 1977/1987
coast states have high rates of productivity growth.

It is noteworthy as well, that no clear adjustment process occurs. While some states with initially (1977) low levels of productivity experience above average rates of labor productivity growth, many states with high levels of 1977 labor productivity also have very high rates of such growth.

The general trend over the 1977-1987 period is for the expansion of output and increases in labor productivity to be greatest in the sunbelt. The northeast coast, particularly New England, among older manufacturing regions, experiences considerable output growth, and comparatively very high increases in labor productivity. Such patterns suggest a likely Verdoorn relationship in the industry.

5.3 Machinery

The U.S. machinery industry's labor productivity (and labor compensation) is not as high in 1977 as it is in many other durables producing sectors, many of which are more capital intensive. Yet, of the three industries in this study, it is easily the most capital intensive, a consequence of which is its similarly high comparative level of labor productivity. Wide
variability of capital intensities at the state level punctuate this otherwise high overall level, and this is also accompanied by substantial labor productivity variability. In fact the average capital to output ratios\(^3\) of states displays a much greater range in machinery, exhibiting both higher values and, in fact, lower values than are found in either the apparel of electronics/instruments sectors. Similarly, the range of output per labor hour is greater in machinery, although labor productivity levels in apparel do range below the lowest evidenced in machinery.

This state variability in output per labor hour appears to be highly regionalized as well. In 1977, high levels of output per labor hour are clearly associated with the northeast quadrant of states, but are also evidenced in the central west, and parts of the southwest (figure 4). In the former group of states, the machinery industry's traditional heartland, the complexity of user industries, particularly the metals and durables assembly sectors, almost certainly help to keep the industry viable, at least up until 1977. Distinct from these areas are the southeast and the interior northwest, where virtually all of the states

\(^3\)Measured as shown in section 4.4
Output per labor hour

<20.75  >24.75
20.75 to 24.75  NA

Figure 4: Labor Productivity: Machinery – 1977
with the lowest absolute levels of labor productivity are located.

Of the three sectors, machinery manifests the lowest rate of overall output growth over the ensuing decade (less than 0.4 percent per annum in real terms, though the average of states is higher, at 1.6 percent). However, considerable regional variability is evidenced within this nearly zero-sum decade. In fact, the period is one of substantial interregional output volatility, as many south central states, in addition to most midwest and northeast states, contract, while others elsewhere expand, many precipitously (figure 5).

As with the electronics/instruments sector, the outlines of the more general sunbelt to snowbelt shift of manufacturing activity are discernible in machinery. However, in the instance of machinery, within the very broad area of actually declining output, severe cases are numerous. Illinois, Iowa, Michigan, Ohio, Maryland, New York, West Virginia, and Vermont all have output losses of greater than 2 percent per annum over the 1977 to 1987 period. Once again, in the northeast quadrant, only New England states experience at least moderate growth. Higher growth rates are characteristic of parts of the west and north central, where some states in these regions grow rapidly on a relative small output
Figure 5: Output Growth: Machinery – 1977/1987

Percent per annum

- <0
- >2.8
- 0 to 2.8
- NA
base. However, the regional pattern is not definitive, as other states in these regions actually experience losses. Many of them as severe as those of northeastern states, including the greater than 2 percent per annum declines in Texas, Utah, and Nebraska. The growth in Minnesota and California, like that in New England’s Massachusetts and New Hampshire, can be largely attributed to the expansion of the computer and office equipment subsector (US Department of Commerce, 1977, 1987). The southeast stands out as the most readily identifiable region of uniformly high growth. Many of these states have growth rates in excess of an annual 5 percent.

Over the period, labor productivity increases at the highest rates in states which experience output growth, notably in the southwest and in New England, in a number of north central states and in California (figure 6). While this delimits a rough correspondence between productivity growth and output growth, numerous qualifications intrude. Most states of the old manufacturing belt experience at least modest rates of labor productivity growth despite output losses. Conversely, some western states, subject to moderate or even high rates of output growth, exhibit labor productivity declines.
Figure 6: Labor Productivity Growth: Machinery – 1977/1987
Moderate gains in productivity in the midwest and large gains in New England, where rates of labor productivity had typically been already high in 1977, are not supportive of regional capital or technological convergence. On the other hand, high productivity growth in the southeast, where productivity levels had been very low, does support the notion of convergence, but also conforms to a Verdoorn explanation of productivity growth.

Although the midwest and part of the northeast undergo output losses, the overall pattern is not quite as close a match to the generalized snowbelt to sunbelt shift as is the electronics/instruments pattern. In terms of productivity growth, outside a scattering of states in the central northwest and in California, the large concentration of high growth states is along the east coast.

5.4 Apparel

As noted in chapter 3, apparel production operations have not been especially amenable to process innovations. This has resulted in low levels of capitalization. Compared to electronics/instruments and machinery, capital to output ratios are lower and vary
across states in a narrower range. They tend to be higher in the northeast and midwest, and in California and Texas, than elsewhere. While state distinctions in labor productivity may correspond to these differences in capital intensities, such distinctions also result from intrasectoral product specializations, the range of which tend to be greater in the northeast and midwest.

In 1977, regional differences in labor productivity, particularly a north to south distinction in the eastern half of the country, are as much in evidence in the apparel as in the machinery industry (figure 7). The southeast has uniformly low levels of output per labor hour, the upper and border south has intermediate levels, and the northeast quadrant is represented mostly, but not entirely, by states that have comparatively high 1977 labor productivities. Alone among western states, California and Nevada have high levels of output per labor hour.

During the subsequent decade, the overall U.S. rate of real output growth is low, at 1.45 percent per annum, but the rate of productivity growth, nearly 3.5 percent per annum, is surprisingly high.

The output growth is concentrated in the southeast (where labor productivity and labor costs are lowest), and in some western states (figure 8). With notable
Figure 7: Labor Productivity: Apparel - 1977
Figure 8: Output Growth: Apparel - 1977/1987
exceptions, most states in the northeast quadrant experience output losses, as do a set of states in the central part of the country. This pattern conforms to the general sunbelt to snowbelt shifts of manufacturing, but also corresponds to characteristics inherent in apparel production. The industry is well known for its particular tendency to relocate comparatively rapidly when faced with increasing labor costs, enabled, at least, by low capital requirements. At the national as well as the global scale, the regionalized ebb and flow of the industry is attributable to its ease of relocation. Of course there are exceptional product specializations, and, possibly, alternative methods of producing, some associated with newly developed process technologies. These have potential to fuse at least a portion of the industry to particular locations, notably within, or near, large metropolitan areas of apparel localization.

Over the 1977 to 1987 period, however, interregional output changes do not seem to warrant this latter supposition. Only California, among the major states with apparel producing agglomerations and initially (in 1977) high levels of labor productivity, experiences a high rate of output growth. It is, in fact, very high. With real growth approaching 4.6
percent per annum, it grows more rapidly over the period than any of the fast growing southeastern states. However, it should be noted that the industry does not have the long history in California that it does in the northeast. One might speculate that California does indeed represent the possibility of flexibly productive growth in the apparel industry, where growth enhances productivity through changes to the production system, and this, then, becomes the alternative to labor cost containment through relocation.

Unfortunately, the pattern of labor productivity growth from 1977 to 1987, even in California, does not warrant such speculation. California, and western states in general, show very low rates of productivity growth. Output growth in California does not apparently result in correspondingly higher levels of productivity as it does in some southeast states, and in those northeast and midwest states where output growth actually occurs.

Overall, however, the changes in productivity over the period show a mixed picture (figure 9). Labor productivity growth occurs in states experiencing output losses, and only minor productivity gains are registered where growth is substantial. Certainly no convergence of productivity levels is evidenced, as the highest
Figure 9: Labor Productivity Growth: Apparel - 1977/1987
rates of productivity growth are represented in all regions, when in 1977 the highest levels had been concentrated in the northeast and midwest. Growth does seem to induce some productivity effects, but an invariant Verdoorn relationship appears least likely in the apparel industry.

5.5 Summary

In all three industries, output changes seem to indicate a close correspondence to general snowbelt to sunbelt shifts of production activity. However, labor productivity growth has continued to be maintained in the northeast quadrant of the country to a greater extent than might be expected given these output changes. This appears to be particularly the case in apparel, where productivity growth is, for the U.S. generally, especially high given the rather low overall rate of output growth. This is true only to a degree in machinery, where state level output losses are most numerous and overall growth output and productivity is lowest. In electronics/instruments, if a interregional labor productivity growth pattern exists, it tends to favor the sunbelt.
6.1 Initial AVM Estimates

The basic augmented Verdoorn model, equation (14), is estimated for each of the three industries. These initial OLS estimates are shown in table 1.

The results for the different industries exhibit varying levels of statistical strength. The Verdoorn impact is greatest and most significant for machinery. This results in a comparatively high F-ratio for the machinery model, despite the insignificance of neutral technological progress and capital deepening parameters. In contrast, the electronics/instruments estimation indicates a lesser Verdoorn effect, and a model that is, overall, less significant. For apparel, however, both the Verdoorn effect and capital deepening are significant, although the model as a whole explains less variance in the growth of labor productivity than does machinery.

Because of considerations addressed in chapter 4, the value of the neutral technological progress constant
**TABLE 1: OLS estimations of the Initial Model**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>F</th>
<th>(n)</th>
<th>(v)</th>
<th>(k)</th>
<th>(N_{obs})</th>
<th>(R^2_{adj})</th>
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</thead>
<tbody>
<tr>
<td>Electronics/ Instruments</td>
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<td>-.029</td>
<td>.229</td>
<td>.079</td>
<td>34</td>
<td>.30</td>
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<tr>
<td></td>
<td></td>
<td>(.027)</td>
<td>(.063)</td>
<td>(.045)</td>
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<tr>
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<td>-.001</td>
<td>.520</td>
<td>.016</td>
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<td>.60</td>
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<td></td>
<td></td>
<td>(.028)</td>
<td>(.064)</td>
<td>(.051)</td>
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<tr>
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<td>.290</td>
<td>.147</td>
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<td>.40</td>
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<td></td>
<td>(.025)</td>
<td>(.087)</td>
<td>(.048)</td>
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</table>

Note: Standard errors are in parentheses

**TABLE 2: Iterative estimations of the Initial Model**

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<tr>
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<th>(n)</th>
<th>(v)</th>
<th>(k)</th>
<th>(N_{obs})</th>
<th>(R^2_{cor})</th>
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<tr>
<td>Electronics/ Instruments</td>
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<td>.000</td>
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<td></td>
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<td>(.070)</td>
<td>(.027)</td>
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<td>.015</td>
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<td>(.066)</td>
<td>(.050)</td>
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</tr>
<tr>
<td>Apparel</td>
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<td>.000</td>
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<td>.056</td>
<td>34</td>
<td>.37</td>
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<td>(.000)</td>
<td>(.092)</td>
<td>(.005)</td>
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</tr>
</tbody>
</table>

Note: Standard errors are in parentheses
is squared in order to retain a non-negative value, and a reestimation of the augmented Verdoorn model is performed. The results of this iterative procedure are shown in table 2.

In terms of the significance levels for the entire model, and for individual parameters, they are similar to the OLS estimates. Only slight fluctuations in the corrected $R^2$ statistic are evidenced. The lower $F$ ratios are generally attributable to the imposition of the non-negative intercept restriction. Overall, the results indicate a slight improvement in the machinery and electronics/instrument models, but a slight reduction in the significance of the apparel model. In view of the general theoretical requirement to ensure positive neutral technological progress coefficients, and the largely equivalent accuracy of the estimations, these intercept constrained results are considered more

---

36 The sequential quadratic programming algorithm is NPSOL, version 4.03 (Fortran Package for Nonlinear Programming) and is available on SPSS (Gill, et al., 1986). Each of the major iterations contains a subprogram of minor iterations that finds the search direction with respect to the constraint. The major iteration then determines the steplength, and the function is reevaluated at the new set of values. An optimal solution is obtained when the residual sum of squares is unchanged at eight significance digits. Most estimated solutions, including the many adjusted (backward eliminated) models, required fewer than 45 iterations, but at most, 70 iterations.
appropriate for further analysis. As such, all subsequent analysis is based upon the results of estimates made via this constrained non-linear iterative procedure.\textsuperscript{37}

Judged by the coefficient value to standard error ratios, the individual parameter estimates, v and k, have substantially the same statistical strength in the non-linear estimates. However, the magnitudes of the k coefficient values are typically lower. Neutral technological progress is essentially nil once the n coefficient value is squared.\textsuperscript{38} Overall, the non-linearly estimated parameters are suggestive of similar production relationships that are evidenced by the OLS estimates. In apparel, both the Verdoorn (v) and capital deepening (k) coefficients are positively and strongly associated with labor productivity growth. In electronics/instruments only the Verdoorn coefficient is

\textsuperscript{37}Every non-linear estimate must necessarily be preceded by an OLS regression so as to establish initial parameter values that are as close to the final iteratively obtained global solution as possible.

\textsuperscript{38}In table 1 the n coefficient estimates are reported as n=0. Maximally the estimations, in all instances, are n<.0001; the interpretation being that the neutral technological progress contributes virtually nothing to labor productivity growth. According to these estimates, the contribution is not greater than an annual .01 percent of the growth in labor productivity.
significant, and here it has the slightest impact. In machinery as well, only the Verdoorn coefficient is significant. However, its value is much higher, indicating the more substantial role of returns to scale in that industrial sector.

As a further aid in the interpretation of these results, table 3 is constructed. Here the effects of scale and capital deepening appear in terms of the \( E \) parameter and of the annual percent of capital intensification \( (k_p) \), respectively. The structural parameter \( E \) represents the role of returns to scale, where \( v=\frac{E-1}{E} \). As reviewed in section 4.2, \( E \) increases at an increasing rate with higher values of \( v \), and is indicative of increasing returns to scale if \( E>1 \). Capital deepening is most easily interpreted in terms of percent per annum changes of capital per labor unit \( (k_p) \). In table 3 the \( k_p \) values are shown, though it is noted that only in the case of apparel is the estimate statistically significant.

The role of scale changes is clearly most important in machinery, where it accounts for twice the increase in output per labor hour than would otherwise occur. As reviewed in section 5.3, the machinery sector is characterized by numerous declining \( Y' \) values, where
states experience reductions to output over the 1977-87 period. The strong relationship between labor productivity growth and the growth of output in this industry therefore reveals both the positive as well as the negative significance of localization changes. If $Y'$ values are negative, a strong negative impact upon labor productivity change is indicated.

The implication is that the localization effect of the Verdoorn relationship works in both directions. Localizations can both deepen and integrate, or they can weaken and unravel. Because the machinery estimation includes the greatest number of $Y'$ values, its
particularly good statistical fit and significant $v$ (and $E$) values are especially suggestive of this implication.

While having less influence upon changes to labor productivity in the apparel and electronics/instruments sectors, localized returns to scale are nonetheless of substantial importance in these industries. In addition, a considerable annual increase in capital per labor unit is evidenced in apparel, an industry that begins the study period as the least capitalized (with the least cross state variability of capital intensities) of the three sectors.

These results are empirically reasonable. They show that Verdoorn effects exist at the two digit level of resolution across U.S. states. However, a spatially invariant Verdoorn coefficient is difficult to accept. In view of recent studies on changes to production systems that are implicated in processes of spatial localization and agglomeration, the premise of stable Verdoorn and capital deepening coefficients is particularly untenable. Accordingly, the remainder of this chapter constitutes an examination of variability in the $v$ and $k$ parameters as evidenced with the use of the expansion method.
6.2 Expanded Estimates

Following procedures outlined in sections 4.3.2 and 4.4 (Casetti, 1972, 1982), the initial augmented Verdoorn model is expanded by each of the expansion variables such that the following four equations are estimated for each of the three industries:

\[ p = n + v_0Y' + v_1(Y' * PS') + k_o KS + k_1 (KS * PS') \]  
\[ p = n + v_0Y' + v_1(Y' * VS') + k_o KS + k_1 (KS * VS') \]  
\[ p = n + v_0Y' + v_1(Y' * D) + k_o KS + k_1 (KS * D) \]  
\[ p = n + v_0Y' + v_1(Y' * MT) + k_o KS + k_1 (KS * MT) \]

where \( p \) is the annual change in labor productivity through the 1977-87 study period. The spatial variability of Verdoorn and capital deepening effects is defined by, respectively, the \( v_1 \) and \( k_1 \) coefficients.

Subsequent to running initial OLS regressions and establishing first approximations of the coefficient values, all equations are estimated iteratively in order to impose the non-negativity constraint on the constant \((n)\). The results appear in tables 4 through 7, where they correspond respectively to equations (33) through (36).
Each of the expansions increases the corrected $R^2$ level of explanation, though adding variables diminishes the $F$ statistic in numerous instances. Generally the annual change of plant sizes and the annual rate of vertical integration impact the initial model more significantly than do the proxies for existing agglomerations (D and MT). Both PS' and VS' are significantly related to the labor productivity role of capital deepening in all industries. In the case of apparel, PS' strongly influences the Verdoorn effect, though in other industries its impact is not statistically significant. In none of the industries is the Verdoorn coefficient strongly impacted by VS'. The pattern of individual parameter effects is more mixed for the D and MT expansions. In terms of the overall fit, apparel is improved more by the MT expansion, and electrical/instruments by the D expansion. The machinery estimate is improved only slightly in either case.
6.2.1 Analysis of Contextual Influence

To isolate the direction of contextual impact upon the augmented Verdoorn model, tables 8 and 9 are constructed. They summarize the influence of each expansion variable upon the Verdoorn and capital deepening parameters, respectively. As such they are the slopes, \( v_i \) and \( k_i \), of the interactive variables (i.e., the derivatives of the Verdoorn and capital deepening variables with respect to the expansion). In the following section, these influences are described and interpreted with attention given to the direction of impact.\(^3\)

---

\(^3\)As indicated above, some of the expansion coefficients are not statistically significant. Therefore, in a number of instances the sign of the expansion coefficient can be observed as evidence of the direction of impact, but the magnitude of such impact is not observable. The review of the single variable expansions in this section (6.2.1) notes these instances, while consideration of the magnitude of expansion impact is left for section 6.2.2, where industry expansion estimations are reviewed.
### TABLE 4: PS' expansion estimates

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Electronics/Instruments</th>
<th>Machinery</th>
<th>Apparel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.000**</td>
<td>.022**</td>
<td>.000</td>
</tr>
<tr>
<td>Y'</td>
<td>.438**</td>
<td>.825**</td>
<td>-.166</td>
</tr>
<tr>
<td>Y' * PS'</td>
<td>-2.737</td>
<td>2.873</td>
<td>-23.369**</td>
</tr>
<tr>
<td>KS</td>
<td>.012</td>
<td>-.062</td>
<td>.085**</td>
</tr>
<tr>
<td>KS * PS'</td>
<td>-.695**</td>
<td>-1.642**</td>
<td>1.114**</td>
</tr>
<tr>
<td>R² cor</td>
<td>.54</td>
<td>.83</td>
<td>.65</td>
</tr>
<tr>
<td>F</td>
<td>6.50</td>
<td>41.24</td>
<td>10.62</td>
</tr>
</tbody>
</table>

### TABLE 5: VS’ expansion estimates

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Electronics/Instruments</th>
<th>Machinery</th>
<th>Apparel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>Y'</td>
<td>.195**</td>
<td>.373**</td>
<td>.302**</td>
</tr>
<tr>
<td>Y' * VS'</td>
<td>-7.918</td>
<td>3.100</td>
<td>-1.313</td>
</tr>
<tr>
<td>KS</td>
<td>.032**</td>
<td>.019</td>
<td>.054**</td>
</tr>
<tr>
<td>KS * VS'</td>
<td>2.042**</td>
<td>1.011**</td>
<td>1.199*</td>
</tr>
<tr>
<td>R² cor</td>
<td>.59</td>
<td>.80</td>
<td>.49</td>
</tr>
<tr>
<td>F</td>
<td>8.14</td>
<td>32.05</td>
<td>5.30</td>
</tr>
<tr>
<td>TABLE 6: D expansion estimates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coefficients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independent Variables</td>
<td>Electronics/Instruments</td>
<td>Machinery</td>
<td>Apparel</td>
</tr>
<tr>
<td>Intercept</td>
<td>.000</td>
<td>.000</td>
<td>.000**</td>
</tr>
<tr>
<td>$Y'$</td>
<td>.868**</td>
<td>.841**</td>
<td>.414</td>
</tr>
<tr>
<td>$Y'*D$</td>
<td>-.143**</td>
<td>-.073</td>
<td>-.003</td>
</tr>
<tr>
<td>KS</td>
<td>-.042</td>
<td>-.025</td>
<td>.012</td>
</tr>
<tr>
<td>KS*D</td>
<td>.016**</td>
<td>.009**</td>
<td>.009*</td>
</tr>
<tr>
<td>$R^2_{cor}$</td>
<td>.46</td>
<td>.66</td>
<td>.46</td>
</tr>
<tr>
<td>$F$</td>
<td>4.72</td>
<td>15.93</td>
<td>4.70</td>
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<table>
<thead>
<tr>
<th>TABLE 7: MT expansion estimates</th>
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</thead>
<tbody>
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<td><strong>Coefficients</strong></td>
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<td>Independent Variables</td>
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<tr>
<td>Intercept</td>
</tr>
<tr>
<td>$Y'$</td>
</tr>
<tr>
<td>$Y'*MT$</td>
</tr>
<tr>
<td>KS</td>
</tr>
<tr>
<td>KS*MT</td>
</tr>
<tr>
<td>$R^2_{cor}$</td>
</tr>
<tr>
<td>$F$</td>
</tr>
</tbody>
</table>
### TABLE 8: Summary of Verdoorn parameter (v) drift with respect to the expansion variables

<table>
<thead>
<tr>
<th></th>
<th>dv/dPS'</th>
<th>dv/dVS'</th>
<th>dv/dD</th>
<th>dv/dMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics/</td>
<td>-2.737</td>
<td>-7.918</td>
<td>-.143</td>
<td>-.347</td>
</tr>
<tr>
<td>Instruments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>2.873</td>
<td>3.100</td>
<td>-.073</td>
<td>-.578</td>
</tr>
<tr>
<td>Apparel</td>
<td>-23.369</td>
<td>-1.313</td>
<td>-.003</td>
<td>-1.266</td>
</tr>
</tbody>
</table>

### TABLE 9: Summary of capital deepening (k) variation with respect to the expansion variables

<table>
<thead>
<tr>
<th></th>
<th>dk/dPS'</th>
<th>dk/dVS'</th>
<th>dk/dD</th>
<th>dk/dMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics/</td>
<td>-.695</td>
<td>2.042</td>
<td>.016</td>
<td>.014</td>
</tr>
<tr>
<td>Instruments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>-1.642</td>
<td>1.011</td>
<td>.009</td>
<td>.006</td>
</tr>
<tr>
<td>Apparel</td>
<td>1.114</td>
<td>1.199</td>
<td>.009</td>
<td>.076</td>
</tr>
</tbody>
</table>
6.2.1.1 Plant size change

No prevailing pattern exists concerning the impact of plant size changes. The parameter effect of PS' is distinctive for each of the three industries.

In the apparel and electronics/instruments sectors, the Verdoorn coefficient is negatively impacted by an increase in plant size. Conversely, the coefficient is positively associated with PS' in the case of machinery. This is an indication that for U.S. states with increasing output, a returns to localization effect enhances productivity growth through diminishing plant size for apparel and electronics/instruments, but not for machinery. Only in the case of apparel, though, is the interactive coefficient significant.

The capital deepening parameters are all impacted significantly by a change in plant size. Plant size growth is associated with higher rates of capital intensification in the case of apparel, while plant size reductions supplement capital deepening in the electronics/instruments and machinery industries. The negative interactive parameter that is associated with the latter two industries is suggestive of a substitution effect at the plant level, where
efficiencies are achieved through the replacement of labor. In the apparel industry, however, capital intensification is a function of an increase (or a more limited decrease) in plant size. Therefore, the implication for the apparel industry is that the expansion of internal scale (with the Verdoorn effect controlled for) is a significant factor of capitalization. Capital intensification occurs in apparel production, then, where labor is not, or not significantly, replaced at the plant level of organization.

While not all states in any of the industries

40That this occurs only at the plant level should be emphasized. The apparel industry experienced a significant decline in employment over the 1977-1987 period, much of it attributable to the effect of capital intensification. This effect is recognizable at the aggregate national or state level (Dickensen, 1991), and exists at the plant level. Technically, though, it may be necessary to expand the size of individual plants (implying a reduction in the number of plants if demand does not expand sufficiently over the period) to achieve efficiencies when introducing labor-saving capital. At the plant level, therefore, capital is introduced in the context of plant size increases, or with minimal (rather than greater) decreases, measured by the per plant number of workers. In this study, this is measurably distinct from the capitalization conditions of the electronics/instruments and machinery sectors, where the substitution of capital for labor, to the extent that it occurs, is evidenced at the plant level as well as in the aggregate. Additionally, it should be noted that such impacts are independent of the scale (i.e. localization) effects of the Verdoorn relationship.
experiences diminishing mean plant sizes, a reduction in average plant size is the overall trend across these sectors, as well as in manufacturing in the U.S. generally (US Department of Commerce, 1977, 1987). Despite this cross industry generalization, no prevailing regularity of impact is evident across estimated augmented Verdoorn production functions. In electrical/instruments both the productivity enhancing effect of the Verdoorn coefficient and of capital deepening occur in the context of decreasing plant size. In machinery, capital deepening is also positively conditioned by plant size reductions, but such decreases have a negative influence on the Verdoorn productivity effect. Distinctively, the apparel industry’s Verdoorn coefficient is a function of decreasing plant size, while its capitalization is positively related to plant size growth.

6.2.1.2 Vertical Integration

A largely consistent pattern of vertical integration exists across industries. As is predicted by theory, the empirical evidence in this study shows that a capital deepening effect is positively impacted
by vertical integration.

The coefficients of the \((Y'*VS')\) interactive term are negative for apparel and electronics/instruments, and positive for machinery. However, for none of these industries are the parameter estimates statistically significant. Therefore, the negative sign of the first two industries is merely suggestive of the possible relationship between localized/agglomerative growth economies and vertical disintegration, as is proposed in geographically oriented flexible production theory. Without controlling for other contextual effects, such as the diminished plant sizes associated with the apparel and electronics/instruments Verdoorn effects, the role of vertical disintegration is unresolved.

6.2.1.3 Urbanization Economies

As reviewed in section 4.4, the AVM is expanded by population density \((D)\) and the proportion of population that is urbanized \((MT)\), equations (35) and (36), in order to capture the model's sensitivity to existing agglomeration economies. Results of these are, in turn, reviewed in sections 6.2.1.3.1 and 6.2.1.3.2 below.
6.2.1.3.1 Density (D)

Relatively high rates of productivity growth during the 1977-1987 period (figures 3, 6, and 9) in some areas of the old manufacturing belt suggest that an existing agglomeration effect exists. It is supposed that this effect is likely to augment the impact of either, or both, returns to scale and capital deepening.

The greatest impact of D occurs in the electronics/instruments industry. The impact is negative with respect to the Verdoorn coefficient and positive relative to capital deepening. The D impact upon the Verdoorn coefficient conforms to notions pertaining to the development of electronics manufacturing localizations in new growth areas. The capital deepening result is broadly interpretable along neo-classical lines, given the assumption that labor costs are initially greatest in high density locations.\(^{41}\)

The signs associated with the expansion parameters for both apparel and machinery of \(Y'\) and KS are, 

\(^{41}\)Neo-classical in the sense that capital substitutes for labor. In terms of interregional patterns, however, as is well known empirically, high wage areas of the U.S. have not necessarily attracted inward labor migration (Barro and Sala-i-Martin, 1991; Crandell, 1993).
respectively, negative and positive as well. However, they do not have the magnitude of impact, nor are they, especially in the case of the Verdoorn coefficient, as statistically significant as with electronics/instruments.

Generally, for all of the industries, D amplifies the capital deepening effect of productivity growth. While the effect is consonant with the neo-classical mechanisms, it also conforms to the notion that existing public infrastructure and externalities increase the marginal returns to capital investment. This may indicate that there is an interactive effect between private and public capital. However, where output growth is negative, it also indicates a degree of economic rationalization, where the least efficient operations are eliminated during the process of restructuring (Michl, 1985; Rigby, 1992).

Interpretations of the Verdoorn coefficient need to be considered with particular care, as the variable itself, output growth (Y'), can take on both positive and negative values. In the case of the D expansion, a negative expansion coefficient can be understood to supplement the productivity effects of output growth in less densely populated locations. Conversely, the
negative expansion discounts otherwise higher rates of productivity growth in high density locations. These outcomes occur with a positive Verdoorn coefficient ($v_o > 0$), where the Verdoorn observation is positive ($Y_i' > 0$; $i$ indexing a state observation) as well. However, where $v_o > 0$, but $Y_i' < 0$, the initial Verdoorn relationship is reversed, in the sense that a higher $v_o$ is associated with lower comparable rates (or possibly higher negative rates) of productivity growth. Therefore, a negative expansion coefficient ($v_1 < 0$) is associated with higher rates of productivity growth than is a positive expansion coefficient ($v_1 > 0$) where $v_o > 0$ and $Y_i' < 0$.

In essence, the positive productivity effects of Verdoorn are detrimental under conditions of negative growth, as they indicate a relative loss of localization economies. In the case of the electronics/instruments industry, for the several states of the midwest that experience negative growth over the 1977-1987 period (figure 2), the negative $v_1$ coefficient (of $Y' * D$) has the effect of limiting the high negative impact of the (positive) Verdoorn coefficient. Therefore, these states, with relatively high $D$ values, have greater productivity growth than would be the case if output
losses where not obviated, to an extent, by an indicator of existing returns to agglomeration.

6.2.1.3.2 Metropolitan Population (MT)

Like the D expansions, MT, the proportion of a state’s population resident in metropolitan areas, proxies for existing urbanization economies. As reviewed in section 4.4, it measures a continuum of state observations that are distinct from that measured by D. Indeed, although the estimated signs are all the same, the MT effects are stronger where the density variable is relatively weak; namely, in its impact upon the apparel and machinery Verdoorn effects.

The greatest impact of MT is upon the apparel industry, where it influences the Verdoorn effect negatively, and augments capital deepening. The Verdoorn coefficient for machinery is also influenced by MT in the same, negative, direction. The MT expansion does not generally improve the electronics/instruments estimate relative to the initial model. In fact the very low F value suggests the detrimental consequences of this particular expansion.

As with the D expansions, special care should be
taken with the interpretation of the Verdoorn expansion parameters \(v_1\). The statistically significant parameters of both the machinery and apparel estimates are negative, meaning that states with greater levels of urbanization have reduced Verdoorn effects. However, a number of states in the northeast quadrant of the country have negative rates of growth \((Y'_i<0)\), for which a strong positive Verdoorn effect is detrimental to productivity growth. The negative expansion parameters indicate that this detrimental effect is at least partly offset by metropolitan locations.

6.2.2 Industry Expansions Models

In order to gain a more complete parametric portrayal of each of the three industries, and to obtain a spatial representation of the Verdoorn and capital deepening labor productivity effects, a set of "industry expansion models" are estimated. Two different expansion variants of the AVM are estimated for each industry, again using the iterative algorithm subsequent to running initial OLS regressions that establish first approximations of coefficient values. The PS' and VS' variables are used in each of these expansions together
with $D$ in a first variant, and $MT$ in a second.

Accordingly, procedures for the case of $n$ expansion variables are followed. As surveyed in section 4.4, the parameters $v$ and $k$ of the initial AVM (4.10) are expanded such that:

$$v = v_0 + v_1 Z_1 + \ldots + v_n Z_n$$  \hspace{1cm} (20)

$$k = k_0 + k_1 Z_1 + \ldots + k_n Z_n$$  \hspace{1cm} (21)

where $Z_n$ represents the $n$th expansion variable. The first variant of the industry expansion (hereafter the D model, or the D variant) is obtained by substituting $PS'$, $VS'$ and $D$ for the $Z$ variables in (20) and (21). The resulting expansion equations are:

$$v = v_0 + v_1 PS' + v_2 VS' + v_3 D$$  \hspace{1cm} (37)

$$k = k_0 + k_1 PS' + k_2 VS' + k_3 D,$$  \hspace{1cm} (38)

where the Verdoorn coefficient ($v$) and capital deepening ($k$) are defined as functions of the change in plant size ($PS'$), change in vertical integration ($VS'$), and of existing urbanization economies represented by population density ($D$). Substituting the right side of (37) and (38) for the corresponding parameters of the initial AVM (14), an industry expansion model (D
variant) is obtained:

\[
p = n + v_0 Y' + v_1(Y' * PS') + v_2(Y' * VS') + v_3(Y' * D) \\
  k_0 KS + k_1(KS * PS') + k_2(KS * VS') + k_3(KS * D)
\]  

(39)

The MT variant is obtained by replacing \( D \) with the metropolitanization variable, \( MT \), in (37) and (38), the resulting equations' right sides of which substitute for the parameters of the initial AVM, yielding:

\[
p = n + v_0 Y' + v_1(Y' * PS') + v_2(Y' * VS') + v_3(Y' * MT) \\
  k_0 KS + k_1(KS * PS') + k_2(KS * VS') + k_3(KS * MT),
\]  

(40)

the MT variant. These two industry expansion models are used for the remainder of the analysis. The expansion equations, (37) and (38), and those corresponding to the MT variant, are used to discern the spatial patterns of the Verdoorn effects and of capital deepening as surveyed in chapter 7.

Because a degree of multicollinearity is likely to arise among the independent variables of the industry model estimations, insignificant variables are removed by backward elimination. A first estimation includes all the variables as determined in equations (39) and (40). Thereafter, independent variables are removed on the basis of their statistical significance. Each step
entails the reestimation of the model less the variable removed during the previous step. The reestimation may or may not reveal additional insignificant variables. If it does, the least statistically significant of those identified is removed and another reestimation is made. This is repeated until all variables retained exceed an appropriate level of statistical significance.

An exception to this is that Y' and KS, the two initial variables of the AVM, are not removed during backward elimination, and are retained in the final backward model. This is justified on theoretical grounds. The integrity of the initial AVM is considered important to maintain regardless of the comparable statistical strength of any of the contextual indicators.

In this study, the basis for the removal of variables is the ratio of the estimated coefficient value to its standard error. At each step the variable with the lowest such ratio is removed from the model, as it is considered to be a failed null hypothesis rejection of the coefficient equaling 0. Elimination terminates when all retained ratios are greater than 2. This corresponds to a t value of 2, and a 95 percent level of statistical confidence.
The results of the industry model estimations are reviewed below in sections 6.2.2.1 through 6.2.2.3.

6.2.2.1 Electronics/Instruments

The estimation results of the electronics/instruments AVM industry expansions are shown in tables 10 and 11. The parameter estimates are similar to the single equation variable expansions (tables 4 through 7). Only the signs of statistically insignificant coefficients have shifted, and these relate to the minor distinctions between the D and MT estimations. As all indicators of existing urbanization economies are eliminated in the backward procedure, the D and MT models are convergent. As a result, the second columns of tables 10 and 11 are equivalent. They show that PS' and VS' remain in the model after backward elimination, the former impacting the Verdoorn coefficient only, the latter retained to influence both the Verdoorn and capital deepening productivity effects.

The Verdoorn effect is augmented by decreasing plant size and by decreasing levels of vertical integration (that is, by vertical disintegration). Figure 10 shows the relationship between the Verdoorn
TABLE 10: Estimates for Electronics/Instruments
(D Model)

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Full</th>
<th>Backward</th>
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<tbody>
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<td>.000</td>
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<tr>
<td></td>
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<td>(351.49)</td>
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<td>$Y'$</td>
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<td>.269</td>
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<td></td>
<td>(.312)</td>
<td>(.051)</td>
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<td>$Y'*PS'$</td>
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<td>-4.613</td>
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<tr>
<td></td>
<td>(1.643)</td>
<td>(1.485)</td>
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<tr>
<td>$Y'*VS'$</td>
<td>-9.333</td>
<td>-14.869</td>
</tr>
<tr>
<td></td>
<td>(6.864)</td>
<td>(5.937)</td>
</tr>
<tr>
<td>$Y'*D$</td>
<td>-.068</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(.066)</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>-.016</td>
<td>.030</td>
</tr>
<tr>
<td></td>
<td>(.030)</td>
<td>(.004)</td>
</tr>
<tr>
<td>KS*PS'</td>
<td>-.233</td>
<td>-</td>
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<tr>
<td></td>
<td>(.277)</td>
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</tr>
<tr>
<td>KS*VS'</td>
<td>1.601</td>
<td>2.246</td>
</tr>
<tr>
<td></td>
<td>(.638)</td>
<td>(.491)</td>
</tr>
<tr>
<td>KS*D</td>
<td>.009</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(.006)</td>
<td></td>
</tr>
<tr>
<td>$R^2_{cor}$</td>
<td>.74</td>
<td>.70</td>
</tr>
<tr>
<td>F</td>
<td>7.44</td>
<td>10.35</td>
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TABLE 11: Estimates for Electronics/Instruments (MT Model)

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<td>.000</td>
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<td></td>
<td>(314.07)</td>
<td>(351.49)</td>
</tr>
<tr>
<td>$Y'$</td>
<td>.169</td>
<td>.269</td>
</tr>
<tr>
<td></td>
<td>(.271)</td>
<td>(.051)</td>
</tr>
<tr>
<td>$Y'$*PS'</td>
<td>-4.933</td>
<td>-4.613</td>
</tr>
<tr>
<td></td>
<td>(2.255)</td>
<td>(1.485)</td>
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<tr>
<td>$Y'$*VS'</td>
<td>-14.004</td>
<td>-14.869</td>
</tr>
<tr>
<td></td>
<td>(6.422)</td>
<td>(5.937)</td>
</tr>
<tr>
<td>$Y'$*MT</td>
<td>.212</td>
<td>-</td>
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<td></td>
<td>(.359)</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>.027</td>
<td>.030</td>
</tr>
<tr>
<td></td>
<td>(.022)</td>
<td>(.004)</td>
</tr>
<tr>
<td>KS*PS'</td>
<td>-.182</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(.320)</td>
<td></td>
</tr>
<tr>
<td>KS*VS'</td>
<td>2.057</td>
<td>2.246</td>
</tr>
<tr>
<td></td>
<td>(.583)</td>
<td>(.491)</td>
</tr>
<tr>
<td>KS*MT</td>
<td>-.003</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(.025)</td>
<td></td>
</tr>
</tbody>
</table>

$R^2_{cor}$           | .71      | .70      |

$F$                    | 6.46     | 10.35    |
Figure 10: Variation in the Verdoorn coefficient (v) relative to PS' and VS'. - Electronics/Instruments
Figure 11: Variation in E relative to PS' and VS' - Electronics/Instruments
Figure 12: Capital deepening relative to rates of vertical integration - Electronics/Instruments
coefficient and the combined influence of diminishing plant size and vertical disintegration. In it, the Verdoorn coefficient increases across 1.5 standard deviations of the plant size change continuum (the mean is -.0068 per annum, or -.68 percent per annum; the average for the US is -.41 percent per annum), at selected levels of vertical integration. The corresponding relationship concerning the structural scale parameter $E$ is shown in figure 11. An acceleration of $E$ is necessary to maintain a linear increase in the Verdoorn coefficient with respect to diminishing plant size and vertical disintegration.

The capital deepening productivity effect is heightened by vertical integration, as is shown in figure 12. Across a domain of over 1.5 standard deviations of the annual rate of vertical disintegration, capital deepening varies from 0 to 6 percent per annum.

Each of these results appear to conform to arguments concerning the impact of flexible specialization in the electronics/instruments industry. Within intensifying localized growth clusters, Verdoorn effects are strengthened by vertical disintegration accompanied by smaller plant sizes. However, capital
intensification occurs in the context of vertical integration. As has been noted in some of the recent literature (Schoenberger, 1989; Harrison, 1994), the adoption of the newest flexible technologies may require increasing integration as a coordinating mechanism.

6.2.2.2 Machinery

Of the three industries, machinery consistently exhibits the strongest statistical results. Its strength is a consequence of the singular significance of the Verdoorn coefficient. By itself, the Verdoorn effect accounts for a relatively large proportion of interstate variation in labor productivity (table 2). This is true regardless of the fact that the machinery industry has both the lowest rates of output growth and productivity growth among the industries. In effect, output growth, whether it is positive or negative, closely parallels the proportional changes in labor productivity over the period. The industry expansion estimates, shown in tables 12 and 13, are overall highly explanatory, with high $R^2_{cor}$ coefficients and F ratios.

Of the two models, the D model is clearly superior, initially and after backward selection. It looses no
**TABLE 12: Estimates for Machinery (D Model)**

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Full</th>
<th>Backward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>.013</td>
</tr>
<tr>
<td></td>
<td>(.131)</td>
<td>(.067)</td>
</tr>
<tr>
<td>Y'</td>
<td>.830</td>
<td>.627</td>
</tr>
<tr>
<td></td>
<td>(.259)</td>
<td>(.058)</td>
</tr>
<tr>
<td>Y'*PS'</td>
<td>1.367</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(1.608)</td>
<td></td>
</tr>
<tr>
<td>Y'*VS'</td>
<td>1.569</td>
<td>2.855</td>
</tr>
<tr>
<td></td>
<td>(1.734)</td>
<td>(1.192)</td>
</tr>
<tr>
<td>Y'*D</td>
<td>-.035</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(.050)</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>-.063</td>
<td>-.068</td>
</tr>
<tr>
<td></td>
<td>(.030)</td>
<td>(.030)</td>
</tr>
<tr>
<td>KS*PS'</td>
<td>-1.212</td>
<td>-1.023</td>
</tr>
<tr>
<td></td>
<td>(.252)</td>
<td>(.182)</td>
</tr>
<tr>
<td>KS*VS'</td>
<td>.531</td>
<td>.543</td>
</tr>
<tr>
<td></td>
<td>(.235)</td>
<td>(.230)</td>
</tr>
<tr>
<td>KS*D</td>
<td>.010</td>
<td>.009</td>
</tr>
<tr>
<td></td>
<td>(.002)</td>
<td>(.002)</td>
</tr>
<tr>
<td>$R^2_{cor}$</td>
<td>.92</td>
<td>.92</td>
</tr>
<tr>
<td>$F$</td>
<td>46.28</td>
<td>57.30</td>
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</table>
TABLE 13: Estimates for Machinery (MT Model)

<table>
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<th>Backward</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Coefficients</td>
<td>Coefficients</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
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<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(0.078)</td>
<td>(0.060)</td>
</tr>
<tr>
<td>Y'</td>
<td>0.609</td>
<td>0.666</td>
</tr>
<tr>
<td></td>
<td>(0.190)</td>
<td>(0.066)</td>
</tr>
<tr>
<td>Y'*PS'</td>
<td>0.539</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(1.900)</td>
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</tr>
<tr>
<td>Y'*VS'</td>
<td>3.215</td>
<td>4.018</td>
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<tr>
<td></td>
<td>(2.057)</td>
<td>(1.215)</td>
</tr>
<tr>
<td>Y'*MT</td>
<td>0.061</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.247)</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>-0.053</td>
<td>-0.052</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.034)</td>
</tr>
<tr>
<td>KS*PS'</td>
<td>-1.145</td>
<td>-1.212</td>
</tr>
<tr>
<td></td>
<td>(0.280)</td>
<td>(0.205)</td>
</tr>
<tr>
<td>KS*VS'</td>
<td>0.490</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.275)</td>
<td></td>
</tr>
<tr>
<td>KS*MT</td>
<td>0.029</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td></td>
</tr>
<tr>
<td>R^2_\text{cor}</td>
<td>0.88</td>
<td>0.86</td>
</tr>
<tr>
<td>F</td>
<td>30.88</td>
<td>50.67</td>
</tr>
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</table>
real explanatory significance as a result of backward elimination, where only two variables, \((Y'*PS')\) and \((Y'*D)\), are removed. After backward elimination, all of the contextual variables interactive with KS are retained in the D model, while in the MT model both vertical integration and urbanization economies as capital deepening contexts are removed.

Both models indicate that the Verdoorn coefficient is positively impacted by vertical integration \((Y'*VS')\). This is distinct from the electronics/instruments sector, and is at variance with most of the flexibility thesis literature that is concerned with agglomerative growth. However, recent suggestions concerning the way new technologies operate, and their coordination requirements, makes this an interpretable finding. Note also that were a state to have negative growth, vertical disintegration, rather than integration, would enhance labor productivity growth (ie. ameliorating the extent of losses resulting from the absence of output growth).

Interestingly, at least in the D model, vertical integration is indicated positively in the capital deepening productivity effect as well. Whether labor productivity growth is due to returns to scale or to
capital deepening, vertical integration reinforces the effect. Unlike the electronics/instruments case, where VS’ has a divergent influence, in machinery the direction of the vertical integration impact upon both the Verdoorn and capital deepening coefficients is the same.

In both models capital deepening is associated with diminishing average plant size (as the KS*PS’ sign is negative), and in the D model, the density variable augments capital deepening. Both of these results are consistent with standard perspectives on capital intensification. The first is interpretable as the plant level impact of capital for labor substitution. The second is consonant with the notion that existing externalities (represented by high densities) increase the marginal returns to private capital.

The combination of these different contextual effects upon capital deepening are shown in figures 13 and 14. The two graphs show, respectively, the per annum percent of capital deepening at two different D

---

42Capital for labor substitution does not, of course, necessarily entail diminished plant size. Plant size is sensitive to technological requirements, and overall, the substitution of labor may result in larger and, without substantial output growth, fewer plants.
Figure 13: Capital deepening relative to $PS'$; $VS'$ variously fixed; $D=4.6$ (pop density=100); Machinery
Figure 14: Capital deepening relative to PS'; VS' variously fixed; D=6.4 (pop density=600): Machinery
values. In each case capital deepening is related to a standard deviation range of PS' values at various levels of VS'. While diminishing plant size is the most crucial contextual effect in the case of machinery, the vertical integration and urbanization impacts are significant, if not of great magnitude.

Machinery is the only industry for which the change in plant size has a significant impact upon the capital deepening effect. However, the industry is similar to the other sectors in that its capital deepening is significantly impacted, in the same direction, by vertical integration and urbanization economies.

6.2.2.3 Apparel

The estimated results of the apparel AVM industry expansions are shown in tables 14 and 15. Differences between the two models are not decisive, the MT model performing slightly better with all of the variables present, and the D model improving a bit more after backward elimination.

The full estimations exhibit parameter signs that are the same as those for the single variable equations (tables 4 through 7), with the exception of the VS'
TABLE 14: Estimates for Apparel (D Model)

<table>
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<tr>
<th>Independent Variables</th>
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<td>Intercept</td>
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<td>.000</td>
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<tr>
<td></td>
<td>(830.27)</td>
<td>(.000)</td>
</tr>
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<td>Y'</td>
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<td>.226</td>
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<tr>
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<td>(.086)</td>
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<td>Y' * PS'</td>
<td>-18.998</td>
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<tr>
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<td>(5.326)</td>
<td>(3.164)</td>
</tr>
<tr>
<td>Y' * VS'</td>
<td>9.958</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(10.911)</td>
<td></td>
</tr>
<tr>
<td>Y' * D</td>
<td>-.067</td>
<td>-</td>
</tr>
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<td></td>
<td>(.052)</td>
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<td>.010</td>
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<td></td>
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<td>(.003)</td>
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<tr>
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<td>F</td>
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<td>12.25</td>
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TABLE 15: Estimates for Apparel (MT Model)

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<td>(.000)</td>
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<td>.115</td>
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<td>(.083)</td>
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<td>Y'*PS'</td>
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<tr>
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<td>(5.090)</td>
<td>(3.685)</td>
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<tr>
<td>Y'*VS'</td>
<td>11.652</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(10.922)</td>
<td></td>
</tr>
<tr>
<td>Y'*MT</td>
<td>-.623</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(.386)</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>.026</td>
<td>.023</td>
</tr>
<tr>
<td></td>
<td>(.022)</td>
<td>(.022)</td>
</tr>
<tr>
<td>KS*PS'</td>
<td>.483</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(.317)</td>
<td></td>
</tr>
<tr>
<td>KS*VS'</td>
<td>.565</td>
<td>1.157</td>
</tr>
<tr>
<td></td>
<td>(.496)</td>
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<td>KS*MT</td>
<td>.057</td>
<td>.046</td>
</tr>
<tr>
<td></td>
<td>(.023)</td>
<td>(.018)</td>
</tr>
</tbody>
</table>

R^2 corr

.78    .71

F

9.26   10.74
expansion of the Verdoorn coefficient. However, this interactive variable lacks significance in the industry models and is removed during backward elimination. Otherwise, as with the single variable equations, the expansion variables influence the Verdoorn coefficient negatively, and capital deepening positively.

With backward elimination, half of the expansion variables are dropped from the model estimations. Only plant size change ($PS'$) is retained to impact the Verdoorn coefficient, but its influence is marked. Capital deepening is impacted by vertical integration ($VS'$) and an indicator of urbanization economies ($D$ or $MT$ depending upon the model).

As with electronics/instruments, decreasing plant size augments the Verdoorn effect. The extent of this effect is indicated in figure 15, which shows the relationship between the Verdoorn coefficient and plant size change using the D model results. The effect conforms to the localization effects suggested by the flexible specialization thesis. States with output growth have higher than expected productivity growth where plant sizes diminish most precipitously. However, states, generally in the northeast, such as New York, with negative output growth, would have negative
Figure 15: Variation in the Verdoorn coefficient (v) relative to rates of plant size growth - Apparel
productivity growth given the singular Verdoorn effect. That they do not is a partial function of their lessened decreases in plant size. Where output growth is negative smaller decreases (or larger increases) to plant size mitigate the negative productivity effects of the Verdoorn relationship in these instances.

Another source of labor productivity growth, particularly important in the apparel sector,43 is capital deepening. Its impact is significantly associated with vertical integration and existing urbanization economies. These interrelationships are shown in figures 16 and 17, where capital deepening is related to the annual rate of vertical disintegration, respectively, at various levels of population density and proportional metropolitan populations.4 The role of integration and metropolitan location are consistent with some standard perspectives concerning capital deepening in the apparel industry. With the adoption of the newest technologies it is thought that phases of manufacturing and even spheres of production (ie.

4See tables 2 and 3.

4The per square mile densities equivalents for D values of 3.5, 5.0, and 6.5 are, respectively, 33, 148, and 665.
Figure 16: Capital deepening relative to VS’ at varying levels of D - Apparel
Figure 17: Capital deepening relative to VS' at varying levels of MT - Apparel
design, information coordination, and manufacture) are increasingly subject to integration. Especially in the apparel industry, however, this does not necessarily enable plants to be independent of metropolitan economies, due, it is suspected, to market demands for more specified products under greater time constraints.

6.3 Discussion of Results

Augmented Verdoorn model estimates show that the Verdoorn relationship holds, to varying degrees, for each of the industries investigated in this study. Capital deepening is most important to the growth of labor productivity in the apparel industry. This is not unexpected as the industry has the lowest initial level of capital intensity, and, therefore, an opportunity to accrue substantial efficiencies from even small absolute increments to its stock of capital equipment. Measured without reference to production contexts, however, capital deepening is not significant to labor productivity growth in either the electronics/instruments or machinery industries (table 2).

45The apparel industry also has the lowest initial mean levels of labor productivity (figure 7).
6.3.1 Estimated Parameters of Individual Variables

Single variable expansions reveal that the Verdoorn coefficient is subject to some contextual drift. The proxies for urbanization economies have a uniformly negative influence upon the Verdoorn effect. However, it is also noted that in cases of declining output, typical in the country’s northeast quadrant and especially so in the machinery industry, this is tantamount to a reversal of a negative Verdoorn relationship. Also, in the apparel industry, diminishing average plant size has a very strong interactive relationship with output growth. Except for PS' and VS' in the case of machinery, the signs of all the Verdoorn expansion coefficients are negative (table 8). The interpretation is that in apparel and electronic/instrument production, vertical disintegration and diminishing plant sizes are reinforcing contexts of the Verdoorn effect, a finding in agreement with much of flexibility thesis literature.

Also, in all industries, the signs associated with the expansions denoting existing urbanization economies are negative, indicating that the strongest (positive or negative) Verdoorn effects occur away from population or
metropolitan centers.

Capital deepening generally appears to be more contextually dependent than are Verdoorn effects, an attribute revealed by the single variable expansions. The systematic significance of capital deepening in electronics/instruments and machinery, particularly, is evidenced through these contexts rather than as an invariant influence (table 9).

As much standard theory concerning the underlying organizational and technological determinants of internalized production has shown, vertical integration tends to accompany capital intensification (section 2.4.2). Vertical integration accommodates higher capital intensities because it supplements an increase in the marginal product of capital, particularly when the capital entails combining production processes (into continuous processes). This is likely to be true, as well, of the influence of urbanization economies, as their presence may allow for increased capital intensity with a reduced onset of diminishing returns. Gains to labor productivity, then, quite plausibly are tracable to new process technologies and to urbanized infrastructure, both allowing capital to generate higher returns (Romer, 1986; Lucas).
The capital deepening effect of changes to plant size does not have the same uniform influence across sectors. The negative effect of plant size growth indicates that capital deepening is accompanied by diminishing average plant sizes in electronics/instruments and machinery. At the plant level, this is an indication of capital substituting for labor. Evidence concerning technical changes in the manufacturing process suggests that the labor content of production continues to diminish, particularly in these two sectors. Even with further integration at the plant level, it is likely that, in terms of workers, plant size will continue to decrease. This is particularly true in the already more highly capitalized industries where a new generation of flexible machinery is presumably replacing older dedicated machinery. While this may be the case in the long run for apparel as well, over the study period this industry is

"Overall, the trend in plant size for the U.S. as a whole is negative over the study period. The U.S. percent per annum reductions in plant size are -.41, -1.99, and -.76 for electronics/instruments, machinery, and apparel, respectively.

"Although this is more valid of production labor than for non-production labor, the latter not so clearly substituted for by capital (Schoenberger, 1989), and often even complementing capital (Clark, other)."
characterized by a distinctive trend. The capital deepening effect in apparel is lessened by extreme reductions in plant size. Although average plant sizes in the industry decrease, more minimal decreases (as well as some increases) are associated with greater capital deepening.

6.3.2 Industry Expansions

The industry expansions, while they do not greatly alter these general findings, do suggest some distinctive interpretations as a consequence of the controlled for contextual effects. In both the electronics/instruments and apparel sectors diminishing average plant size reinforces the Verdoorn relationship, while it does not have significant effect upon the already substantial Verdoorn relationship in the machinery industry. Verdoorn effects are also enhanced in the electronics/instruments sector by the process of vertical disintegration. These results for electronics/instruments and apparel are generally supportive of the thesis of agglomerative flexibilities as fashioned in the industrial geographic literature by Scott (1988a), Saxenian (1983), Storper and Walker
(1989), among others. However, not only is the direction of such Verdoorn contexts unobserved in the machinery industry, evidence of vertical integration suggests that in this sector the Verdoorn effect works differently. Rather than disintegration effects, there are integration effects.

Presumably because of the controlling effects of the PS' and VS' variables, the impacts of urbanization economies are not typically significant in the industry expansions. This conforms, as well, to notions of new industrial spaces, in the sense that the productivity role of existing agglomerations does not appear to be decisive.

In terms of capital deepening, as suggested above, the effects of vertical integration and existing urbanization economies are uniformly positive where they occur.

The positive influence of vertical integration upon capital deepening occurs in all three industries, and is suggestive of a pervasive (ie. across manufacturing sectors) technological relationship that augments labor productivity growth. No conclusion regarding flexible machinery per se is deducible, however, as continuous process technology has been increasingly available
regardless of its degree of flexibility. Any such capital equipment, flexible or not, tends (note review in section 2.4) to complement plant level integration. In addition, recent considerations of flexible technology have pointed to a capital equipment effect that potentially overrides any necessary (or likely) inclination to vertically disintegrate (section 2.4 and 3.2) (Schoenberger, 1989; Gertler, 1992).

The positive capital deepening influence of existing urbanization economies occurs for machinery and apparel. Machinery, as already noted with regard to vertical integration in association with both the effects of Verdoorn and of capital deepening, is not characterized by geographically defined flexible specialization attributes. To the extent that the productivity growth effect of capital deepening in the machinery industry is augmented by existing agglomerated activity, the comparative importance of new industrial sites (i.e. new industrial spaces) is diminished. The association of capital deepening productivity effects and existing agglomerations agrees with the findings of some researchers who suggest that industrial rejuvenation due to both organizational and technological innovations is at least as prevalent in
the northeast quadrant of the country as it is in the
sunbelt (Rees, Briggs, and Oakey, 1985; Florida and
Kenny, 1992). However, where output losses occur,
productivity gains also indicate a degree of plant
rationalization (Rigby, 1992). The importance of
metropolitan locations to the apparel industry,
particularly for the production of highly specified
products, is widely taken as fundamental. Such
locations augment the capital deepening effect.
Finally, except in the machinery industry, plant
size changes do not impact capital deepening.
Diminishing plant size is important in
electronics/instruments and in apparel as a Verdoorn
coefficient effect, but in machinery as a capital
deepening effect.

6.3.3 Conclusion

These divergent effects underscore the differences
in the three industries. On balance, the
electronics/instruments and apparel industries appear to
evidence characteristics similar to those associated
with flexible forms of agglomerative production, while
the machinery sector does not.
CHAPTER VII - SPATIAL REPRESENTATIONS

7.1 Introduction

This chapter reviews the spatial variability of the Verdoorn (v) and capital deepening (k) parameter estimates. Discussion centers around the interregional pattern of coefficient values as portrayed in a set of choropleth maps.48

48The capital deepening coefficient values are divided into three groups consisting of equal numbers of observations (figures 19, 21, and 23). Equal observation categories of the Verdoorn coefficients are also employed, but they are based upon the number of positive Y’ values. An important feature of the Verdoorn effect is that it can be positive or negative depending upon whether output is respectively positive or negative. As output values are sometimes negative in each of the three industries, separate categories are reserved for such instances. In electronics/instruments, two equal observation categories for positive Verdoorn effects, and a category for negative Y’ values are used (figure 18). Because machinery has many more negative Y’ values, two groups of these values are distinguished, but the divisions are determined by the equal size categories of positive Y’ observations (figure 20). Likewise for the apparel industry, where the bases for categorizing are the set of positive Y’ values that are specifically accompanied by positive Verdoorn coefficients (v’s) (figure 22). Apparel is the only sector to have negative v values, where there are diminishing returns to increasing scale. Such observations constitute an additional (fifth) category.
Parameter values for each state are computed using forms of the expansion equations (37) and (38). The values of $v$ and $k$ are expressed as functions of the full industry expansion models rather than of the backward eliminations. The former are considered to be superior representations of the production relationships, as their coefficients are estimates of the population parameters, even though some do not have coefficient to standard error ratios indicating levels of significance different than zero (Casetti, 1987).

The industry expansion variant (D or MT) that has the highest level of significance is used to generate the $v$ and $k$ values. Accordingly, these values are obtained from the D model in the case of electronics/instruments and machinery, and from MT in the case of apparel.

7.2 Electronics/Instruments

To the extent that output growth in the industry is greatest along the south Atlantic coast and across the west, and most incidents of output decline are confined to the eastern midwest, the electronics/instruments sector conforms to the more general snowbelt
to sunbelt shift of manufacturing activity during the 1977 to 1987 period (figure 2). In addition, as with the general pattern of interregional trends, parts of the western midwest and of the coastal northeast, particularly New England, are characterized by significant but typically more moderate rates of output growth, higher than in the remainder of the old manufacturing belt.

This clearly regionalized pattern is associated with a less definitive spatial arrangement of productivity gains. Much of the sunbelt and northeast coast experience comparatively high rates of productivity growth, although this broad pattern is punctuated by anomalous cases. The interior of the old manufacturing belt, however, exhibits uniformly lower rates of productivity growth. The coincidence of output and productivity growth suggests a considerable Verdoorn effect, but one that has contextual variance. This is confirmed (tables 2, 10, 11) in the results of chapter 6.

The pattern of contextual influence indicates that the positive Verdoorn effects are more substantial across much of the south and in the western midwest than elsewhere (figure 18). Yet, states of comparatively
Figure 18: Verdoorn Effect: Electronics/Instruments
high output growth, typically identified in the literature as having a particular set of economic strengths associated with agglomerative growth (section 3.2), exhibit only moderate Verdoorn effects. Among these, California, Colorado, Washington, Massachusetts, and Florida are noteworthy. In fact, among the sunbelt states of the west included in the study, only Arizona is characterized by above average Verdoorn effects.

The diminished average plant sizes and vertical disintegration associated with the strongest Verdoorn impacts (theoretically by the flexibility literature and empirically in the present study) do not occur in California and Florida. These states, the former employed consistently to illustrate externally organized agglomerative flexibilities, actually experience plant size increases and vertical integration. Plant sizes in such states as Washington and Arizona, as well as Texas and New York also increase, although all of these states experience a degree of vertical disintegration. Decreasing plant size is more characteristic of the less urbanized parts of the south and of much of the coastal northeast and western midwest (where, however, integration, is more widespread as well, especially in New England).
Overall, this contextual detail results in a pattern of Verdoorn effects that does not obviously conform to the standard spatial image portrayed in the geographically oriented flexibility literature. While the industry expansion estimates of the AVM in this study (tables 10 and 11) do appear to verify the significance of externalized organizational attributes, they indicate a less anticipated interregional pattern. The pattern, associated with smaller average plant sizes and vertical disintegration, is one where the strongest Verdoorn effects are not generally evidenced in the west or even in the eastern coastal states, but rather in parts of the interior south and western midwest.

Along the northeast coast, and especially in New England, the productivity effects of capital deepening are considerable, and complement the moderate Verdoorn relationship evidenced in the region. Elsewhere in the northeast quadrant of the country, capital deepening is at least moderately significant (figure 19). To a degree, it compensates for negative Verdoorn effects incurred by output loses in the eastern midwest. Nevertheless, these states typically experience comparatively low rates of productivity growth.

Capital deepening is important in only selected
portions of the sunbelt (figure 19). It does seem to moderately augment productivity growth in such states as California and Colorado, where the Verdoorn effect is relatively weak.

Overall, the electronics/instruments sector is characterized by a general distinction between the productivity growth patterns of the sunbelt and the snowbelt. The former is characterized by stronger Verdoorn effects, the latter by more significant capital deepening. It is important to note, however, that much of the northeast quadrant experiences slower rates of productivity growth than the sunbelt. Where exceptions arise, notably in New England and in some states in the western midwest, moderate to strong Verdoorn and capital deepening effects combine to determine comparatively higher growth rates of productivity.

7.3 Machinery

As with electronics/instruments, the machinery industry, in broad outline, parallels the larger U.S. interregional trend in manufacturing output growth over the 1977 to 1987 period. Output losses are typical across the northeast quadrant of the country, with the
exception of portions of New England. The southeastern states, and much of the West experience expansion. However, distinct from overall manufacturing patterns is the fact that south central portions of the country are characterized by falling machinery output. Also, while a few states experience high output gains, overall output growth is not great. Nevertheless, the differences in the change in output among states is substantial. In part, it is the considerable variance across states of output change, a continuum of absolute expansion as well as contraction, that generates a strong, spatially defined Verdoorn effect.

The expansion variables do not alter this general result greatly. Productivity growth corresponds closely to variations in output growth, assuring a relatively stable Verdoorn coefficient. The extent of Verdoorn effects is also highly regionalized where, as shown in figure 20, much of the north central and western interior of the country is subject to its positive influence. As most of these regions (excepting parts of the west, particularly the southwest), also witness comparatively high rates of productivity growth, little variability concerning the positive growth effects of the Verdoorn relationship is apparent. Where the
Figure 20: Verdoorn Effect: Machinery
Verdoorn effect is negative, across the midwest and parts of the northeast and south central, such an effect is only moderately limited by some contextual attributes. High population densities and reductions in average plant size are statistically insignificant adjustments (dropping from the estimate subsequent to backward elimination) to the negative Verdoorn effect.

However, these conditioning elements are highly significant in their impact upon capital deepening. In large part, it is the extent of capital deepening that underpins the modest productivity gains of the country's older manufacturing core. The highest rates of capital deepening occur throughout the northeast quadrant and in the central and south central areas (figure 21). This extends to the New England states and northern tier states that also experience positive Verdoorn effects.

In the case of machinery specifically, the capital deepening effect is highly contextualized, as is evidenced by the full backward D model (table 12; figures 13 and 14). In the absence of these indicators of organizational conditions, capital deepening does not appear as a systematic impact upon productivity growth. However, in association with diminishing plant size, increasing vertical integration, and where densities are
Figure 21: Capital Deepening: Machinery
higher, capital intensification continues to be an important determinant of productivity growth. The implication is that these contexts augment capital productivity, such that the marginal product of capital diminishes less than it would otherwise.

In terms of an industry with already high capital to output ratios it is notable that this should be the case (as opposed to say apparel, where such ratios are much lower). Because of it, capital deepening provides a significant and highly regionalized boost to labor productivity. Conceptually, these results are consistent with findings suggestive of continued higher rates of midwest and northeast process innovation (Rees, Briggs, and Oakey, 1986). However, where growth is negative, a degree of rationalization necessarily accompanies labor productivity increases (Rigby, 1992).

7.4 Apparel

The apparel industry is subject to the same apparent snowbelt to sunbelt output growth shifts as are the electronics/instruments and machinery sectors. However, while a reasonably clear regionalization (though not always simply a snowbelt to sunbelt shift) of productivity growth also occurs in these industries,
it does not in apparel. High and low productivity growth states are found in all parts of the country (figure 9).

Indeed, the results of chapter 6 show that the apparel Verdoorn effect, while significant, is highly contextually dependent. Backward elimination reveals the particular importance of plant size change (figure 15). As with electronics/instruments, and in agreement with flexibility notions, it is diminishing average plant size that provides a significant premium to the Verdoorn productivity effect. This is the dominant contextual influence (of the three in the full estimation; table 14) shown in figure 22.

The range of variation in the Verdoorn coefficient is far greater in apparel than in either of the other industries. There exist, in a number of states, and unlike the other industries, declining returns to scale as indicated by a v value less than 0 (E<1), as well as cases where v is well above .52 (E>2.1). Where there is negative output, and the Verdoorn effect has resulting negative productivity growth implications, the values range widely as well. Such negative effects are less pronounced (ie. the Verdoorn coefficient is generally lower) in the old manufacturing belt than in other areas of output loss.
Figure 22: Verdoorn Effect: Apparel
High and positive Verdoorn effects occur throughout the country, but are concentrated in states that do not contain the industry’s agglomerative centers. In such relatively peripheral states, the characteristics associated with agglomerative flexibilities, notably diminishing average plant size, are typically evidenced. This contrasts with states that have existing or growth agglomerations, where the Verdoorn effect is comparatively weak, and its contextual characteristics are not suggestive of flexibly organized production.

It is of interest that California, particularly, experiences declining returns to scale. It is among the most rapidly growing states in terms of output, but has a relatively low associated rate of productivity growth. It also displays characteristics opposite to what is expected of agglomerative growth centers, such as increasing average plant size and virtually no vertical disintegration.

Distinctive relative to the other industries, the apparel estimates reveal a comparatively stable capital deepening parameter. Nevertheless, the range is considerable enough to give a number of states a premium to productivity growth sufficient to overcome low, or negative, Verdoorn effects (figure 23). Particularly in the northeast, where declining output is typical,
Figure 23: Capital Deepening: Apparel
capital deepening rates are particularly high.

Overall, as with the other industries, the apparel Verdoorn effect is considerably stronger in the sunbelt than in the northeast quadrant. The exceptions are, however, noteworthy. California and Florida, prominent centers of output growth, are characterized by diminishing returns to scale. The weak Verdoorn effects of the northeast actually contribute higher than otherwise rates of productivity growth as they reduce the productivity reducing effects of negative growth. In the northeast, especially, capital deepening enhances productivity growth. However, high rates of capital deepening are scattered across other regions.

7.5 Summary

The Verdoorn effect contributes significantly to sunbelt productivity in all three industries under distinctive contextual influences. Only in the case of apparel do some notable states have diminishing returns to scale.

The negative output growth experienced by many states of the northeast results in detrimental productivity impacts, but such impacts are often limited
by ameliorating contextual influences upon the Verdoorn coefficient.

However, capital deepening provides the major source of labor productivity growth in the country's snowbelt. Particularly in machinery and apparel, such productivity growth is often as, or more, substantial than in the sunbelt.
CHAPTER VIII - CONCLUSION

As regionalized patterns indicate, the sunbelt experiences greater growth and an increased concentration of manufacturing activity in the three industries during the 1977 to 1987 period. This pattern is largely, but not entirely, paralleled by associated increases in labor productivity, as would be predicted by the Verdoorn Law when applied to these particular industries. In this sense, the augmented Verdoorn model is a useful foundation for empirically testing flexible contexts of productive efficacy. Regardless of the results with respect to flexibility effects, the Verdoorn relationship is strong for each of the three industries, an indication that dynamic returns to scale are significant despite the particular characteristics of change to production systems.

As scale is critical to productivity growth, it is unlikely that neoclassical convergence is an adequate premise upon which to base assessments of growth and change in the space economy. The generally discontinuous nature of such growth suggests that the
assumption of convergence is theoretically inadequate even when empirically evidenced. Such possible evidence may be largely specious. It may show long run patterns, but take little account of the dynamics occurring due to the relative clustering of activity. When comparing observations across space, the tendency of marginal factor productivities to decline is probably less important than the possibility that returns to capital do not uniformly diminish, and that the extent of increasing returns to scale are regionally variable. This is the corrective that new growth theory lends to the neoclassical framework. It removes the neoclassical assumption of convergence and the notion that disequalibrating trends are necessarily anomalous. The learning and spillover economies that have motivated new growth theorists can also be evaluated as contexts of the Verdoorn relationship.

The Verdoorn relationship has been a central component of demand oriented approaches to economic growth, predating new growth theory. It has represented an alternative to the assumption of interregional convergence, anticipating the significance of spatial concentration and agglomerative cumulation now posited by new growth theory.
The foundation of flexible specialization as a viable system of production relates to the growth and instability of demand. As such it is linked to the Verdoorn regularity, and provides it with contextual grounding. However, as this study has shown, while the Verdoorn regularity is valid across industries (with variable parameter estimates), the production context varies.

It would appear that particularly when considering growth at the level of the industrial sector (i.e. two-digit industries) is the likelihood of spatially concentrated growth significant. Especially in technology-intensive sectors, demand is likely to expand quickly, but to be subject to product (and investment) uncertainties. Factor mobility between industries and regions further suggests that factor supply constraints are less important than demand limitations (and demand growth) as determinants of growth for particular industries and regions. It, therefore, is especially appropriate to assume a Verdoorn relationship when investigating industrial sectors across regions. Aggregate convergent trends can obscure the divergencies of particular industries across space. And particular industries may be important as portends of wider trends
in the manufacturing economy. The results of this study indicate that at the level of the industrial sector, for particular industries that the flexible specialization literature highlights, such trends occur during the 1977 to 1987 period.

Three major findings related to the empirical analysis can be identified. First, in terms of the initial AVM, the Verdoorn effects are significant in all three industries, while the systematic capital deepening effect is evidenced only for the apparel industry. Second, AVM expansions indicate that each industry is characterized by distinctive contextual effects. With regard to returns to agglomerative flexibilities, the results are mixed and sectorally specific. Lastly, the interregional variability of the v and k parameter estimations based upon the full industry expansions indicate generalized snowbelt/sunbelt distinctions.

The electronics/instruments and apparel industries exhibit some of the characteristics associated with agglomerative flexibilities. The Verdoorn relationship, with the productivity effect of capital deepening and existing urbanization economies controlled for, is enhanced by the contextual variables in the direction proposed by the geographically oriented flexibility
thesis. In the electronics/instruments sector particularly, both diminishing mean plant size and vertical disintegration reinforce the Verdoorn effect. In apparel, only reduced plant size is significant, but the magnitude of impact is very strong.

Apparel and electronics/instruments also experience significant capital deepening. This is especially true in apparel, where low initial capital intensities presumably enable substantial capital for labor substitution given the development of appropriate technology. The literature suggests that this technology is becoming available (Gibbs, 1987; Dickerson, 1991). However, its availability is likely to favor relatively large firms as it may necessarily entail plant level consolidation. While it is possible that agglomerated small plants are capable of the coordinating vertical phases (as well as combining spheres) of production, it seems just as likely that such coordination may take the form of integration. This is strongly suggested by the empirical results of this study, where vertical integration significantly augments the rate of capital deepening. This contextual effect is evidenced not only in apparel, but also in the electronics/instruments and machinery industries as
well. In the apparel industry, the capital deepening effect is also positively impacted by urbanization indicators (D and MT).

While the machinery industry estimates indicate a strong Verdoorn effect, they do not display characteristics associated with externalized organizational flexibilities. Contrary to such expectations, the Verdoorn coefficient varies positively in association with vertical integration. As noted above, vertical integration also has a positive influence upon capital deepening. Vertical disintegration, therefore, has negative consequences for productivity growth without respect to the source of such growth. Reduced mean plant size and existing urbanization also have a positive impact upon capital deepening in the machinery sector. This suggests that capital for labor substitution occurs at the plant level, and that it occurs to a greater degree in more densely populated (generally northeast quadrant) states.

The results of the expansion estimates at least selectively confirm the significance of external organizational conditions to the Verdoorn relationship in a manner envisioned within the flexibility literature. However, the spatial Verdoorn pattern is at
some variance with such flexibility expectations.

The electronics/instruments and apparel sectors exhibit variable Verdoorn effects related to agglomerative flexibilities, but the highest estimated Verdoorn coefficients are not associated with states where such conditions are generally purported to be greatest. States with only moderate electronics/instruments Verdoorn effects are many of those identified with the economic strengths of agglomerative growth in the industry. In apparel, the strongest Verdoorn effects are scattered across the country. In some states with comparatively very high rates of output growth, low, or even diminishing (0<E<1), returns to scale are evidenced, and the contextual attributes associated with the Verdoorn coefficient are often the reverse of what is expected of growth agglomerations (section 7.4; figure 22). Hence, even in those industries where the contextual influences apparently fit correctly the hypothesized manner and direction of impact, the interregional pattern of parametric drift is not obviously representative of expectations.

Beyond these considerations, a general tendency for the Verdoorn effect to be a somewhat more significant determinant of productivity growth in the sunbelt rather
than in the country's northeast quadrant is notable. Of course, the negative output growth that is experienced in much of the old manufacturing core eliminates the possibility of positive Verdoorn effects, especially in the eastern midwest. Also, high positive Verdoorn effects are not uniform across the sunbelt, with some core states of new growth, such as California and Florida, having comparatively low productivity returns to output growth.

Capital deepening ameliorates, to a degree, the otherwise detrimental impact of negative output growth in the old manufacturing belt. For parts of the northeast quadrant, New England in electronics/instruments and machinery and the western midwest in electronics/instruments and apparel, considerable capital deepening complements a moderate to strong Verdoorn influence. In parts of the sunbelt as well, notably in the southeast in electronics/instruments and apparel, capital deepening and Verdoorn effects both contribute to productivity growth.

In general, capital deepening is greater in the northeast quadrant of the country than it is elsewhere. Again, the pattern is course, with many states in the sunbelt exhibiting moderate to strong returns to capital
intensification, particularly in apparel and electronics/instruments. In the former industry especially, a snowbelt/sunbelt distinction is barely evident.

Overall, these results do not indicate generality with respect to productivity effects of agglomerative flexibilities. At best, evidence of returns to organizational externalities are highly qualified in terms of sectors and regions. Of course, through the 1990's, if the generalizable significance of agglomeration economies really does strengthen, then the empirical results should broaden to include other industries.

It could be that organizational flexibility is important under certain conditions, but that the manufacturing process retains other tendencies. At particular times, in some industrial sectors, and in some regions, specifically flexible conditions of agglomerative growth are significant. Universal trends are, however, less likely.

When and if spheres of production become more integrated through process technology and organization, development of the space economy is likely to be observed under an alternative set of definitions.
Greater product scope does not necessarily preclude production at scale, and in fact, internal scale could be reimposed by the requisites of integrating design and manufacture spheres. Mass production, under these conditions, is not likely to merely exit in favor of flexible production. Rather, externalized organizational attributes are likely to ebb and flow, vary among industries, and particularly among regions. The spatial differentiation associated with product and industry life cycles is likely to continue to characterize interregional distinctions in production, with the initial stage(s) identified with more flexibly agglomerative production.

What can be said from the results of this study is that: (1) productivity growth is significantly associated with output growth in each sector, providing additional confirmation of a Verdoorn relationship within industrial sectors; and (2) that such an effect is not consistently augmented by agglomerative flexibilities. Such flexibilities, while they are associated with electronics/instruments and apparel, are absent in the case of machinery.
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