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INTEGRATION, SPECIALIZATION, AND ADJUSTMENT

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ABSTRACT

In the United States, many industries have a Silicon Valley-type geographic localization. In Europe, these same industries often have four or more major centers of production. This difference is presumably the result of the formal and informal trade barriers that have divided the European market. With the growing integration of that market, however, there is the possibility that Europe will develop an American-style economic geography. This paper uses a theoretical model of industrial localization to demonstrate this possibility, and to show the possible transition costs associated with this shift.

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Geographers have long noted the importance of "industrial districts" in interregional specialization within the United States. In many industries firms tend to cluster together, drawn by the availability of a strong local base of specialized suppliers (often including a pool of labor with specialized skills); this local base in turn owes its existence to the local concentration of demand. Thus a circular process of agglomeration takes place. Historical industrial districts include such famous examples as the Detroit-centered automotive region and the New York garment industry; today the phenomenon is perhaps best represented by California's Silicon Valley and Boston's Route 128.

Unlike geographers, economists studying international trade have traditionally paid little attention to the role of industry agglomerations as a cause of specialization (with the notable exception of Ohlin (1933), who used the jewelry concentration in Solingen to illustrate the role of increasing returns). This neglect may in part be viewed as a theoretical blind spot: before 1980 trade theorists were reluctant to address the role of increasing returns in any form, and the post-1980 literature on "intraindustry" trade initially tended to emphasize internal as opposed to external economies of scale. The neglect of agglomeration may also, however, have been a realistic judgement. While industrial districts like the auto region have obviously played a crucial role in <u>interregional</u> specialization within the United States (and within other countries as well), their role in <u>international</u> trade is less apparent. To take the clearest example, the European automotive industry never developed a single hub comparable to Detroit.

There is no mystery about why agglomeration has been a more potent force for interregional than for international specialization. Barriers to trade between national economies -- both formal barriers such as tariffs and the de facto barriers created by differences in language and culture, lack of factor mobility, and the sheer nuisance presented by the existence of a border -- are often enough to block the expansion of a successful industrial district beyond its national market. Detroit's initial advantage allowed it to crowd out its competitors in New York, Connecticut, and Pennsylvania before World War I; no European automotive center could do the same in the far less integrated European auto market.

For this reason, industries within Europe are in general much less geographically concentrated than their counterparts within the United States. Table 1 offers some examples, exploiting the fact that the four major US regions are roughly comparable in population and income to the four large European economies. It is obvious that in each case production is far more localized in the US.

Recently, however, the European Community has introduced sweeping measures designed to create a truly unified continental market. The Community was already a free trade area in the conventional sense, but now there will also be guaranteed freedom of direct investment, labor mobility, harmonization of regulations, and a complete elimination of border formalities. While Europe will not be able to emulate the US in adopting a common language, in all other respects it will constitute a highly integrated and for the most part geographically compact economy -- precisely the conditions under which one might expect many industries to serve the market from a single local agglomeration rather than be shared by three or four countries.

This prospect raises several questions. First, where will the industrial districts of 21st century Europe be located? That is, which country will get Europe's Silicon Valley, its Wall Street, and so on? Second, will the formation of such districts be beneficial to the European economy? Finally, how will the adjustment take place -- if an industry that currently has several national centers coalesces around a single European center, what happens to the workers left behind?

This paper makes a first step toward answering these questions by developing a stylized theoretical model of the relationship between industrial agglomeration and international trade. The model is closely related to recent work in economic geography, e.g. Krugman (1991); unlike most of the recent geography papers, however, it assumes that factors are immobile between countries. Following Venables (1993), we find that vertical linkages among industries can play a role in industrial specialization similar to that played by factor mobility in more aggregate agglomeration stories. In particular, we find that increased integration -- a reduction in the costs of doing business across space -- somewhat paradoxically makes it more likely that firms in the same industry will cluster together.

While this paper was inspired by the issues surrounding European integration, we believe that the model is of broader interest as well. It offers a somewhat novel perspective on the forces driving international specialization and trade in general. And we believe that this model, in which strongly nonlinear dynamics emerge as a natural consequence of the economic analysis, illustrates the likely importance of such dynamics in economic modelling more broadly.

1. The model

Imagine a world in which there are several industries, in each of which both goods intended for final consumption and intermediate goods are produced subject to economies of scale. Imagine also that there are several countries with similar resources and technology, all of which are capable of producing both final and intermediate goods in these industries. Suppose, however, that initially transport costs between these countries are very high. Then it is natural to suppose that each country will maintain the full range of industries, producing both final goods and the intermediate inputs into those final goods. There may be some intraindustry trade in differentiated products, but there will be no process of interindustry specialization.

But now suppose that transport costs fall to a lower level (though not to zero). Then a country with a somewhat stronger initial position in some industry than its competitors may find itself with an advantage that cumulates over time. Producers of final goods will find that the country with the larger industry supports a larger base of intermediate producers, which gives them low enough costs to export to other markets; producers of intermediate goods will find that it is to their advantage to concentrate their production near the large final good industry. Thus each industry will tend to concentrate in one of the countries. The result, somewhat paradoxically, will be that greater integration will lead countries to become more different -- when transport costs fall below some critical level, a dynamic process of regional specialization and differentiation will take place.

This is a simple and intuitively plausible story, but it is not that easy to formalize. Indeed, a formal model of this process must contain what may at first seem a daunting number of features. It must have an input-output structure with several classes of both final and intermediate goods; it must involve increasing returns, and therefore must somehow deal with the problem of imperfectly competitive market structure; and it must introduce transport costs, no easy matter when there are both an input-output structure and imperfect competition. One might easily conclude that any attempt at formal modeling would quickly lead to an unwieldy structure and bog down in taxonomy.

To avoid this, we inevitably rely on a series of modeling tricks. These include the now-familiar devices of the "new trade theory", namely assuming special functional forms and symmetry at several levels. But even this turns out not to be enough: at the final stage we are obliged to turn to numerical methods to explore the model. Thus our results make no pretense of generality. They are, however, highly suggestive.

We assume, then, a world in which there are two countries, Home and Foreign. The countries are symmetric; we will write the equations describing Home's tastes and technology, and simply note that the same equations apply to Foreign.

The countries share common tastes for two groups of products, 1 and 2. The tastes of both countries can be represented by the same utility function,

$$U = C_1^{0.5} C_2^{0.5} \tag{1}$$

where C_i, $i=1,2$ is consumption of an aggregate of a large number of differentiated products, taking the form

$$C_i = \left[\sum_j c_{ij}^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)} \tag{2}$$

Each country has only a single factor of production, labor. Production of any individual good does not, however, involve labor alone: it also involves the use of intermediate inputs. We represent this by defining a composite input Z_i used in each industry, with

$$Z_i = L_i^{1-\mu} M_i^{\mu} \tag{3}$$

In this setup, μ is a measure of the importance of intermediate goods.

But what is the intermediate good? It, like the consumption aggregates in (1), is an aggregate of many diferentiated products.

And we make the major strategic simplification of assuming that the definition of the aggregate intermediate input is identical to that of the aggregate consumption good in each industry:

$$M_i = \left[\sum_j m_{ij}^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)} \tag{4}$$

We also assume that production of any differentiated product j is subject to economies of scale. In the familiar way, we represent this by assuming a fixed cost and a constant marginal cost -- but not in terms of labor, but in terms of the composite input Z:

$$Z_{ij} = \alpha + \beta Q_{ij} \tag{5}$$

where the output Q_{ij} may be used either for consumption or as an intermediate input.

Notice the trick here: we have in effect assumed that each industry, which produces a variety of goods subject to economies of scale at the level of the individual plant, uses its own output as an input. This gives rise to external economies of scale, since a larger industry provides itself with a larger variety of inputs and thus lowers its own costs. (Venables (1993) considers the more general case in which intermediate and final goods are distinct. The advantage of the formulation in this paper is that it leads to a more natural formulation of the dynamics).

We will assume free entry into both industries in both countries. Given the existence of a large number of symmetric potential products, not all of which are actually produced (because of the fixed costs), this implies a monopolistically competitive economy in which firms exercise monopoly power but profits are dissipated through entry. The assumptions made here imply, in particular, a Dixit-Stiglitz (1977)-type economy in which each firm sees itself as facing the constant elasticity of demand σ.

To complete the model, we turn to trade and factor markets. The two countries are assumed able to trade with each other, but only at a cost. This cost is, in the manner now familiar from the geography literature, assumed to take Samuelson's "iceberg" form: in order to deliver one unit of any good from one country to the other, $\tau>1$ units must be shipped.

In the factor markets, we assume that labor is immobile between the two countries, and choose units so that each country has a labor force of 1. Labor is fully employed, and can be employed in either industry. It does not, however, move instantaneously. Instead, we impose an ad hoc rule under which workers move gradually toward the industry that offers the higher wage rate.[1] Our qualitative results do not depend on the specific rule assumed, but for the sake of concretness (and for numerical examples) we impose the specific functional form

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[1]Ideally, the adjustment of the labor force would be derived from a complete model in which workers face explicit costs of adjustment and take into account expected future wages rates as well as the current wage differential. As shown in Krugman (1991) and Matsuyama (1991), however, forward-looking adjustment together with external economies easily leads to severe problems of indeterminacy, problems that would tend to obscure the rather straightforward economic logic of this paper. Thus we choose to limit ourselves to a simple adjustment rule.

$$\frac{dL_1}{dt} = \delta \ln(w_1/w_2) L_1 L_2 \tag{6}$$

This completes the model. We turn next to the determination of short-run and long-run equilibrium.

2. Solving the model

The dynamics of the model just presented can most usefully be described as a trajectory in resource allocation space. At any point in time each country has a certain amount of labor in industry 1, the remainder in industry 2. Given L_1 and L_1^*, it is possible to solve for the wage rates w_1, w_2, and so on; it is these wage rates that in turn determine the evolution of the resource allocation in each country, following the dynamic equation (6). So our eventual objective is to be able to draw a map showing how the economy evolves from any initial position in L_1, L_1^* space; we will see several such maps later. In order to do this, however, we must be able to solve the static problem of determining wages given the resource allocation.

In describing the solution of this static problem, it is useful to think in terms of a computational loop. Suppose you had initial estimates of wage rates in each industry and in each country, as well as estimates of the true price indices for each industry (a concept we will define shortly). Then it would be possible to determine national incomes and national expenditure on each industry's output; these in turn make it possible to make new estimates of the true price indices and wage rates, which can then be used for a second round, and so on. Not coincidentally, this is precisely the method used to calculate the numerical examples in Part 3 of this paper. But we find it a useful way to organize the discussion as well.

Let us begin, then, with the determination of the number of differentiated products manufactured in each industry in each country. We note that this is a Dixit-Stiglitz-type setup, with constant elasticity of demand. In this type of model, the zero-profit condition establishes a unique size of firm that is independent of the size of the market:

$$Q_{ij} = \frac{\alpha}{\beta}(\sigma - 1) \tag{7}$$

This in turn implies that the number of differentiated products manufactured in that industry is proportional to the composite input of labor and intermediate goods:

$$n_i = Z_i / \alpha\sigma \tag{8}$$

But how much of that composite is supplied? At any point in time the labor allocated to each industry is given, but the ratio of intermediate input to labor depends on the ratio of the true price index of the input to the wage rate:

$$\frac{M_i}{L_i} = \frac{\mu}{1-\mu}\frac{w_i}{T_i} \tag{9}$$

Suppressing some constant terms, this implies that the number of intermediate goods produced in each country can be determined given labor input, w, and T:

$$n_i = L_i(w_i/T_i)^{\mu} \tag{10}$$

Next we turn to the determination of income in each country, which is simply the sum of wages earned in each sector:

$$Y = w_1 L_1 + w_2(1-L_1) \tag{11}$$

What matters for industry location is not, however, aggregate income but expenditure on that industry's products. This includes expenditure for products used as intermediate inputs. Bearing in mind that a share μ of the value of industry sales is spent on intermediates, we may write the Home expenditure on industry i as

$$E_i = 0.5Y + \frac{\mu}{1-\mu} w_i L_i \tag{12}$$

We may note that in (12) a large domestic industry -- that is, a large L_1 -- implies a large domestic market for that industry's products. This "backward linkage" is one of the two forces that work toward industry agglomeration.

The other force working toward agglomeration is the "forward linkage" that works via the cost side. The marginal cost of production depends on the wage rate and on the price of intermediates; again suppressing some constant terms, we may write

$$MC_i = w_i^{1-\mu} T_i^{\mu} \tag{13}$$

The true price of intermediates -- which is also the true price of the corresponding aggregate consumption good -- depends on the prices of typical products and on the numbers of these products available. A domestic good supplied to the domestic market has a price that is proportional to the marginal cost MC_i; a domestic good supplied to the foreign market is sold at a price equal to the domestic price multiplied by the transport cost τ. Thus we may write the domestic price index for aggregate i as

$$T_i = \left[n_i MC_i^{1-\sigma} + n_i^* (\tau MC_i^*)^{1-\sigma}\right]^{1/(1-\sigma)} \tag{14}$$

Notice that other things equal a large domestic industry, as represented by a large n_i, tends to mean a lower price index. But the price index enters into the cost of production, so this is a "forward linkage" which, like the backward linkage through demand, tends to promote agglomeration.

Finally, we can determine the wage rate in each sector in each country. The value of the total sales of Home-based firms in industry i can be shown to be

$$S_i = n_i \left[E_i \left(\frac{T_i}{MC_i}\right)^{\sigma-1} + E_i^* \left(\frac{T_i^*}{\tau MC_i}\right)^{\sigma-1}\right] \tag{15}$$

Of these total sales, a fraction $1-\mu$ represents labor income; this must equal the total labor income $w_i L_i$ earned in that industry, implying the wage equation

$$w_i = (1-\mu)\,\frac{n_i}{L_i}\left[E_i\left(\frac{T_i}{MC_i}\right)^{\sigma-1} + E_i^*\left(\frac{T_i^*}{\tau MC_i}\right)^{\sigma-1}\right] \tag{16}$$

We now have all of the ingredients for a solution of the model for any given resource allocation. Equations (10), (11), (12), (13), (14), and (16) -- together with their counterpart equations for Foreign -- form a simultaneous system that can be solved for n_i, Y, E_i, MC_i, T_i, and w_i in both industries and in both countries. And given the wage rates, we are then able to describe the dynamics.

This system of simultaneous equations is easy to solve numerically given values of the parameters. Furthermore, its properties can be fairly thoroughly explored numerically, since there are only three parameters that cannot be eliminated by choice of units: the transport cost τ, the elasticity of substitution σ, and the share of intermediates in cost μ. The system does not, however, lend itself to any easy analytical solution. Taking into account the existence of two countries (but subtracting one equation after defining a numeraire), there are actually 21 variables to be simultaneously determined, by equations that are highly nonlinear in some cases. As we will see, it is possible to get some useful analytical information out of the system all the same; but as a starting point, we turn next to some numerical exploration.

3. Dynamic behavior

We begin our exploration of the model's dynamics with a series of numerical examples. In all of these examples we set $\sigma=4$ and $\mu = .5$. These are not intended to be especially realistic numbers; they imply a high degree of market power and very strong backward and forward linkages, so that it takes very large transport costs to prevent specialization. The reason for choosing these parameters is simply to make prettier pictures. For more realistic numbers the qualitative results are the same, but crucial aspects of the figures are less visible.

Figure 1 illustrates the model's dynamics for the case of high transport costs, $\tau = 4$. On the axes are the employment in industry 1 in Home and Foreign, L_1 and L_1^*. The arrows illustrate the direction and speed of change, as determined by (6). (Each arrow is determined by solving our general equilibrium model for the resource allocation corresponding to the vector's origin; the implied wage rates then determine the position of the head).

It is immediately apparent that in this high-transport-cost case the allocation of resources always converges to a symmetric outcome in which each industry is equally divided between the two countries. That is, this figure illustrates a "European" outcome in which the backward and forward linkages are not strong enough to lead to agglomeration.

Figure 2 shows the contrary case, in which transport costs are much lower, $\tau = 2.2$. In this case, it is clear that the system is saddle-path unstable: except along a knife-edge path that leads to a symmetric outcome, each industry will end up completely concentrated in one country. That is, this figure illustrates the "American" outcome in which highly localized industries serve the whole continental market.[2]

Are these the only possible cases? No: for intermediate values of τ a more complex picture appears. Figure 3 shows the dynamics when $\tau = 2.7$. This figure shows not two but three "basins of attraction." If the economy starts with a fairly equal division of each industry between the two countries, it will converge to a "European" outcome without agglomeration; but if the industries are initially very unequally distributed, the concentrations are self-reinforcing and we end up with complete specialization.

To understand the dynamics better, Figures 4 and 5 offer two alternative ways of looking at this intermediate case. Figure 4 is a more conventional phase diagram, showing the calculated loci along which $dL_1/dt = 0$ and $dL_1^*/dt = 0$; arrows indicate the directions of motion in each region. It is clear that there is a locally stable equilibrium with equal division of the industries, flanked along the main diagonal by two unstable equilibria. The

[2]For more realistic parameter values, Figure 2 tends to be dominated by a movement toward the main diagonal, with very short arrows pointing the way toward concentration. In effect, the model tells us that market forces will quickly ensure that the industry as a whole is the right size, but take their time about getting it in the right place. We suspect that this may represent the truth as well as the way our model works, but for illustrative purposes we choose to use parameters that exaggerate the tendency to agglomeration.

broken lines show schematically how the space is divided into the central basin of attraction, i.e., initial conditions leading to the central equilibrium, and the basins that lead to the corners.

Figure 5 calculates the basins of attraction directly, by allowing the model to evolve for 100 time periods from a number of starting points. If the outome approximates concentration in Home, the starting point is represented by a square; if it approximates concentration in Foreign, the starting point is represented by a triangle; initial conditions that lead to approximately equal shares get a diamond. (Points that meet none of the criteria get circles).[3]

The qualitative behavior of this economy, then, depends on the level of transport cost. At high levels of transport cost there is never agglomeration; there is a range of transport costs for which agglomeration may but need not occur; and at sufficiently low transport costs only agglomerated equilibri: are stable. This changing behavior can be illustrated by a bifurcation diagram like Figure 6, which shows calculated equilibrium values of L_1 as a function of τ. (Since the economy always ends up on on the main diagonal, $L_1^* = 1 - L_1$ in equilibrium, allowing us to represent outcomes in terms of a single variable). In the figure, solid lines represent stable equilibria, while broken lines represent unstable equilibria. There are two critical levels of τ: a "sufficient"

[3]It may be worth pointing out that while the story here is quite intuitive, modern computing is rather helpful for constructing examples. Figure 5 requires the solution of 8100 CGE models!

level below which agglomeration can happen, and a lower "necessary" level below which it must happen.

It is possible to derive some analytical results about the "sufficient" level. Consider the case where each industry is concentrated in one country, that is, where $L_1 = 1$ and $L_1^* = 0$. (The reverse pattern of specialization is of course symmetric). This will be a locally stable outcome if $w_1 > w_2$ given that resource allocation; in that case Home workers will have no incentive to move out of industry 1, and the symmetrical Foreign workers will have no incentive to move out of industry 2.

Computing wages for this corner solution is much easier than in the general case, because many of the terms in the model drop out. In particular, it is possible to show that

$$V = \left(\frac{w_2}{w_1}\right)^{\sigma(1-\mu)} = \tau^{-\mu\sigma}\left[\frac{1-\mu}{2}\tau^{\sigma-1} + \frac{1+\mu}{2}\tau^{1-\sigma}\right] \qquad (17)$$

Agglomeration is locally stable if $V<1$.

The right-hand side of (17) looks familiar: it is identical to the criterion for agglomeration derived for the case of a geographical model with factor mobility in Krugman (1991). The only difference is in the interpretation of μ. In Krugman (1991) μ was the share of manufactures in the economy as a whole, whereas here it is the share of intermediate goods in production costs. In either case, however, μ determines the importance of forward and backward linkages and thus of localized external economies.

Since the criterion for agglomeration is identical to that in the earlier paper, the results carry over directly. Provided that $\mu < (\sigma-1)/\sigma$ -- in effect, if linkages and scale economies are not too strong -- the relationship between τ and V has the shape illustrated in Figure 7. There is a critical level of τ below which $V<1$, and in which agglomeration is therefore self-sustaining.

It is shown in Krugman (1991) that this critical level of τ in turn depends on the levels of σ and μ: agglomeration is more likely to be sustainable if μ is high and σ is low. In the context of our model, that means that agglomeration is likely if intermediates are a large share of cost and if economies of scale at the level of the firm are large.

It is much more difficult to derive analytical results for the "necessary" level of τ, that level below which agglomeration must occur. Numerical examples suggest, however, that it is affected by μ and σ in the same way.

We have now described the dynamics of industry agglomeration. The next step is to consider the policy issues that this process may pose.

4. The adjustment problem

Suppose that we take this model as a highly stylized representation of the reasons for the striking difference between the pattern of industry location between the US and Europe. That is, the geographic concentration of industry we consider to result from the historically higher degree of economic integration. What would we then expect to happen as Europe becomes a single market?

One possibility is that in spite of 1992, European markets will remain substantially less integrated than those in the United States. It is certainly arguable that differences in language and culture will continue to segment markets, whatever the European Commission may do. In that case, of course, nothing will happen.

A second possibility is that while European markets become as integrated as those in North America, this increased integration is not sufficient to destabilize the existing geography of production. This case would correspond to the intermediate range of τ in Figure 6, in which there are multiple structural equilibria: markets are sufficiently well integrated so that agglomeration is possible but not so integrated that it is necessary. If a continent has developed highly geographically concentrated industries, they will persist; but a polycentric geography is also sustainable.

The worrisome possibility, however, is that the increased integration of European markets will, in fact, push the continental economy into the range in which existing national industries unravel, agglomerating into a smaller number of industrial districts serving the continent as a whole.

Why is this a worrisome possibility? Because while the end result will be to raise real incomes, there may well be serious adjustment problems along the way.

Figure 8 shows how the real wages of Home workers in each industry vary as the allocation of labor is moved along the main diagonal, that is, where $L_1^* = 1-L_1$. In this figure, we assume $\tau = 2$, that is, integration has proceeded to the point where agglomeration must take place. We may imagine that initially the European economy is at a point where $L_1=0.5$, that is, with industries equally divided among the two countries. Given the new, higher degree of integration, however, this is no longer a stable equilibrium, and Home will specialize over time in one or the other industry.

Suppose that it specializes in industry 1. As it does so, the real wages of workers in industry 1 will rise. And since in the long run all Home workers will in fact be in industry 1, the long-run effect of agglomeration is unambiguously beneficial. In the short and medium run, however, some workers will remain in industry 2 -- and they will suffer a decline in real wages as L_1 rises. The reason is that the shrinkage of their industry means a loss of forward and backward linkages, coupled with increasingly effective competition from the growing industry in Foreign.

The workers left behind in industry 2, then, will initially be hurt by integration and specialization. In a more realistic model, we might well imagine that in addition to a fall in real wages they will also experience a rise in unemployment, adding to the painfulness of the adjustment.

The political difficulties posed by this adjustment problem are obvious. European nations may be enthusiastic about the benefits of economic integration in the abstract. But when it turns out that such integration involves losses as well as gains, and in particular that the geographic consolidation of industries means that some national industries vanish, the charges of "social dumping" are sure to fly.

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Table 1: Shares of industry employment

	Steel	Autos	Textiles
United States (1990)			
Northeast	13.4	7.9	14.2
Midwest	51.8	65.6	3.2
South	24.5	23.4	79.6
West	10.4	7.0	3.9
EC (1989)			
France	18.9	25.3	15.8
Germany	20.2	34.7	13.2
Italy	18.7	9.5	17.4
UK	15.8	13.0	18.6

Source: OECD Employment Statistics.

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FIGURE 1

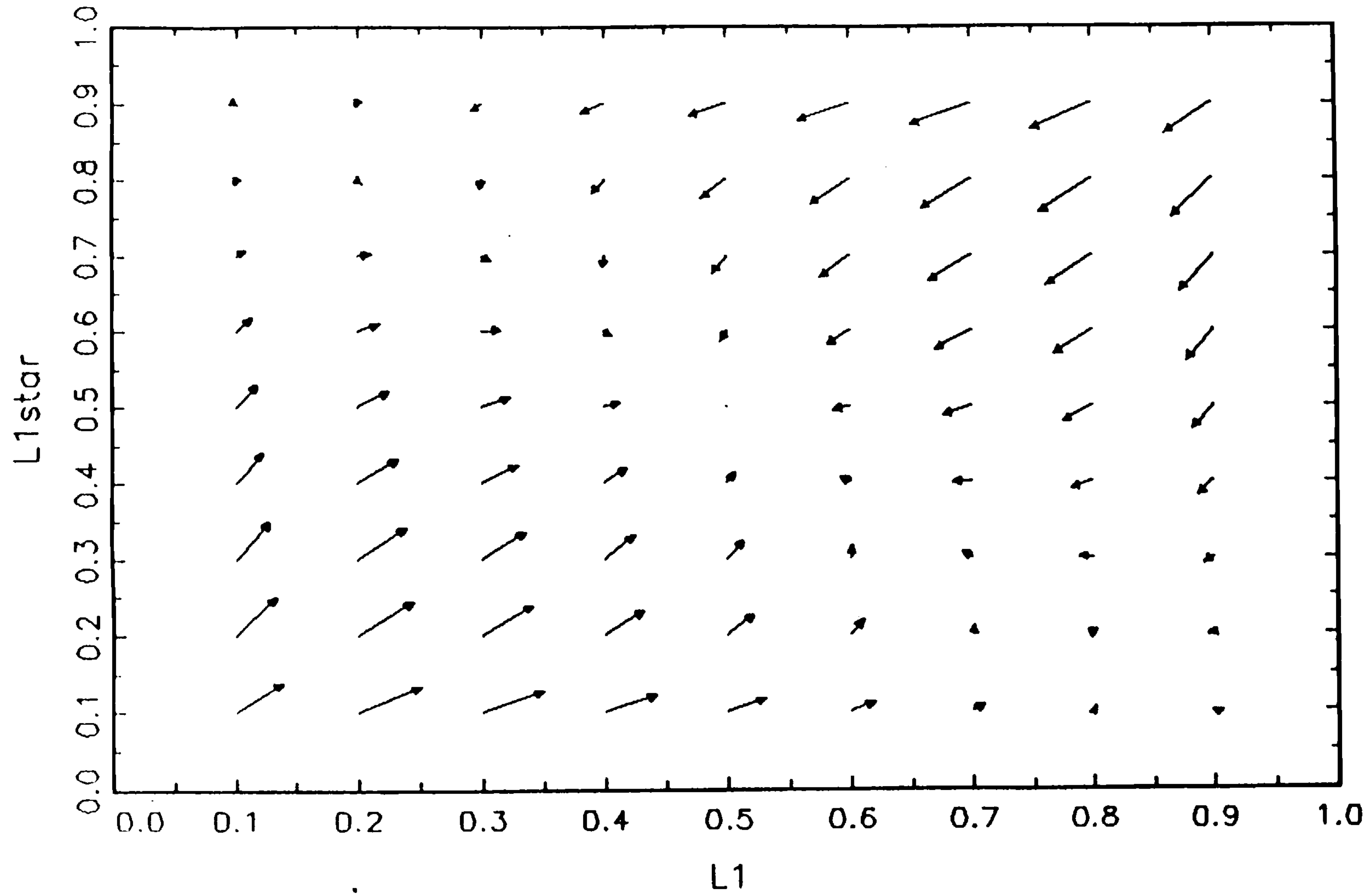

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FIGURE 2

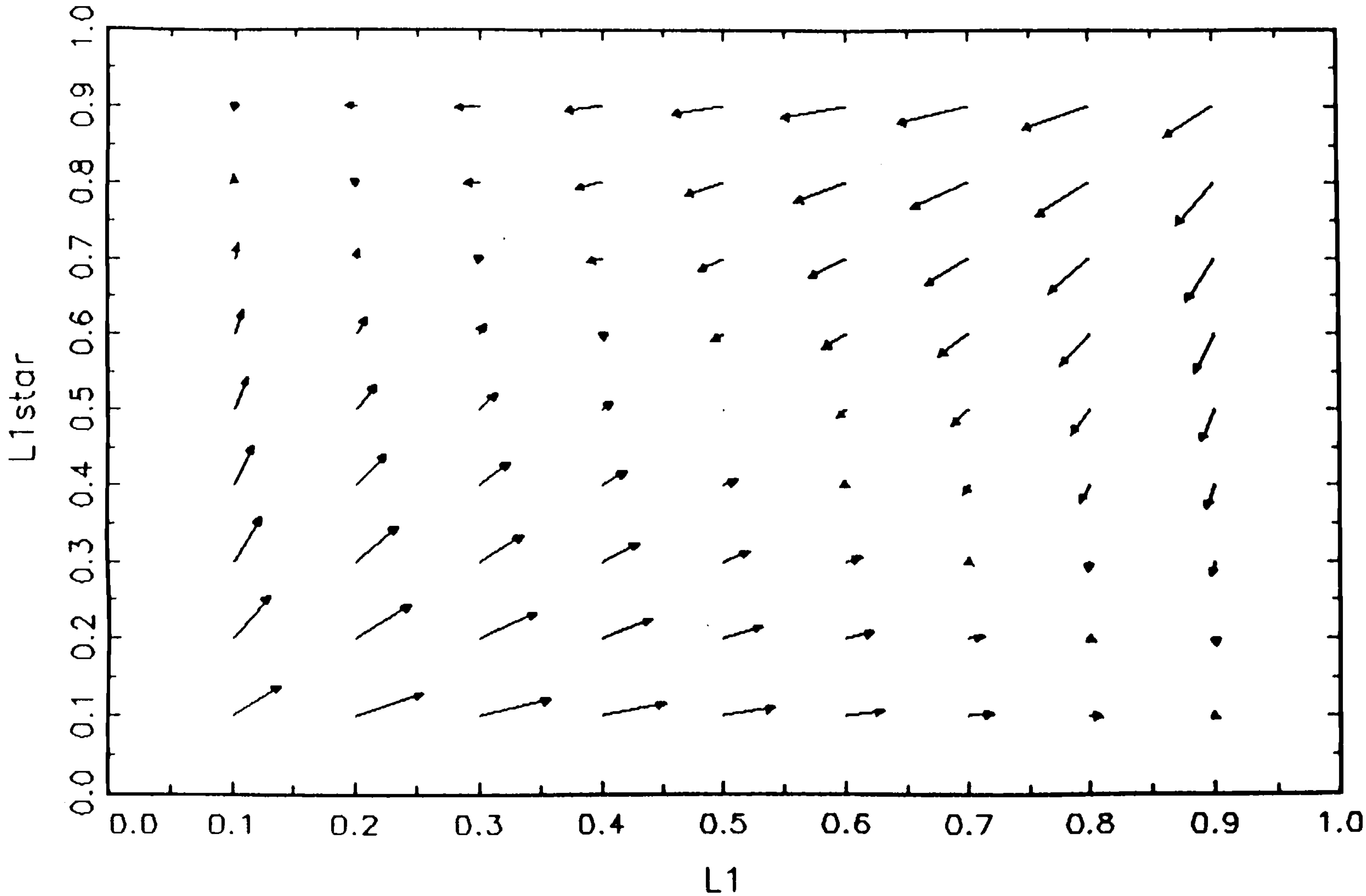

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FIGURE 3

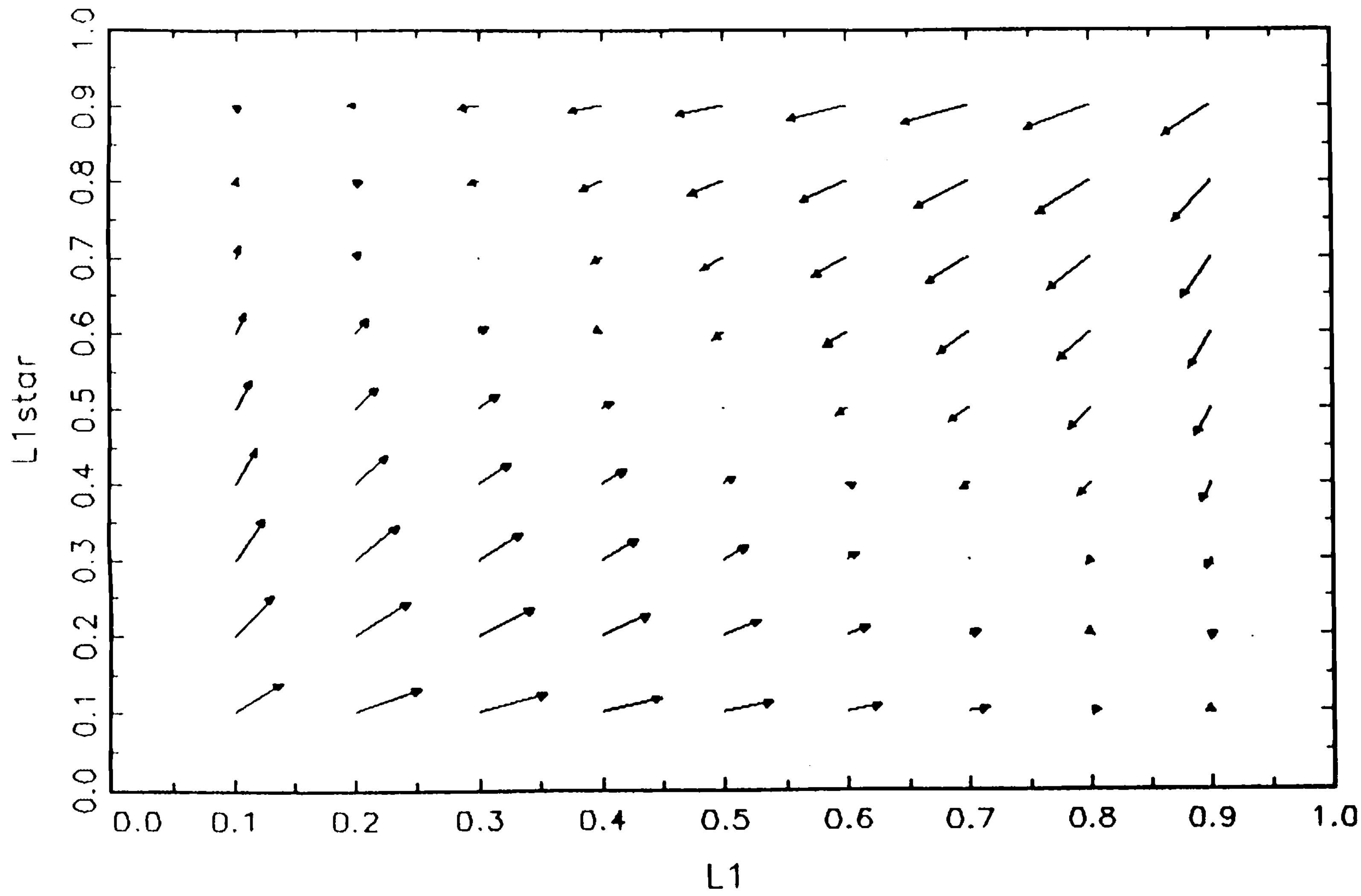
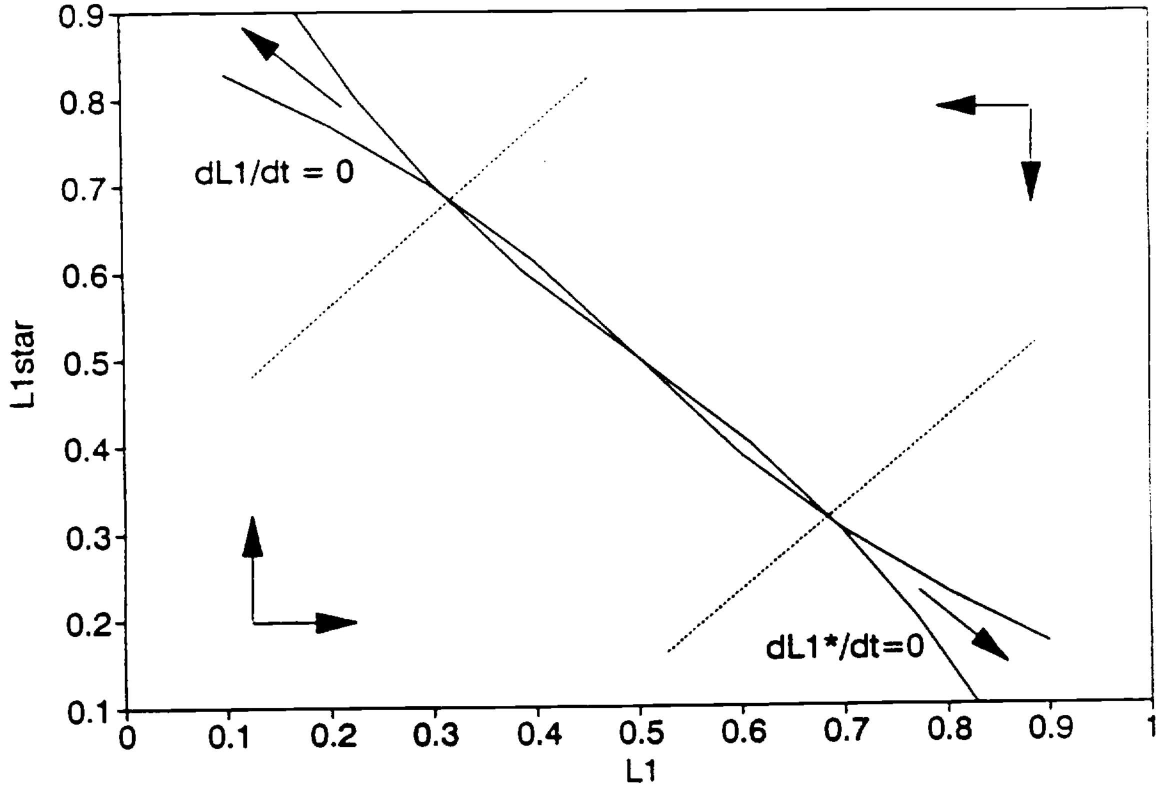


FIGURE 4



0.9
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0.7
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0.3
0.2
0.1
L1star
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dL1*/dt=0
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0.9
1
L1

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FIGURE 5

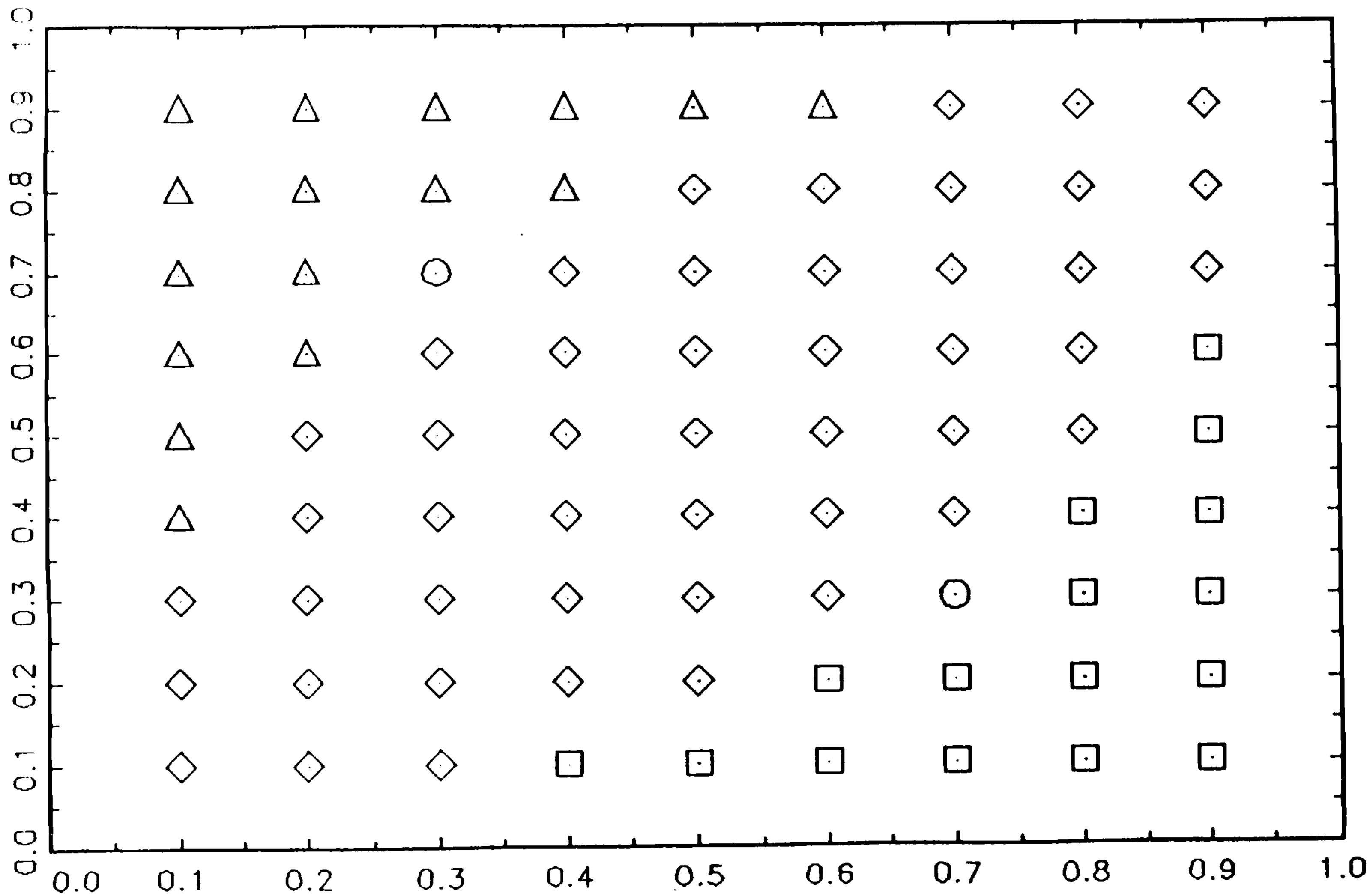


FIGURE 6

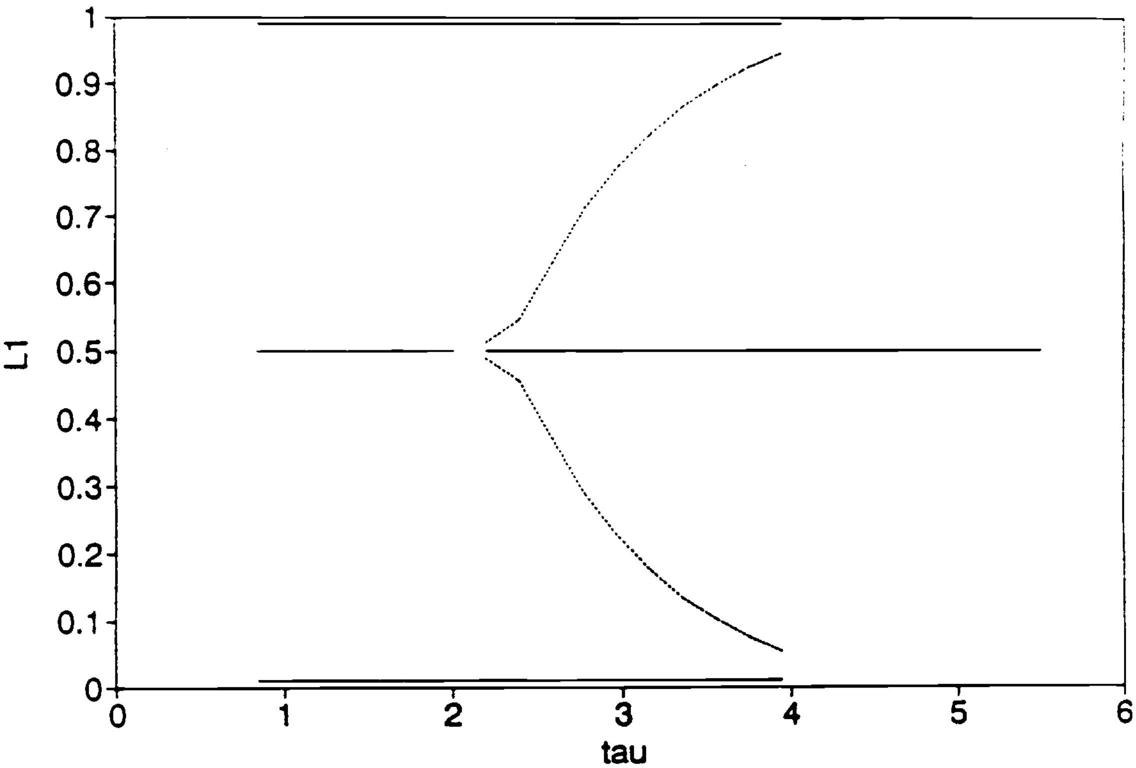


FIGURE 7

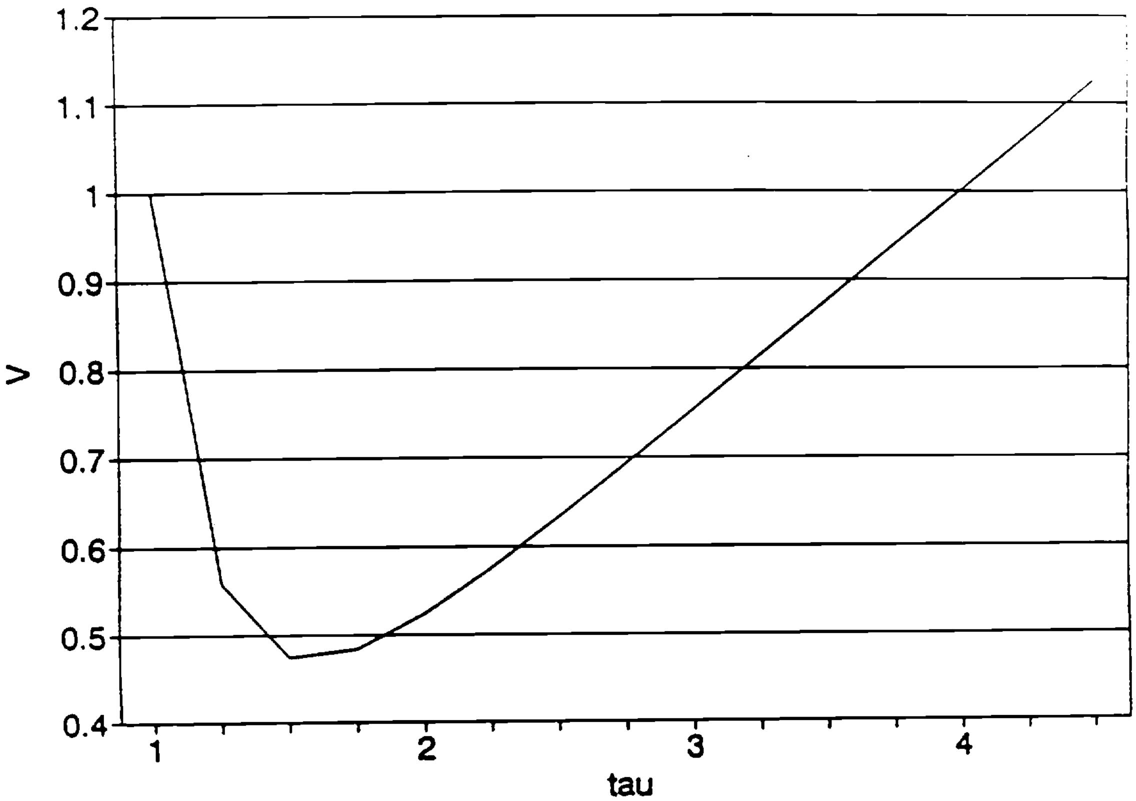
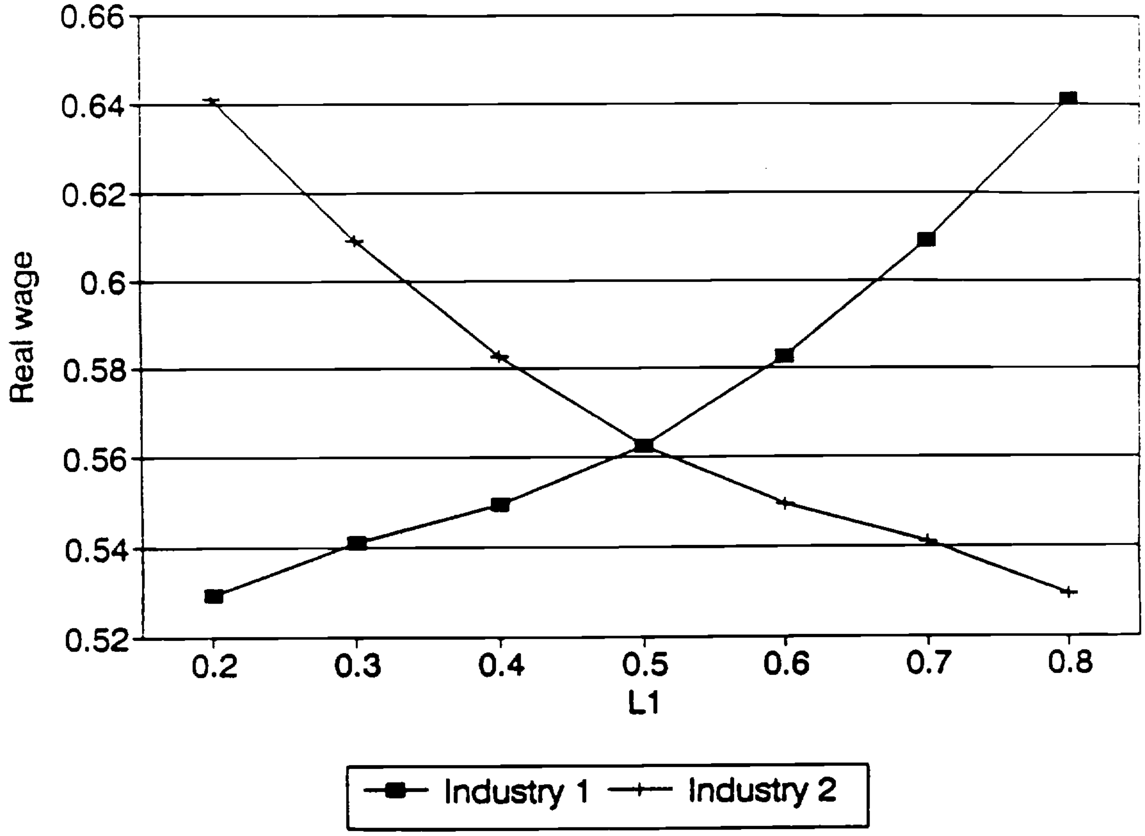


FIGURE 8


0.66
0.64
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0.54
0.52
Real wage
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0.4
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0.8
L1
Industry 1
Industry 2