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**Capital and Trade as Engines of Growth in France: An Application  
of Johansen's Cointegration Methodology**

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Abstract

An aggregate production function is estimated with recent cointegrating techniques that are particularly appropriate for estimating long-run relationships. The empirical results suggest that the growth of output in France has been spurred by increased trade integration within the European Community and by the accumulation not only of business sector capital--the only measure of capital included in most empirical studies--but also by the accumulation of government infrastructure capital, residential capital, and R&D capital. Calculations of potential output indicate that trade and capital--broadly defined--account for all of the growth in the French economy during the last two decades.

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### Summary

The importance of trade and capital as determinants of trend or potential economic growth is widely acknowledged. Empirical studies of the determinants of output based on aggregate production functions, however, rarely incorporate any variable to capture the impact of trade. Empirical studies have also usually focused only on a narrow definition of capital, typically the business sector capital stock. This paper presents new estimates of an aggregate production function for France, focusing on the role of trade and the importance of capital accumulation by government, households, and businesses, including their expenditures on research and development.

The production function is estimated with recent cointegrating techniques suggested by Johansen (1989, 1990). The cointegrating methodology emphasizes the identification of long-run relationships and, hence, is particularly appropriate for the study of the determinants of trend or potential output. The empirical results suggest that increased trade within the European Community has spurred efficiency and productivity in France. They also indicate that, in addition to the stock of business sector capital, the stock of government infrastructure capital, the stock of residential capital, and the stock of research and development capital have contributed to the growth of output in France.

The estimated production function is used to calculate potential output. These calculations indicate that trade and capital--broadly defined--account for all of the growth in the French economy in the last two decades. Although labor input is also an important determinant of output, it made no contribution to growth during 1971-91. Thus, over the past two decades trade and capital have been the engines of growth in France. The growth of potential output is estimated to have averaged 3 1/4 percent a year in 1987-91; this figure is projected to decline to slightly less than 3 percent a year in 1992-97. To foster more robust growth, France must encourage capital accumulation, implement labor market policies to reduce unemployment, and take steps to revitalize the trade-liberalization process.



## I. Introduction

The importance of trade and capital as determinants of trend or potential economic growth is widely acknowledged. The collapse of world trade following the passage of the Smoot-Hawley tariffs in the United States in 1930 helped to trigger the great world depression of the 1930s. By contrast, the brisk expansion of world trade in the 1950s and 1960s contributed to unusually rapid growth in the industrial countries. More recently, the fast-growing economies of Southeast and East Asia have built their success on an outward orientation and rapid increases in intra-regional trade. High rates of capital accumulation also spurred growth in the industrial countries in the postwar period and in the dynamic economies of Asia more recently. The slowdown in growth after the mid-1970s in France and other industrial countries coincided with a moderation in the growth of world trade and, in some countries, with a reduced pace of capital formation, particularly by the business sector. 1/

Although, empirical studies based on aggregate production functions have always emphasized the importance of capital accumulation by the business sector, the importance of other types of capital accumulation has received considerably less emphasis; and the role of trade has, in general, only been emphasized in empirical studies based on computable general equilibrium models. This paper presents new estimates of an aggregate production function for France focusing on the role of trade and the importance of capital accumulation by government, households, and businesses, including their expenditures on research and development (R&D).

The production function is estimated with recent cointegrating techniques suggested by Johansen (1988, 1989). This methodology emphasizes the identification of long-run relationships, and hence is particularly appropriate for the study of the determinants of trend or potential output. The empirical results suggest that increased trade within the European Community has raised efficiency and productivity in France. The empirical results also indicate that in addition to the stock of business sector capital--which is the only measure of capital included in most empirical studies--the stock of government infrastructure capital, the stock of residential capital, and the stock of R&D capital have also contributed to the growth of output in France.

The estimated production function is used to calculate potential output. These calculations indicate that trade and capital--broadly defined--account for all of the growth in the French economy in the two decades from 1971-91. Although labor input is also an important determinant of output, its contribution to growth has been nil over the 1971-91 period. Thus, over the past two decades trade and capital have been the engines for

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1/ This slowdown has rekindled interest in the determinants of growth and in growth theory, as evidenced by the recent emergence of a large and expanding literature on endogenous growth. See Lucas (1988), Sala-i-Martin (1990), and Helpman (1992).

growth in France. The growth of potential output is estimated to have averaged 3 1/4 percent a year in 1987-91, and this is projected to decline to slightly below 3 percent a year in 1992-97. To foster more robust growth, France must encourage capital accumulation, implement labor market policies to reduce unemployment, and take steps to revitalize the trade-liberalization process.

The paper is organized as follows. The next section discusses the cointegration methodology and the advantages of the Johansen approach to cointegration. Section III discusses the specification of the production function, presents the estimation results, and tests a number of features of the production function related to endogenous growth. Section IV presents estimates of potential output and its determinants for 1971-91 and projections for 1992-97. Concluding remarks are in the final section.

## II. Johansen's Cointegration Methodology

Over the last few years, important advances have been made in cointegration techniques to estimate long-run relationships. 1/ The basic idea of cointegration is that two or more variables may be regarded as defining a long-run equilibrium relationship if they move closely together in the long run, even though they may drift apart in the short run. This long-run relationship is referred to as a cointegrating vector. Because there is a long-run relationship between the variables, a regression containing all the variables of a cointegrating vector will have a stationary error term, even if none of the variables taken alone is stationary.

Stock (1984) demonstrates that ordinary least squares (OLS) estimates of the cointegrating vector are not only consistent, but in the case of cointegrated nonstationary series, they converge on their true parameter values much faster than in the stationary case. This property is referred to as "super consistency." 2/ The proof of consistency does not require the assumption that the regressors be uncorrelated with the error term. In fact, the estimates will remain (super) consistent if any of the variables in a cointegrating vector is used as the dependent variable.

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1/ Cuthbertson, Hall, and Taylor (1992) presents a survey of cointegration.

2/ The intuition behind the super-consistency result is that, for values of the parameters which do not cointegrate, the residual series will itself be nonstationary and therefore have a very large estimated variance. When the estimated parameters are close to the true cointegrating parameters, the residual becomes stationary and its variance shrinks. Since least squares and maximum likelihood methods essentially minimize the residual variance, they will be extremely good at picking out the cointegrating parameters if they exist.

More generally, most of the classical assumptions underlying the general linear model are not required for OLS or maximum likelihood estimates of the cointegrating vector to have desirable properties. This is particularly important because errors in variables and simultaneity--both of which would normally be cause for concern in the data set used here--will not affect the desirable properties of the estimates. Moreover, because the cointegration approach focuses on long-run relationships, problems associated with variations in factor utilization or with autocorrelation do not arise. Indeed, given the possibility of sustained short-run deviations from the long-run path of output, autocorrelation is to be expected.

A popular approach to cointegration has been to use unit root tests, such as the Dickey-Fuller (DF) or the augmented Dickey-Fuller (ADF), to test the degree of integration of the relevant variables and then to apply the Engle and Granger (1987) two-step procedure, which is based on an OLS estimate of the cointegrating vector and a unit root test on its residuals. Although it is easy to implement, there are a number of problems with the Engle and Granger two-step procedure. Banerjee and others (1986) show that there may be significant small sample biases in the OLS estimates of the cointegrating vectors, and Hendry and Mizon (1990) illustrate that conventional DF and ADF tests generally suffer from parameter instability. In addition, the limiting distributions for the DF and ADF tests are not well defined, implying that the power of these tests is low, and the standard errors of the cointegrating vector are biased and cannot be used for hypothesis testing. Perhaps most damaging is the possibility that any given set of variables may contain more than one long-run relationship, that is, there may be multiple cointegrating vectors. OLS estimates of the cointegrating vector cannot identify multiple long-run relationships or test for the number of cointegrating vectors.

Johansen (1989) and Johansen and Juselius (1990) present a cointegration estimation methodology that overcomes most of the problems of the two-step approach. The Johansen procedure, which is discussed in Annex I, is based on maximum likelihood estimates of all the cointegrating vectors in a given set of variables, and provides two likelihood ratio tests for the number of cointegrating vectors. Johansen demonstrates that the likelihood ratio tests have asymptotic distributions that are a function only of the difference between the number of variables and the number of cointegrating vectors. Therefore, in contrast with the DF and ADF tests, the Johansen likelihood ratio tests have well defined limiting distributions. Unlike the two-step approach, the likelihood ratio tests for the existence of cointegrating vectors make it unnecessary to initially test for the order of integration of the individual variables. 1/ Johansen and Juselius also provide a methodology for testing hypotheses about the estimated coefficients of the cointegrating vectors based on likelihood ratio tests with standard chi-squared distributions.

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1/ All of the variables used below are, in fact, integrated of order 1 based on the Dickey-Fuller and augmented Dickey-Fuller tests.

### III. Production Function Estimates

The Johansen procedure has been used to estimate the long-run relationship between real value added in the nonfarm business sector ( $y$ ), hours worked in the nonfarm business sector ( $h$ ), the stock of capital ( $k$ ), the stock of R&D capital ( $k^{r\&d}$ ), and intra-EC trade as a percent of total EC output (EC). This long-run relationship can be expressed as the following production function:

$$y = \alpha h + \beta k + \gamma k^{r\&d} + \theta EC + \text{constant}$$

where variables with lower case symbols are logarithms (of indices with 1985:I=1). The production function is estimated on quarterly data for France, from 1971:I to 1991:IV (84 observations). Estimation results based on alternative specifications are discussed below and data sources and definitions are reported in Annex II.

The estimated production function has some novel features. One unusual aspect is the inclusion of a measure of European trade integration as a determinant of the productivity of capital and labor in France. This variable is included to capture the beneficial effects on French enterprises from heightened competition, increased specialization, and economies of scale through increased trade within the European Community (Figure 1). As noted below, the same variable has been used to explain long-run developments in total factor productivity in Germany.

A second novel feature is the treatment of capital. The physical capital stock is broadly defined to include the stock of government infrastructure capital and residential capital in addition to the capital of private and public enterprises (Figure 2). The potentially important role of infrastructure capital in increasing productivity and output has received considerable attention recently, although it has proven difficult to estimate separate elasticities for infrastructure capital. 1/ Including residential capital is appropriate since value added in the business sector includes imputed services from the housing stock. More generally, housing is an important aspect of an economy's infrastructure that, like roads, bridges, and nonresidential structures such as hotels, contributes to its ability to produce real goods and services. 2/ This focus on a very broad definition of capital is in contrast to most empirical studies that typically consider only the business sector capital stock.

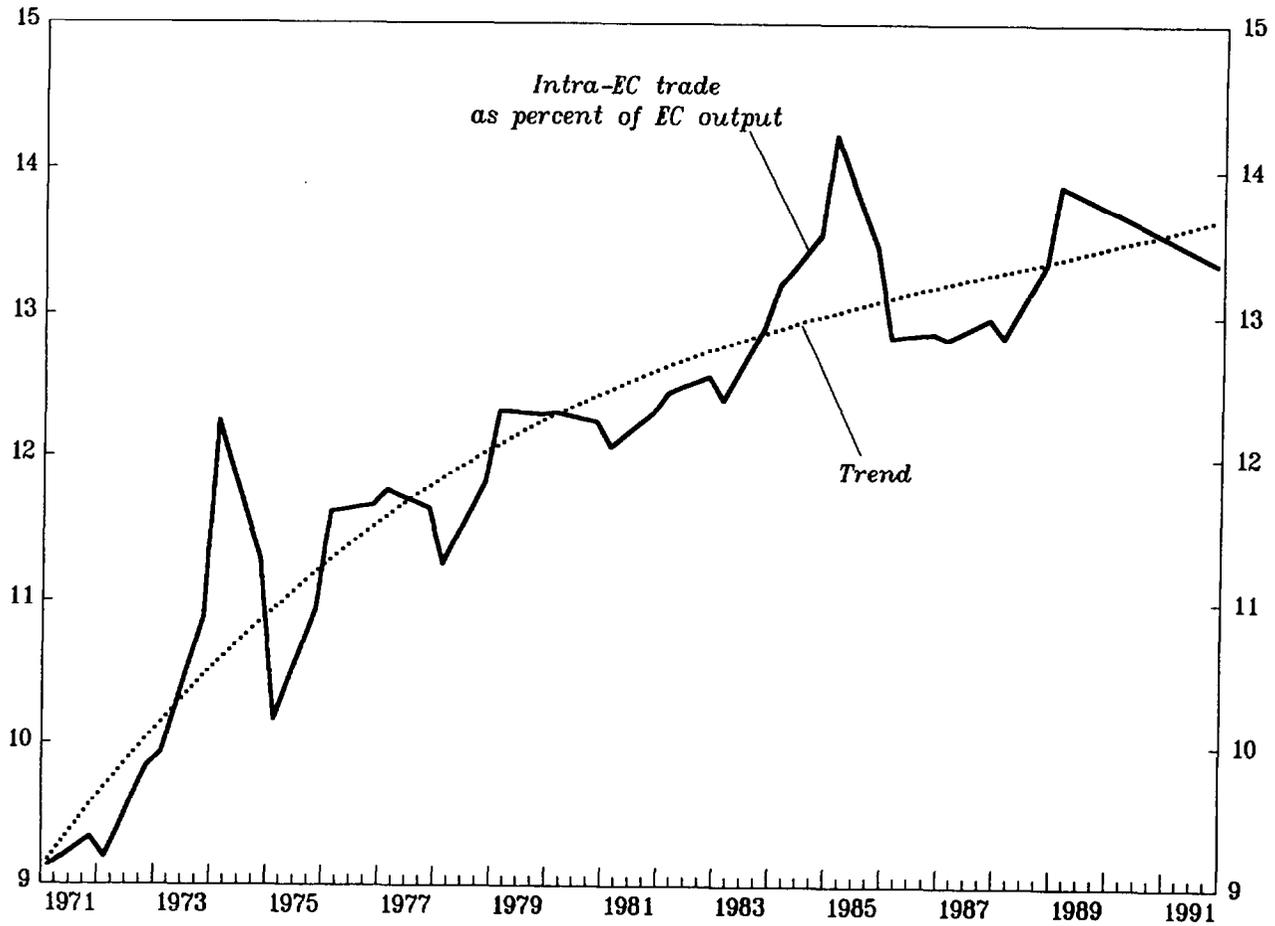
In addition to the stock of physical capital, the stock of R&D capital is included as a distinct factor of production. This allows the process of technological progress to be modeled explicitly, as suggested by

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1/ See the cross country evidence presented in Ford and Poret (1991) and the evidence for the United States presented in Munnell (1990).

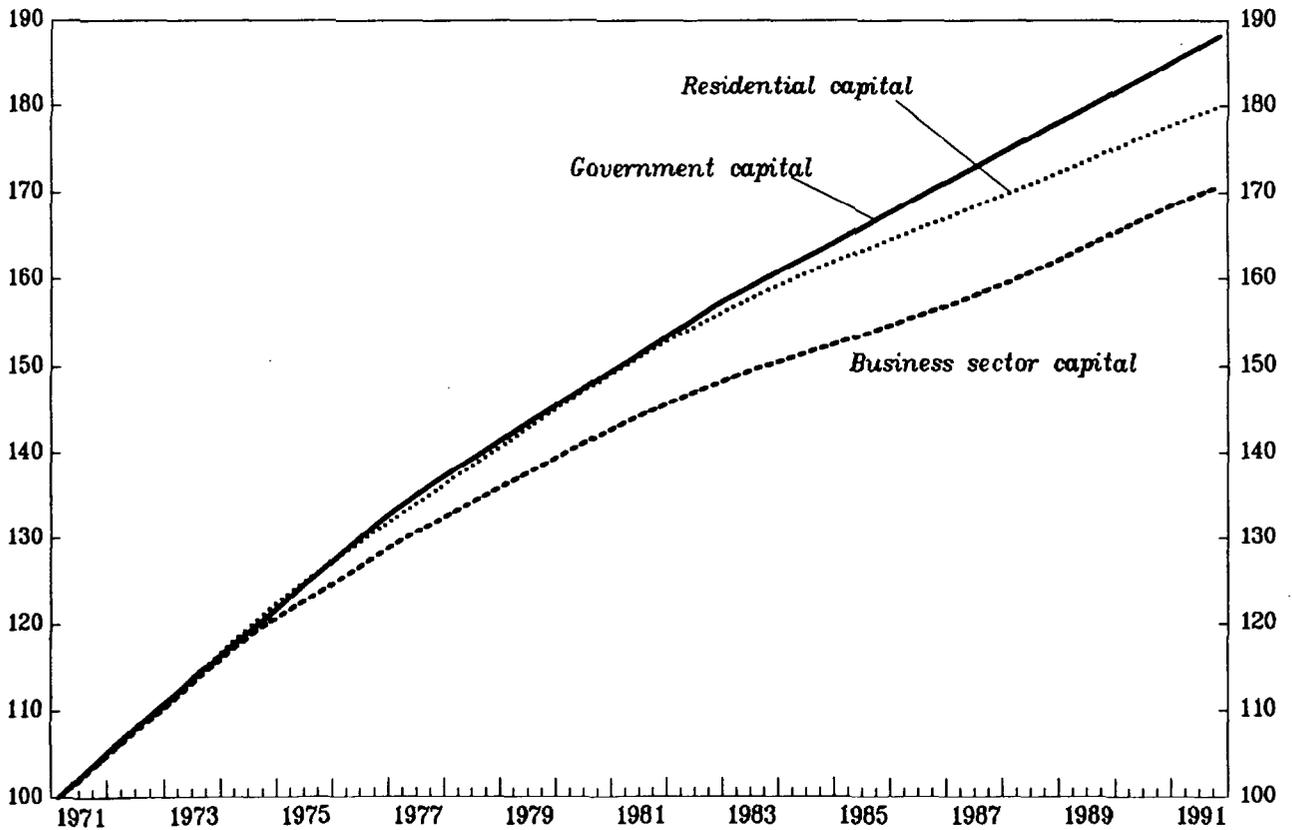
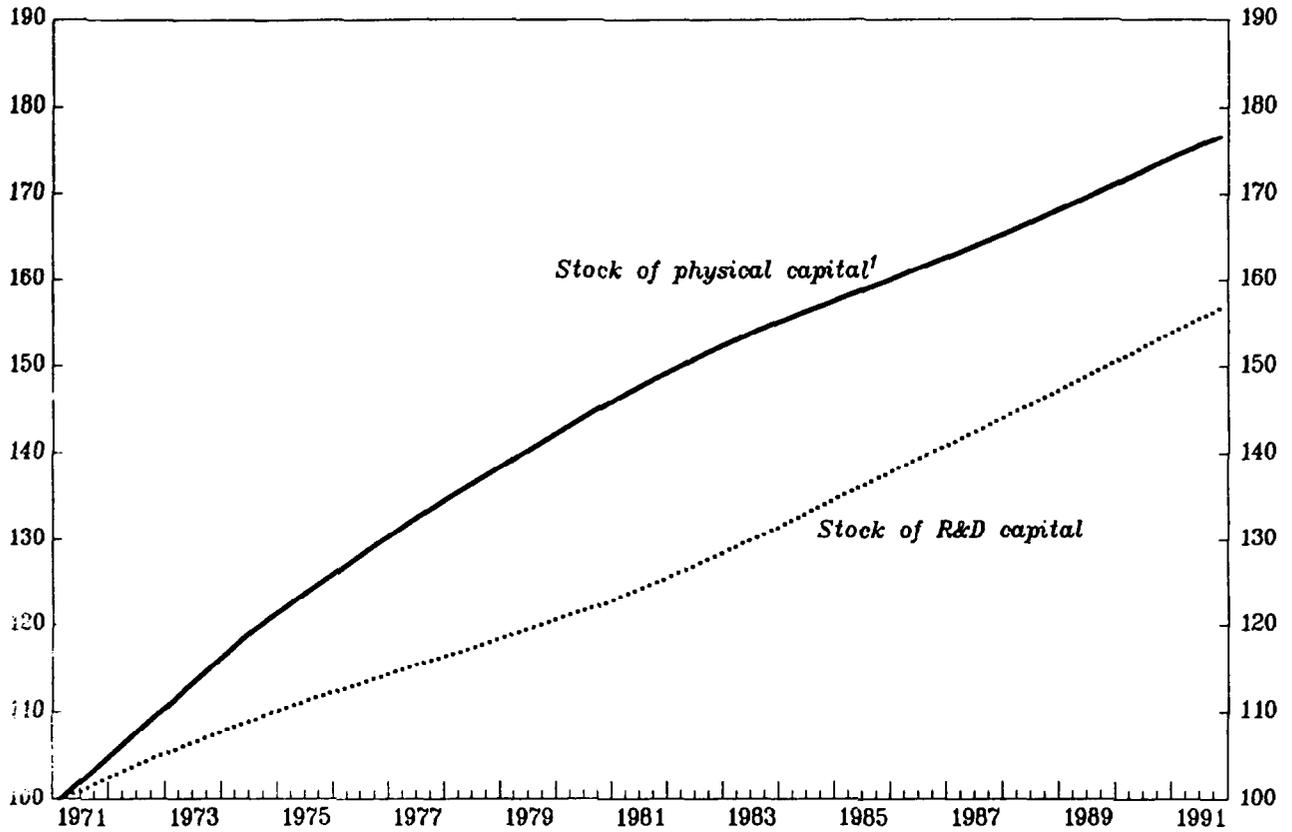
2/ An increase in the stock of housing, for example, may increase labor mobility.

Figure 1. EC Integration  
(In percent)





**Figure 2. Capital Stocks**  
(In logarithms, 1971 = 100)



<sup>1</sup>Including business sector, residential, and government capital stocks.



Griliches (1988). The importance of R&D capital, which is complementary to human capital, is emphasized in endogenous growth theories (Lucas, 1988, and Helpman, 1992).

A final unusual feature of the production function is that the coefficients on capital and labor input are freely estimated, whereas in many studies the estimated coefficients are either constrained to sum to unity or factor shares are imposed and the production function is estimated as a total factor productivity equation. One reason to estimate the coefficients on capital and labor is that R&D capital is included as an additional factor of production, and it is not clear how its factor share would be calculated. Moreover, endogenous growth theories have questioned the assumption of constant returns to scale, and some have argued that the coefficient on capital should be much larger than suggested by its factor share. 1/

The test statistics and the estimated cointegrating vectors from the Johansen procedure are reported in Table 1, where  $r$  denotes the number of cointegrating vectors. 2/ Panel A reports the maximal eigenvalue test of the null hypothesis that there are at most  $r$  cointegrating vectors against the alternative of  $r+1$  cointegrating vectors. Starting with the null hypothesis that there are no cointegrating vectors ( $r=0$ ) against the alternative of one ( $r=1$ ), the test statistic (35.27) is greater than the 95 percent critical value (33.32), rejecting the null hypothesis and indicating that there is at least one cointegrating vector. The null hypothesis of  $r \leq 1$  against  $r=2$ , however, cannot be rejected, suggesting that there is a unique cointegrating vector. Panel B reports the trace test of the null hypothesis that there are at most  $r$  cointegrating vectors against the alternative that there are more than  $r$ . Both the null of  $r=0$  against  $r \geq 1$  and the null of  $r \leq 1$  against  $r \geq 2$  are rejected. However, the null of  $r \leq 2$  against  $r \geq 3$  cannot be rejected indicating that there are at most two cointegrating vectors. 3/

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1/ See, for example, Romer (1987) and Sala-i-Martin (1990). There are a number of practical problems with imposing factor shares, one of which is that they are not constant over the sample period. In addition, there are a variety of ways to calculate factor shares, depending, for example, on the way that self-employment income is allocated to capital or labor.

2/ The Johansen procedure involves the simultaneous estimation of dynamic vector autoregressive (VAR) equations, for which fourth order lags were included. Estimation has been done on MICROFIT 3.0, see Pesaran and Pesaran (1991).

3/ Studies using the Johansen procedure often obtain much less clear cut results; see, for example, Moghadam and Wren-Lewis (1990), Boughton (1991), and MacDonald and Taylor (1992).

Table 1. Johansen Maximum Likelihood Tests and Parameter Estimates

1971:I to 1991:IV (84 observations), maximum lag in VAR = 4,  
Eigenvalues in descending order: 0.34, 0.21, 0.18, 0.14, 0.13E-5

A. Cointegration likelihood ratio test based on maximal eigenvalue of the stochastic matrix.

Hypothesis <u>1/</u>		Test Statistic	95% Critical Value	90% Critical Value
Null	Alternative			
$r = 0$	$r = 1$	35.27	33.32	30.84
$r \leq 1$	$r = 2$	20.14	27.14	24.78
$r \leq 2$	$r = 3$	17.15	21.07	18.90
$r \leq 3$	$r = 4$	12.43	14.90	12.91
$r \leq 4$	$r = 5$	.0001	8.18	6.50

B. Cointegration likelihood ratio test based on trace of the stochastic matrix.

Hypothesis <u>1/</u>		Test Statistic	95% Critical Value	90% Critical Value
Null	Alternative			
$r = 0$	$r \geq 1$	85.00	70.60	66.49
$r \leq 1$	$r \geq 2$	49.73	48.28	45.23
$r \leq 2$	$r \geq 3$	29.58	31.52	28.71
$r \leq 3$	$r \geq 4$	12.43	17.95	15.66
$r \leq 4$	$r = 5$	.0001	8.18	6.50

C. Estimated cointegrating vectors, coefficients normalized on y in parentheses.

Vector	<u>y</u>	<u>h</u>	<u>k</u>	<u>k<sup>r&amp;d</sup></u>	<u>EC</u>
1	-10.76 (-1.00)	7.66 (0.71)	5.71 (0.53)	1.80 (0.17)	0.34 (0.03)
2	-2.64 (-1.00)	3.17 (1.20)	8.40 (3.18)	-7.60 (-2.88)	-0.10 (-0.04)

1/ r denotes the number of cointegrating vectors.

Panel C of Table 1 presents the two estimated cointegrating vectors. The coefficients in parentheses are normalized on  $y$ . In the first cointegrating vector, all of the estimated coefficients have the expected signs and are of reasonable magnitudes, although the normalized coefficients for labor and capital inputs are both somewhat higher than their factor shares (see below). In the second cointegrating vector, the estimated coefficients are of implausible magnitudes, incorrectly signed, or both. In light of these results, and given that the existence of two cointegrating vectors is rejected by the maximal eigenvalue test, the first cointegrating vector is taken as the preferred estimate of the production function.

Compared with the estimated parameters on labor and capital input, it is more difficult to judge the plausibility of the estimated parameters on the stock of R&D capital and the variable for EC trade integration. The estimated coefficient on R&D capital is similar to those found in comparable studies for the United States, Japan, and Germany, but is somewhat larger than typically found in studies based on firm and industry level data, perhaps because the estimation of an aggregate production function is better able to capture spillovers that increase the social, and hence the aggregate, return to R&D. 1/

Turning to the estimated coefficient on the EC variable, Coe and Krueger (1991) find the same variable to be a determinant of total factor productivity in the Federal Republic of Germany, although the estimated coefficient for France is somewhat larger than for Germany. The fact that this variable helps to explain medium- to long-term output developments in other European countries, suggests that it is a good proxy for the economic impact of European integration. Moreover, as discussed below, the estimated impact on French growth of European integration is consistent with estimates of the impact of the single market on EC growth reported by Baldwin (1989).

An important question is whether the stock of R&D capital and the proxy for EC integration are necessary for cointegration. Although the Johansen procedure does not provide diagnostics to test the significance of individual variables, 2/ they can be omitted to ascertain whether they are necessary to obtain a cointegrating vector. If either  $k^{R\&D}$  or EC are omitted, both of the Johansen likelihood ratio tests of the null hypothesis that there are no cointegrating vectors cannot be rejected. Thus output and labor and capital inputs are not by themselves cointegrated; both  $k^{R\&D}$  and EC are necessary additional variables for cointegration.

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1/ Recent studies at the aggregate level for the United States, Japan, and Germany find an elasticity of about 0.13; see Adams and Coe (1990), Citrin (forthcoming), and Coe and Krueger (1991), respectively. Griliches (1988) reports that estimated elasticities from firm and industry level data tend to lie between 0.06 and 0.1.

2/ In general, the standard error of any equation including non-stationary variables is biased, irrespective of how it is estimated.

As discussed above, the measure of physical capital used in the estimated equations includes not only the stock of business sector capital, but also the stock of government infrastructure capital and the stock of residential capital. The specification of the equation does not, however, allow the different components of capital--government infrastructure, public enterprises, private business, and residential capital--to have different impacts on output. Specifications with some or all of the components of capital entered separately yielded implausible coefficient estimates and multiple cointegrating vectors.

Because it is much more common to include only the stock of business sector capital ( $k^b$ ), Table 2 reports estimation results using it instead of the stock of total capital ( $k$ ). <sup>1/</sup> The two tests for the existence of a cointegrating vector give conflicting results. At the 95 percent confidence level, the test based on the maximal eigenvalue (panel A) indicates that there are no cointegrating vectors (test statistic of 31.96 against a critical value of 33.32), whereas the test based on the trace indicates that there are at most two cointegrating vectors. Panel C reports the coefficient estimates from the two possible cointegrating vectors. Although the estimated coefficients (normalized on  $y$ , in parentheses) on  $h$ ,  $k^b$ , and  $k^{R\&D}$  are correctly signed, their magnitudes are less plausible than in the specification using total capital reported in Table 1.

Table 3 reports the results of testing the first cointegrating vector reported in Table 1 for a number of restrictions on the estimated coefficients on the three factors of production: labor, capital, and R&D capital. The restriction that the sum of the coefficients on  $h$  and  $k$  is unity cannot be rejected. However, the restriction that the estimated coefficients on  $h$  and  $k$  are equal to the sample average of their factor shares (0.6 and 0.4, respectively) is rejected. The restriction that the estimated coefficients on all three factors sum to unity is also rejected; since the estimated coefficients sum to 1.4, this suggests that there are increasing returns to scale with respect to labor, capital, and R&D capital. Finally, the restriction that the estimated coefficients on the two factors of production that can be accumulated--physical capital and R&D capital--sum to unity is rejected. In Sala-i-Martin's (1990) discussion of economic growth, this condition is necessary for endogenous growth. This is because a sum of coefficients on physical and R&D capital of less than unity implies decreasing returns to capital, which in turn implies--in the absence of exogenous technological progress--a steady-state growth of per capita output of zero.

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<sup>1/</sup> De Long and Summers (1991), based on cross-country data for industrial and developing countries, find equipment investment has a stronger association with growth than other components of investment. Estimates using only the stock of business equipment capital were not possible since this variable is not readily available for France.

Table 2. Johansen Maximum Likelihood Tests and Parameter Estimates  
with the Business Sector Capital Stock

1971:I to 1991:IV (84 observations), maximum lag in VAR = 4,  
Eigenvalues in descending order: 0.33, 0.25, 0.20, 0.13, 0.01

A. Cointegration likelihood ratio test based on maximal eigenvalue of the stochastic matrix.

Hypothesis $\underline{1}/$		Test Statistic	95% Critical Value	90% Critical Value
Null	Alternative			
$r = 0$	$r = 1$	31.96	33.32	30.84
$r \leq 1$	$r = 2$	22.77	27.14	24.78
$r \leq 2$	$r = 3$	17.61	21.07	18.90
$r \leq 3$	$r = 4$	11.09	14.90	12.91
$r \leq 4$	$r = 5$	0.78	8.18	6.50

B. Cointegration likelihood ratio test based on trace of the stochastic matrix.

Hypothesis $\underline{1}/$		Test Statistic	95% Critical Value	90% Critical Value
Null	Alternative			
$r = 0$	$r \geq 1$	84.21	70.60	66.49
$r \leq 1$	$r \geq 2$	52.24	48.28	45.23
$r \leq 2$	$r \geq 3$	29.48	31.52	28.71
$r \leq 3$	$r \geq 4$	11.87	17.95	15.66
$r \leq 4$	$r = 5$	0.78	8.18	6.50

C. Estimated cointegrating vectors, coefficients normalized on y in parentheses.

Vector	$\underline{y}$	$\underline{h}$	$\underline{k}^b$	$\underline{k}^{r\&d}$	EC
1	-9.83 (-1.00)	9.31 (0.95)	2.87 (0.23)	3.50 (0.36)	0.32 (0.03)
2	15.47 (-1.00)	-3.26 (0.21)	-10.69 (0.69)	-4.07 (0.26)	0.12 (-0.008)

$\underline{1}/$  r denotes the number of cointegrating vectors.

Table 3. Tests of Parameter Restrictions

$$(y = \alpha h + \beta k + \gamma k^{R\&D} + \theta EC + \text{constant})$$

Parameter restrictions	Unrestricted estimates	Chi-squared test statistic (degrees of freedom)	Critical values	
			95%	90%
$\alpha + \beta = 1.0$	1.24	1.03 (1)	3.84	2.71
$\alpha = 0.6$ $\beta = 0.4$	$\alpha = 0.71$ $\beta = 0.53$	11.45 (4)	9.49	7.78
$\alpha + \beta + \gamma = 1.0$	1.41	3.86 (1)	3.84	2.71
$\beta + \gamma = 1.0$	0.70	9.83 (1)	3.84	2.71

A number of alternative specifications of the production function were estimated. A demographic variable measuring the proportion of youth (15-24 years) in total employment was added to capture the impact of possible changes in the quality of labor input. Inflation was included to test the hypothesis that high inflation diverts resources from productive activity. The total stock of R&D capital in 21 of France's trading partners was included to test if France benefitted from R&D performed abroad. Cross product and squared terms in the factors of production were added to estimate a translog production function. The variables were first-differenced and the levels of  $k$ ,  $k^{R\&D}$ , and  $EC$  were added separately and in combination to test if there was an impact on growth of the level of capital or trade or both. 1/ None of these formulations generated meaningful cointegrating vectors in the sense that either there was no cointegrating vector or there were multiple cointegrating vectors with estimated coefficients of incorrect signs, implausible magnitudes, or both.

Alternative measures of trade were also tried. To test whether the  $EC$  variable was capturing the effect of increased world--rather than European--integration, world trade as a percentage of world GDP was included in addition to, and instead of, the  $EC$  trade integration variable, but the

1/ If the coefficients on the first differences of each variable are constrained to the estimates reported in Table 1, a cointegrating vector is obtained when either the level of  $EC$  or  $k^{R\&D}$  are added. Although these results suggest that the level of  $EC$  and  $k^{R\&D}$  have an additional positive impact on growth, the impact is quantitatively very small (reflecting the parameter restrictions). Without the parameter restrictions on the differenced variables, the results were not interesting.

estimation results were not interesting. If either France's EC trade as a percent of total French trade or as a percent of French output is included instead of the EC variable, the two likelihood ratio tests for the existence and uniqueness of a cointegrating vector give inconsistent results, although in both cases the estimated coefficients in the vector with the largest eigenvalue were correctly signed and of plausible magnitudes.

#### IV. Potential Output

Potential output, which can be defined as the long-run relationship between output and its determinants, has been calculated from the first cointegrating vector in Table 1: 1/

$$y = 0.71 h + 0.53 k + 0.17 k^{\text{r\&d}} + 0.03 EC - 0.39$$

To calculate potential output--but not to estimate the production function--cyclical movements have been removed from hours worked and the EC variable, in the latter case by estimating a cubic trend (see Figure 1).

The sources of cyclical movements in hours worked can be revealed by decomposing it into hours per employee ( $h/e$ ), the employment ratio ( $e/lf$ ), the participation ratio ( $lf/pop$ ), and population ( $pop$ ): in logarithms,  $h = (h/e) + (e/lf) + (lf/pop) + (pop)$ . Cyclical variations in hours worked mainly reflect movements in the employment ratio and in the participation ratio (Figure 3). A polynomial trend has been used to remove cyclical variations in the participation ratio. Cyclical movements in the employment ratio reflect deviations of the actual rate of unemployment from the natural rate of unemployment. Because there is not a consensus on what the natural rate of unemployment is in France--and since it is beyond the scope of this study to estimate the natural rate of unemployment as a function of its structural determinants--two estimates of potential are presented corresponding to two assumptions about the natural rate of unemployment.

One estimate of potential uses the actual (cyclically adjusted) employment ratio on the assumption that the actual unemployment rate is not too different from the equilibrium natural rate. This assumption is consistent with a hysteresis view of equilibrium unemployment and with the persistence of high unemployment and broadly stable wage inflation during the last three to four years in France. The second estimate of potential

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1/ The concept of potential output is central to many economic policy issues. In the short run, the relationship between actual and potential output indicates the extent to which demand may be exerting either upward or downward pressures on inflation. In the medium to long run, the path of potential output determines the sustainable pace of noninflationary output growth or--alternatively--the scope for increases in real standards of living. See the references cited in the box on potential output in IMF (1991), p. 43; and Martin and Torres (1990).

incorporates an adjustment for hours worked based on a very simple and straight-forward estimate of the natural rate of unemployment. 1/ This estimate of the natural rate reflects two assumptions: that the actual unemployment rate was about the same as the natural rate in the early 1970s, and that increases in the natural rate thereafter can be proxied by trend increases in the unemployment rate for prime-age males (Figure 4). 2/

The two estimates of potential output are shown in Figure 5. Since the mid-1970s the estimated level of potential output incorporating hours worked at the natural rate is higher than the estimate using actual hours worked, reflecting the assumption of greater labor input. By the mid-1980s, when the gap between the alternative estimates of the natural rate was at its maximum, the gap between the two estimates of potential was about 2 1/4 percent. In terms of growth rates, however, the two estimates of potential are broadly similar. From the early 1980s until about 1988, both measures of potential output exceeded actual output and this contributed to the sustained declines in inflation from double digit levels in 1980 to less than 3 percent in 1988. Inflation rose to about 3 1/2 percent in 1989-90 when actual output rose above both estimates of potential. Since 1990:IV, output has again fallen below both estimates of potential, and inflation fell back to about 3 percent. In 1991:IV, the level of potential output based on actual hours worked is estimated to have exceeded actual output by about 2 percent, and potential output based on labor input at the natural rate is estimated to have exceeded actual output by about 3 1/4 percent.

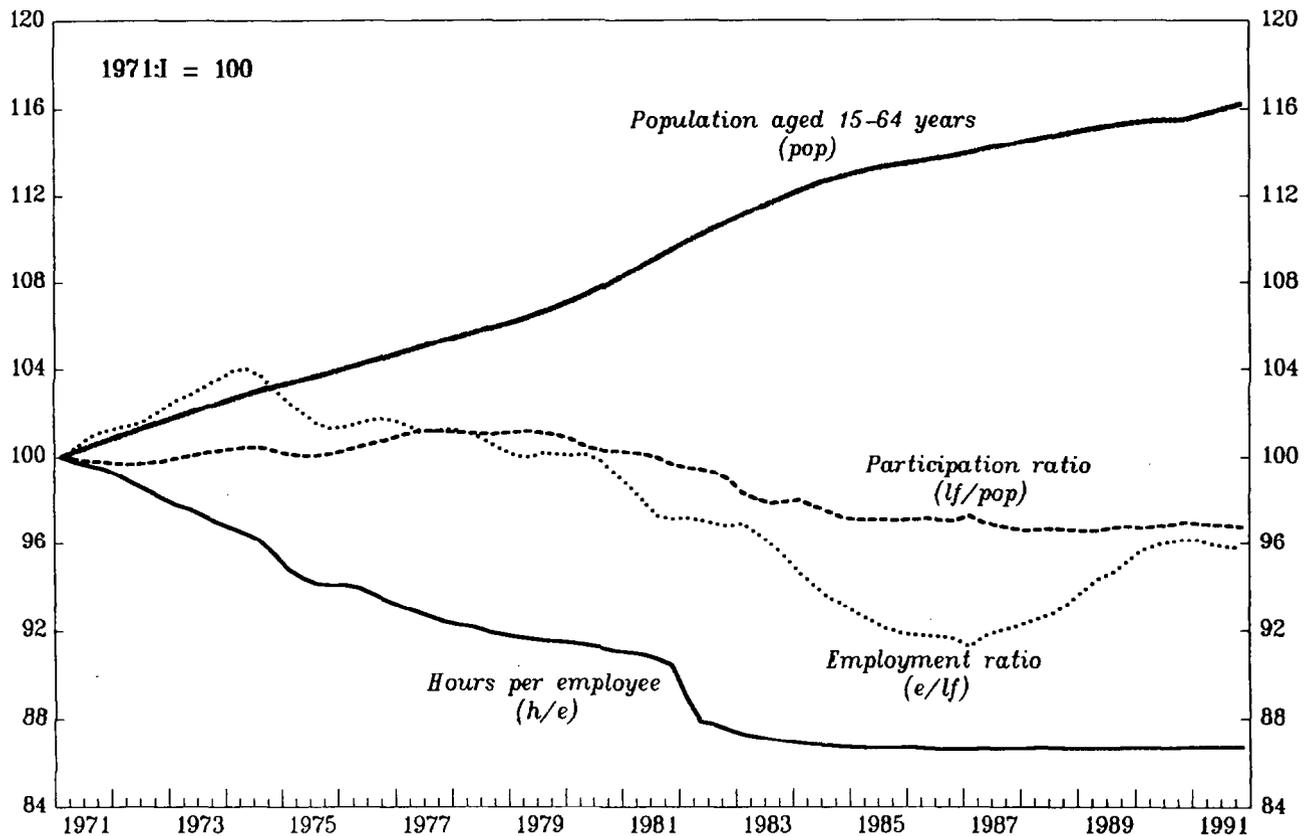
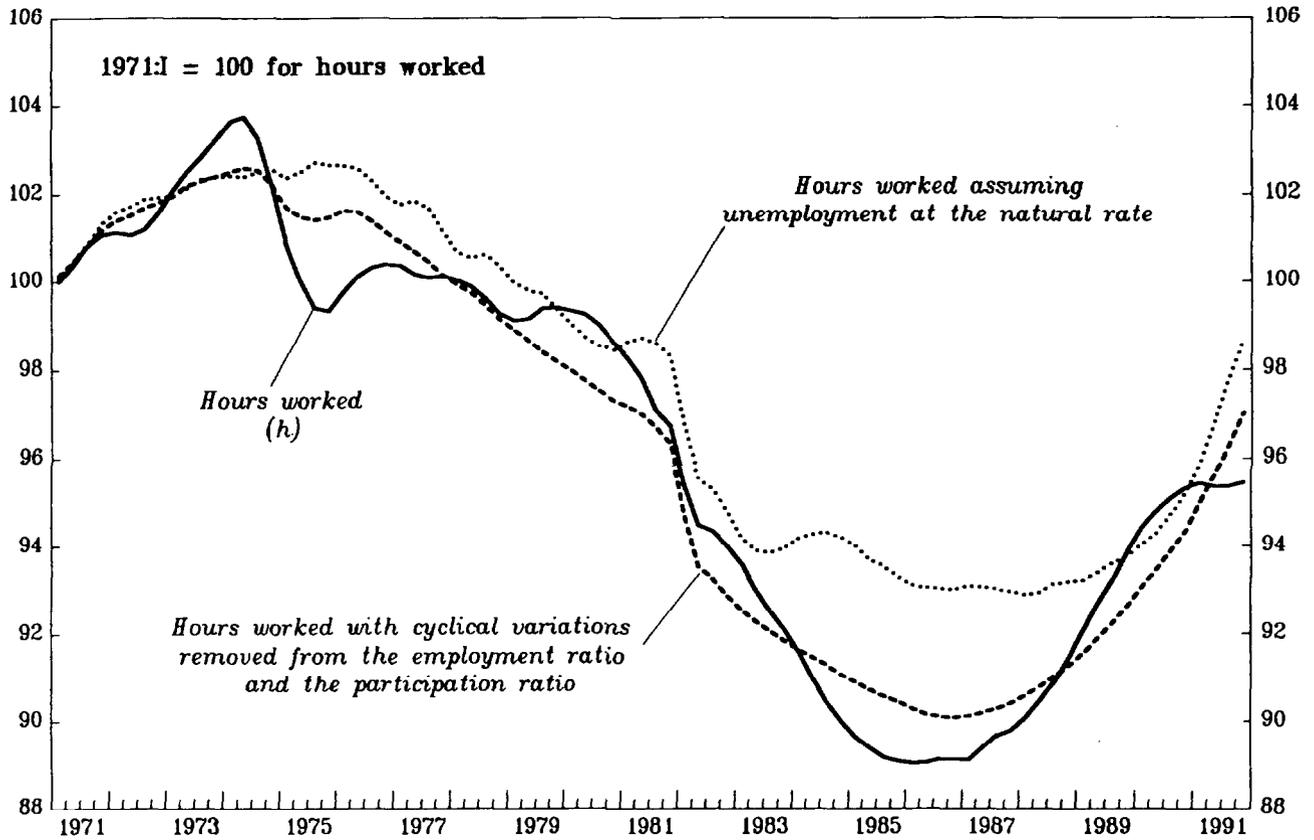
Turning to the estimated sources of potential output growth summarized in the top section of the Table 4 and in Figures 1-3, it is clear that capital and trade have been the engines of growth in France during the last two decades. Much of the slowdown in growth from the mid-1970s to the mid-1980s is accounted for by the slowdown in physical capital formation--real gross fixed capital formation actually declined in 6 of the 10 years from 1975 to 1984. Increases in R&D capital account for almost 20 percent of the total increase in potential output over the 1971-91 period. The contribution of R&D capital to the growth of potential increased slightly in the 1980s, in contrast to the other determinants of potential output that contributed to the slowdown of output growth from the mid-1970s to the mid-1980s.

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1/ Using a "\*" to indicate the variable has been cyclically adjusted or that the unemployment rate (U) is at its "natural" level, the adjustment for hours worked is  $h-h^* \approx (U^*-U)/100$ , which is obtained by substituting  $e/lf = \log(1-U/100) \approx -U/100$  into the equation used to decompose h, and making a similar substitution for  $(e/lf)^*$  into an equation for  $h^*$ .

2/ The prime-age male unemployment rate is often used in estimated wage equations instead of the aggregate unemployment rate; see Cotis and Loufir (1990). The natural rate of unemployment is estimated as a quadratic trend on the 24-50 year old male unemployment rate plus the differential between the aggregate and the prime-age-male unemployment rates in the early 1970s.

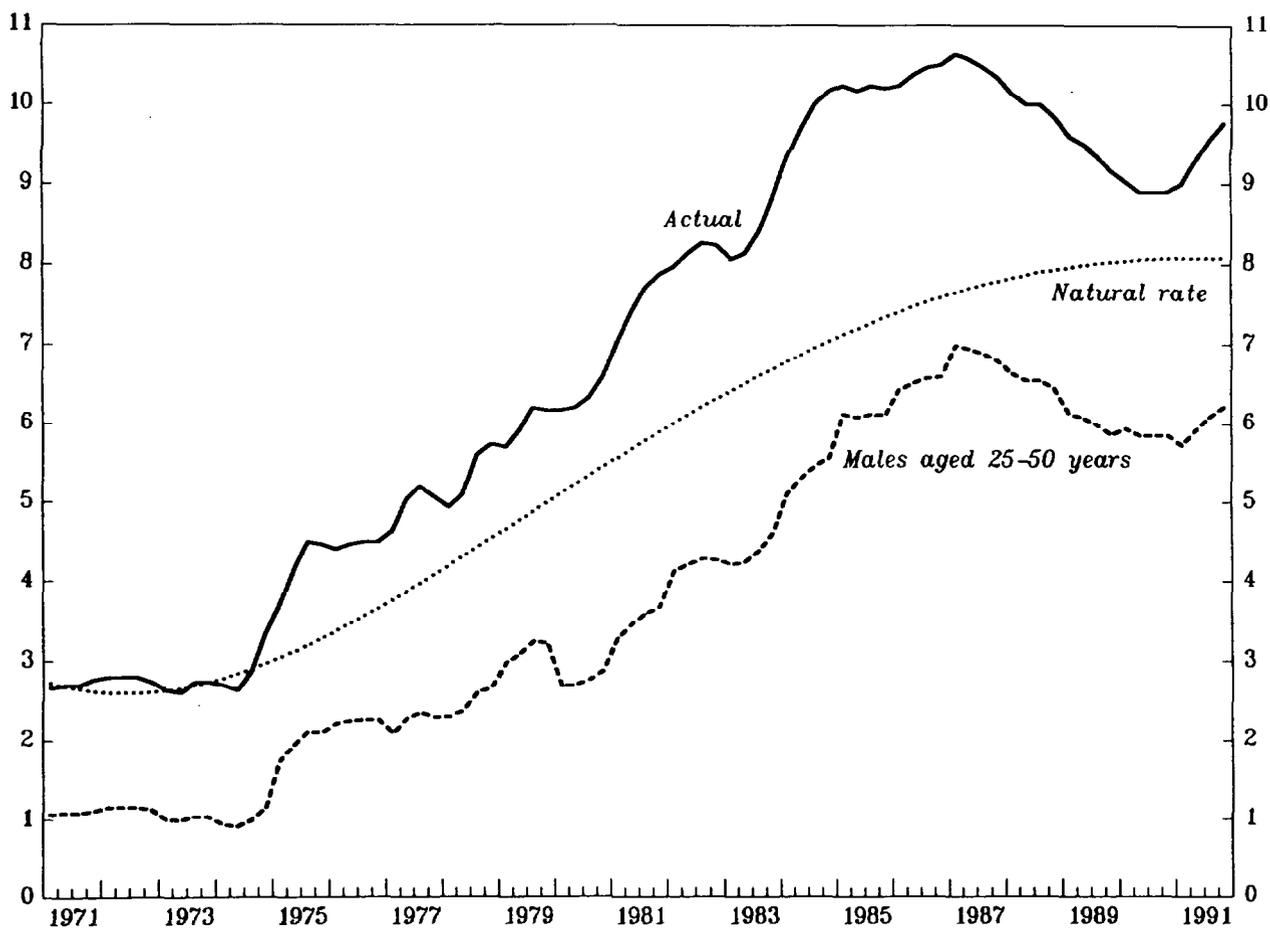
Figure 3. Hours Worked<sup>1</sup>  
(In logarithms)



<sup>1</sup>Nonfarm business sector. The decomposition of hours worked in the lower panel is calculated from  $h = (h/e) + (e/lf) + (lf/pop) + pop$ , where all variables are in logarithms.

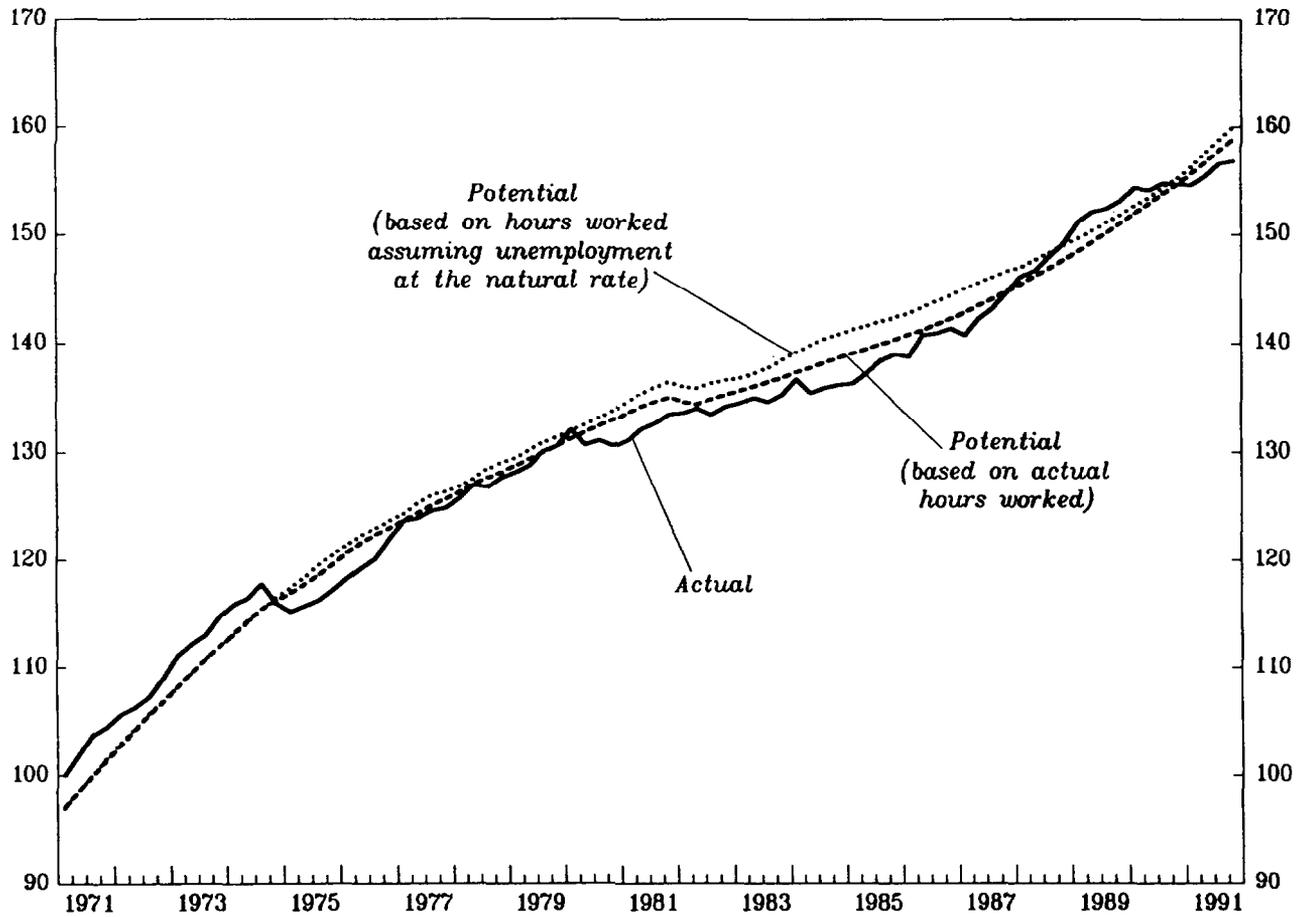


**Figure 4. Unemployment Rates**  
(Percent of labor force)





**Figure 5. Output<sup>1</sup>**  
(In logarithms, actual output = 100 in 1971:1)



<sup>1</sup>Real value added in the nonfarm business sector.



Table 4. Potential Output Growth

(Annual percentage changes)

	1971-91	1971-75	1976-80	1981-86	1987-91	Projections 1992-97
<u>Nonfarm Business Sector</u>						
Potential output	3.0	4.8	2.7	1.5	3.3	2.9
due to:						
Physical capital	2.0	2.8	2.1	1.5	1.5	1.5
R & D capital	0.5	0.4	0.4	0.5	0.5	0.5
European trade integration	0.7	1.3	0.8	0.4	0.3	0.5
Hours worked	-0.1	0.2	-0.6	-0.9	1.0	0.4
Potential output assuming employment at the natural rate	3.1	5.0	2.7	1.8	3.2	2.9
Actual output	2.7	3.5	2.7	1.8	3.1	...
<u>Gross Domestic Product 1/</u>						
Potential output	3.0	4.2	2.8	1.6	3.0	2.9
Actual output	2.6	3.2	2.7	1.8	2.8	...
<u>Memoranda items</u>						
Unemployment rates (end year)						
Actual	9.8	4.5	6.6	10.5	9.8	...
Natural	8.1	3.3	5.5	7.6	8.1	8.1
Nonfarm business output as a share of GDP	0.1	0.2	-0.1	-0.1	0.3	--

1/ The growth of GDP is equal to the growth of output in the nonfarm business sector minus the growth of nonfarm business output as a share of GDP.

The estimation results suggest that European trade integration has given a substantial boost to the growth of potential output in France. The beneficial effects of European integration were most pronounced in the early 1970s when intra-EC trade was increasing much more rapidly than in the more recent period. As noted, Coe and Krueger (1990) report a similar result for the Federal Republic of Germany. The share of potential output growth over the last two decades attributable to closer European integration is estimated to have been less in Germany than in France, reflecting the somewhat less open French economy at the start of the 1970s. It is interesting to note that Baldwin (1989) estimates that the 1992 single market program may increase the EC's long-term growth rate by 0.2 to 0.9 percentage points. This estimate, which is based on a completely different methodology than used here, is consistent with our estimate of the impact that European integration has had, and is likely to have in 1992-97, on growth in France.

Declines in hours worked contributed to a reduction in potential output growth over the 1971-91 period. The drop in hours worked reflected sharp declines in hours per worker up to the early 1980s, and, to a lesser extent, declines in the employment rate from the mid-1970s to the mid-1980s and in the participation rate in the 1980s (see the lower panel of Figure 3). Population increased by an annual average of about 3/4 of 1 percent during the full 1971-91 period. In the first half of the 1980s, the drop in the employment rate and the declines in the participation rate, coupled with continued falls in hours per worker, reduced annual potential output growth to 1 1/2 percent. 1/ In 1987-91, the employment rate rose while hours per worker and the participation rate remained broadly stable; the resulting increase in hours worked was reflected in a sharp rebound in potential output growth.

Turning to the projections for potential output for 1992-97, the contribution from hours worked reflects the IMF staff's medium-term projections for employment and the labor force, and the assumption that weekly hours remain broadly stable at the 1991 level. 2/ The contribution of capital is derived from the medium-term projection for fixed investment and an assumption that the depreciation rate remains unchanged from the average of 1990-91. To project the contribution of R&D capital, a regression relating real R&D expenditures to real output was used to project real R&D expenditures for 1992-97 based on the projection of real

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1/ Even if there had been no increase in the natural rate of unemployment from 1980 to 1986, the average growth of potential would have fallen from 2.7 percent in 1976-80 to 2.0 percent in 1981-86.

2/ The medium-term projections are summarized in Annex II of the October 1992 *World Economic Outlook*, pp. 69-76.

output. <sup>1/</sup> Given the completion of the single market by the end of 1992, it is assumed that there will be an increase in intra-EC trade as a percent of EC output, and hence that its contribution to potential output growth will increase somewhat.

These projections and assumptions imply an average annual growth of potential output of almost 3 percent for 1992-97. Actual output increased about 1 1/2 percent during 1992 and, by 1992:IV, the gap between potential output based on actual hours worked and actual output is estimated to have increased to about 3 1/4 percent. The estimate of potential growth is similar to Artus' (1992) estimate for 1992-93, and slightly higher than the 2.6 percent projected for 1989-95 in Adams and others (1987). The slowdown compared with potential growth during 1987-91 mainly reflects smaller increases in labor input in 1992-97. Although it has been assumed that increases in intra-EC trade will increase potential output growth somewhat over the medium-term, its contribution remains small compared to the 1970s.

#### V. Concluding Remarks

Recent cointegrating techniques that focus on the identification of long-run relationships are particularly appropriate to the study of the determinants of long-run growth. The application of these techniques to French data has yielded a number of interesting empirical results, two of which relate to the role of capital. One is the relatively large estimated elasticity of output with respect to R&D capital. The second is that a broad concept of physical capital--one that includes public infrastructure, residential and nonresidential structures, and plant and equipment capital--performs better than the more common, narrower concept of business sector capital. A third important--and new--result is the empirical estimate of the beneficial effects of European trade integration on French growth.

The estimated production function is not, strictly speaking, characterized by endogenous growth. The factors of production that can be accumulated, physical capital (broadly-defined) and R&D capital, exhibit decreasing returns to scale. As Sala-i-Martin (1990) emphasizes, this implies, in the absence of exogenous technological progress, a steady-state growth of per capita output of zero. More generally, the underlying relationships are between the level of output and the levels of factor inputs and the degree of trade integration. Although capital accumulation and increased trade have boosted growth, a higher level of capital or trade integration will not, in the long run, have an impact on the growth of output.

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<sup>1/</sup> The estimated regression is  $\log(\text{R\&D expenditures}) = 1.1 \log(\text{output}) + \text{constant}$ ,  $R^2 = 0.8$ , annual data 1970-89. The stock of R&D capital was then calculated for 1992-97 by cumulating R&D expenditures with an assumed obsolescence rate of 5 percent.

These results have a number of policy implications. European integration has boosted French growth in the past, and steps to accelerate the process of integration can be expected to enhance growth in the future. The large increases expected in services trade with the completion of the single market, additional steps toward closer economic and monetary union, and closer integration with Central and Eastern European countries may result in a substantially larger contribution to future potential output growth in France than assumed above. Similarly, government infrastructure investment and policies that encourage--or create an environment conducive to--productive investment and research and development will also increase potential output. Finally, labor market policies that reduce the natural rate of unemployment over the medium term, thereby increasing labor input, will boost potential output growth.

The empirical results suggest a number of areas for further study. In order to fully appreciate the implications for inflation of the estimates of potential output, it is necessary to combine them with a more satisfactory estimate of the natural rate of unemployment in the context of a fully specified wage-price system. A second area for further study is the determinants of R&D expenditures and the extent to which R&D contributes to endogenous growth. Finally, there is a need for further study of the impact on growth of other structural features of the French economy, such as the Common Agricultural Policy, and how structural reform would affect medium-term growth prospects in France.

The Johansen Procedure

Johansen and Juselius (1990) consider the following general model:

$$X_t = \Pi_1 X_{t-1} + \dots + \Pi_k X_{t-k} + \mu + e_t, \quad (t=1, \dots, T) \quad (1)$$

where  $X_t$  is a vector of  $p$  variables,  $e_1, \dots, e_t$  are independent normal errors with mean zero and covariance matrix  $\Lambda$ ,  $X_{-k+1}, \dots, X_0$  are fixed, and  $\mu$  is an intercept vector. Economic time series are often nonstationary and systems such as the above vector autoregressive representation (VAR) can be written in the conventional first difference form:

$$\Delta X_t = \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \mu + e_t \quad (2)$$

where

$$\Gamma_i = -(I - \Pi_1 - \dots - \Pi_i) \quad (i=1, \dots, k-1), \quad \text{and} \quad \Pi = -(I - \Pi_1 - \dots - \Pi_k)$$

The only level term in (2) is  $\Pi X_{t-k}$ . Thus, only the matrix  $\Pi$  contains information about the long-run relationships between the variables in the data vector. There are three cases:

- i. If the matrix  $\Pi$  has rank zero, then all the variables in  $X_t$  are integrated of order one or higher and the VAR has no long-run properties;
- ii. If  $\Pi$  has rank  $p$ , i.e., it is of full rank, the variables in  $X_t$  are stationary; and
- iii. The interesting case when  $\Pi$  has rank  $r$ ,  $0 < r < p$ , in which case  $\Pi$  can be decomposed into two distinct  $(p \times r)$  matrices  $\alpha$  and  $\beta$  such that  $\Pi = \alpha\beta'$ .

The third case implies that there are  $r$  cointegrating vectors. The parameters of the cointegrating vectors are contained in the  $\beta$  matrix. Therefore,  $\beta X_t$  is stationary even though  $X_t$  itself is non-stationary. The  $\alpha$  matrix gives the weights with which the cointegrating vectors enter each equation of the system.

To determine the number of cointegrating vectors,  $r$ , Johansen and Juselius describe two likelihood ratio tests. In the first test, which is based on the maximal eigenvalue, the null hypothesis is that there are at most  $r$  cointegrating vectors against the alternative of  $r+1$  cointegrating

vectors. In the second test, which is based on the trace of the stochastic matrix, the null hypothesis is that there are at most  $r$  cointegrating vectors against the alternative hypothesis that there are  $r$  or more cointegrating vectors. The first test is generally considered to be more powerful because the alternative hypothesis is an equality.

Data Sources and Definitions

Real value added, hours worked, and employment in the nonfarm business sector are from the INSEE data tape, in each case subtracting the farm sector (secteur agriculture, sylviculture, pêche) from the total for the business sector (secteurs marchands). The relevant INSEE codes for real value added are PN1\_V008 and PN1\_U018; for hours worked, ACM\_V001, ACM\_U011; and for employment, EFM\_V001, EFM\_U011.

The stock of business sector capital, the stock of residential capital, labor force, and population are from the OECD Analytical Data Bank. The stock of infrastructure capital is taken from the annual estimates of Ford and Poret (1991), reported by them as INF.N (p. 80), interpolated to a quarterly frequency. The share of the labor force aged 15-24 is calculated from OECD, *Labour Force Statistics*.

The stock of R&D capital is calculated analogously to the stock of physical capital with an assumed obsolescence rate of 5 percent:  $k^{r\&d} = k^{r\&d}_{-1} (1-0.05) + (\text{real R\&D expenditures})$ . A benchmark for  $k^{r\&d}$  was calculated using the procedure suggested by Griliches (1980). Real R&D expenditures are gross domestic expenditure on R&D deflated by an average of the GDP deflator and an index of business sector wages. R&D expenditures are from OECD, *Main Science and Technology Indicators*, 1991:1, p. 16. R&D expenditure for 1991 was estimated using the same procedure reported in the text to project R&D expenditures for 1992-97. Annual data for the stock of R&D capital were interpolated to a quarterly frequency.

Data to construct the EC variable are from IMF, *Direction of Trade*. EC is constructed with data for all 12 current members of the EC, even though not all 12 countries were members during the full 1971-91 period. World trade as a percent of world output was constructed from the IMF World Economic Outlook database. Annual data were interpolated to a quarterly frequency.

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