The Identification of Economic Base Industries, with an Application to the Newfoundland Fishing Industry

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ABSTRACT

The contribution of an industry to GDP is typically measured by its value added. However, casual observation suggests that some industries play a greater role in overall economic activity than this measure indicates. Observations of this kind have in particular been applied to resource industries, and have given rise to the concept of the economic base. Unfortunately, empirical and econometric verification of the concept of a base industry has been limited. This paper outlines a theory of base industries, develops a methodology for identifying economic base industries and measuring their impact, and applies this methodology to the fishing industry of Newfoundland.

Keywords: Base industries, economic base, fisheries as a base industry, base multipliers

JEL classification: C32, O11, O13, Q22, R11

1. Introduction

Economies may be seen as a collection of industries. In the national accounts the contribution of each of these industries to the Gross Domestic Product (GDP) is measured by its value added. Thus, superficially, it may appear that the economic importance of each industry can also be measured by the same concept. However, casual observation suggests that some industries play a role in the overall economic activity that differs from this measure. In particular, certain industries appear to be more fundamental than others in the sense that after taking their indirect as well as their direct economic impacts into account, their overall contribution to GDP is higher than that measured by the national accounts.

Observations of this kind have given rise to the concept of the economic base (Tiebout 1956a). The economic base is an industry or a collection of industries that is disproportionately important to a region's economy in the sense that other economic industries depend on the operation of the economic base but not vice versa, at least not to the same extent. Thus the base industry can be regarded as autonomous (or basic) while the other industries are dependent (non-basic). By implication, removing base industries would reduce the GDP more than their direct contribution to the GDP as measured by the national economic accounts and vice versa.

The idea of the economic base has a long history. W.A. Schaffer (1999) traces the origins of this theory back to the Mercantilists, who regarded any activity conducive to a favorable balance of trade as the nation's economic base, and later to the Physiocrats who regarded agriculture as the national economic base. The modern concept of the economic base was initially formulated by the German economic historian, Werner Sombart (Krumme 1968), but has been refined by several researchers in the fields of economic history and regional economics including North (1955) and Tiebout (1956a, 1956b, 1962). Natural resource industries in particular are often associated with the notion of an economic base, and the role of such industries in economic development is the focus of the "staples thesis" developed by Harold Innis (1930).[1]

Unfortunately, in our view, a coherent theoretical framework supporting the notion of an economic base has yet to be developed. Similarly, empirical and econometric verification of the concept of a base industry has been limited. Using data on the fishing industry in the province of Newfoundland in Canada, this paper seeks to advance our understanding of the concept both theoretically and empirically.

Historically, the fishery has been the mainstay of the Newfoundland economy (Innis 1940). By the 1970s, however, the percentage of the labor force composed of fishermen had fallen to approximately 5 percent and it has remained there ever since. From totally dominating the Newfoundland economy a century ago[2], the harvesting sector of the fishery in the last 30 years has constituted less than 5 percent of the provincial economy as measured by the GDP (Government of Newfoundland and Labrador 1994, p 74). Figure 1 shows the value of landings as a percentage of provincial GDP from 1961 to 1994.

Insert Figure 1 around here.

These statistics suggest that the fishery plays only a small role in the modern economy of Newfoundland and Labrador. Is it possible that they underestimate the present economic role of the industry? If this were the case, the fishery might constitute an economic base in the Newfoundland economy. The fishery is, of course, a classic staples industry (Innis 1940), and as such fits naturally into the paradigm of the economic base.

This paper has two main objectives. The first is to test the hypothesis that the

Newfoundland fishing industry has an economic impact that is substantially greater than the value added that it directly contributes to GDP, and so may act as an economic base industry. The second objective is to develop a statistically robust methodology to test such a hypothesis and to obtain estimates of the "true" impact.

One possible way to test whether a fishery is a base industry is to determine whether, even after accounting for the flow of productive resources from the primary factors of production (labor and capital) to the gross domestic product, including those factors of production utilized in the fishing industry, the level of overall activity in the fishery continues to impact on the level of GDP. This is the approach that we adopt. Since the relationship between an economic base and general activity is a long-run one, cointegration analysis is appropriate to this task. If a cointegrating vector relating the appropriate variables exists, then the hypothesis that the fishery is a base industry cannot be rejected. In that case, according to the Granger Representation Theorem (Engle and Granger 1987), an error correction model of the economy of Newfoundland and Labrador should be able to represent the overall dynamic relationship between GDP, primary factors of production, and the fishery. This basic approach was employed in a recent paper by Agnarson and Arnason (2006) and our proposed methodology is an extension and refinement of theirs. The methodology can be used to test for economic base industries in any economy.

Although the empirical part of this study is concerned with testing whether the Newfoundland fishing industry may be regarded as a base industry, we would like to make it clear that we do not think that there is anything special about fisheries in this context. Other industries, especially those based on natural resources, could just as easily constitute base industries in other economies. Moreover, in most advanced economies there are probably not one but a number of base industries.

Section 2 discusses and clarifies the theoretical underpinnings of the economic base model. Section 3 describes the statistical theory underlying our estimating and testing procedures. Section 4 documents the data used in the analysis. Section 5 discusses the statistical estimation procedure and the results. Finally, in section 6 the main conclusions of the paper are presented.

2. Base Industries: Theoretical Outline

Consider a geographical region. Suppose that initially there is no economic activity in the region.[3] Now, assume that a natural resource is discovered in the region and that this resource is brought under exploitation. For simplicity, assume that the output from the resource is exported. This exploitation activity requires labor and therefore local population. This population demands consumption goods. These consumption goods can be either locally produced or imported.[4] Local provision of these goods represents induced economic activity. Let us refer to the value added generated by the base activity by the symbol ϕ. The GDP in the region is now ϕ plus any induced economic activity; more formally $y = y^i + \phi$, where y^i represents induced local net production (i.e., value added) and y represents the total regional GDP.

It can be seen that this economy is modeled as one with two production sectors and four goods. The first production sector is the base industry producing the good ϕ, which is assumed to be exported.[5] The second production sector produces a consumption good which we denote as x_1. The third good x_2, also a consumption good, is imported. The fourth good is labor.[6] All values are expressed in terms of the price of the foreign good which consequently is the numeraire with value unity. For simplicity we assume that the region in question is sufficiently small so that it does not affect the price of the foreign good. The corresponding (real) price of the domestic good is *p* and that of labor *w*. The relative price of transportation and other extra surcharges associated with imports (in terms of the foreign good) is represented by ε. As is customary in simple macroeconomic models, local consumers and industries are represented in aggregate terms: consumers are represented as one representative person (or taken to be all alike), as are producers. Finally, we assume that all markets clear continuously so there is for instance no unemployment.

The induced local production must in equilibrium be equal to the demand and supply for local goods. Local consumers attempt to solve the following problem:

$$\underset{x_1, x_2}{Maximize}\ U(x_1, x_2) \text{ s.t. } y \geq p \cdot x_1 + (1+\varepsilon) \cdot x_2 . \tag{1}$$

The objective function, $U(x_1, x_2)$, is assumed to be increasing in both its arguments and have the usual properties of a utility function.

Maximizing $U(x_1, x_2)$ (assuming an internal solution, i.e., some demand for local goods) leads to the aggregate expenditure or consumption function for local goods:

$$p \cdot x_1^d = D(y, p, \varepsilon) . \tag{2}$$

Let us, for convenience of analysis, assume that the consumption function is differentiable. Then by the usual properties of demand functions, we may take it that D_y, $D_\varepsilon > 0$. We also assume that $1 > D_y$, i.e., that income changes affect both local and foreign demand in the same direction. We further assume that $D_p < 0$, i.e., that demand for local goods falls as the relative price of local goods rises. Total aggregate demand for local production therefore is

$$y^d = \phi + D\,(y, p, \varepsilon\,)\;. \tag{3}$$

The supply of local goods obviously depends on the local production technology and local prices. In our simple framework with labor as the only market input, local producers may be assumed to have a production technology represented by the increasing concave production function $Y(n)$, where n represents labor. Inverting this function yields $n = Y^{-1}(x_1)$.

So, local producers attempt to solve the following maximization problem:

$$\underset{x_1}{Maximize}\; p \cdot Y(n) - w \cdot n \equiv p \cdot x_1 - C(x_1, w)\,, \tag{4}$$

where the cost function $C(x_1, w) \equiv w \cdot Y^{-1}(x_1)$ is linear in w and convex in output.

Solving (4) assuming a positive production level leads to the supply function

$$x_1 = \Psi(p/w)\,, \tag{5}$$

which by the usual properties of supply functions is increasing in p/w. Thus, the real value of aggregate local supply y^s is

$$y = \phi + p \cdot \Psi\left(p/w\right) \equiv \phi + S(p, w) \tag{6}$$

where as usual, $S_p > 0$ and $S_w < 0$.

Now, in equilibrium aggregate supply must be equal to aggregate demand, i.e., $y = y^d = y^s$. Moreover, labor movement in and out of the local economy implies that the real wage must be some increasing function of the real wage in the outside economy. In other words,

$$w = p \cdot F(\overline{w})\,, \tag{7}$$

where $\bar{w}$ is the wage level in the outside economy (the price level in that economy being unity by normalization).

The complete economy is now described by the two functions:

$$\begin{aligned} y &= \phi + D(y, p, \varepsilon) \\ y &= \phi + S(p, p \cdot F(\bar{w})) \end{aligned} \tag{8}$$

It seems likely that the derivative $S_p = \partial S(p, p \cdot F(\bar{w}))/\partial p$ is still positive.

Differentiating Eq. (8) with respect to an exogenous change in the base ϕ yields the system

$$\begin{aligned} \frac{\partial y}{\partial \phi} &= 1 + D_y \cdot \frac{\partial y}{\partial \phi} + D_p \cdot \frac{\partial p}{\partial \phi} \\ \frac{\partial y}{\partial \phi} &= 1 + S_p \cdot \frac{\partial p}{\partial \phi} \end{aligned} \tag{9}$$

It is now easy to verify that the comparative statics impact the base industry ϕ on GDP is given by the expression

$$\frac{\partial y}{\partial \phi} = \frac{S_p - D_p}{S_p \cdot (1 - D_y) - D_p}. \tag{10}$$

Expressions of the type exemplified by Eq. (10) are typically referred to as economic base multipliers (Frey 1989). They represent the response of GDP to a change in the economic base industry. Under our assumptions, this response is unambiguously greater than unity, establishing that the overall contribution of the base industry to GDP is greater than its direct contribution. It follows that the other local industry, i.e., the industry producing x_1, has a smaller impact on the economy than its own direct contribution. Indeed, to make $\partial y/\partial \phi$ unity, either $S_p = 0$ or $D_y = 0$. This basically means that no local consumption good industry arises as a result of the ϕ-industry. Only if there is an increase in local consumption as a consequence of increased ϕ will there be additional GDP effects.

It is easy to verify that $\partial y/\partial \phi$ is monotonically increasing in S_p and falling in (the numerical value of) D_p. Moreover, if either $D_p = 0$ (which we have ruled out by assumption) or $S_p \to \infty$ (a horizontal supply curve) then $\partial y/\partial \phi$ converges to its maximum value $[1 - D_y]^{-1}$, which will be recognized as the simple Keynesian multiplier. Thus, in this model at least,

$$\partial y/\partial \phi \in \left[1, \frac{1}{1 - D_y}\right] \tag{11}$$

Therefore, the more sensitive supply is to price (reflecting local demand) — which can be seen as converging to a horizontal supply curve — the greater the impact of the base industry and vice versa. This seems to be an intuitive result. Similarly, the upper bound for $\partial y/\partial \phi$ is approached as D_p approaches zero. That is to say, the less sensitive demand is to price — up to a vertical demand curve — the higher the multiplier.

Alternatively, the lower bound is approached as S_p approaches zero or D_p approaches infinity. The message of the former is that the more inflexible supply is, the closer the impact of the base industry on GDP comes to be only its own direct contribution. If on the other hand D_p approaches infinity, implying that local goods and imports are perfect substitutes, the base industry multiplier again collapses to unity.

So, what has been shown is that it is possible to construct a fairly standard macro model based on microeconomic foundations under which a certain autonomous industry acts as a base industry. Most importantly, we have demonstrated that the GDP impact of this industry can be well in excess of its direct contribution. This establishes the possibility that base industries in the form that we have characterized them exist. Of course, in any particular economy there may be several base industries or, for that matter, none. To determine this is an empirical matter.

The analysis outlined above suggests that an economic base industry possesses two characteristics: it must in some sense be autonomous or exogenous with respect to the rest of the economy in which it is embedded, and its impact on GDP through the base-industry multiplier must be significantly greater than its direct contribution as measured by the national accounts. The autonomous character of the base industry is a rather general requirement. The base industry could be founded on a natural resource or a geographical feature discovered or rendered valuable by historical developments. It could even be based on a geographically strategic location made valuable by growing industries elsewhere. However, base industries do not have to be founded on natural resources; for instance, local ingenuity could in principle generate a base industry. Moreover, while our theoretical analysis assumes that the base industry is an export industry, this does not have to be the case; for example, it could just as easily be an activity that makes habitation in the area possible.[7]

The size of the base-industry multipliers developed in this section depend on a range of factors. In our simple presentation the key factors are (I) the elasticity of local supply with respect to its own (real) price, (ii) the elasticity of demand for local goods and (iii) the marginal propensity of the local population to consume local goods out of income. The first depends on local production possibilities relative to those in the surrounding economies. The second depends on consumer preferences and the protection afforded by distance to foreign markets. The third depends again on preferences. Therefore, the size of any base industry multiplier cannot be asserted a priori. Empirical measurements are needed.

3. Statistical Theory

As has already been noted, empirical verification of the concept of a basic economic activity and work on the identification of such base industries has been limited. Our approach to this issue is based on the time series analysis of cointegrated economic variables. A stable relationship between production and the utilization of primary factors of production, usually labor and capital, has been a standard feature of empirical macroeconomics since the pioneering work of Paul Douglas (Cobb and Douglas 1928; Douglas 1948). Generally, an aggregate production relationship can be represented in the form $Y_t = A_t + \alpha L_t + \beta K_t$, where output, labor and capital are expressed in logarithms and represented by the variables Y, L, and K respectively, and A_t represents exogenous factors such as the level of technology.

Our basic assumption is that if a particular activity acts as an economic base, it must positively affect this relationship, which would then be written as $Y_t = [A'_t + \theta F_t] + \alpha L_t + \beta K_t$, where F_t is a measure of the size of the basic activity (which we initially take to be the sole basic activity). The base industry contributes value added to the gross domestic product of the economy through its inputs of the primary factors of production that are employed in the industry; the size of the base-industry multiplier is reflected in the parameter θ, which measures the contribution of the base industry to GDP over and above its contribution to value added.

We acknowledge that establishing the existence of such an effect for a particular industry is neither necessary nor sufficient for that industry to act as an economic base. It is not necessary, because there may be other channels through which a base industry may contribute to the general economy.[8] It is not sufficient, either, because the industry identified as a base industry may in fact be impacting the GDP (over and above its contribution to value added) for reasons other than economic base effects. Notwithstanding these caveats, we find that the fishing industry has had an impact on the GDP of the economy of Newfoundland and Labrador that is substantially and significantly in excess of its contribution to value added. Whatever the reasons for this result, it is an important finding, and one that is at least consistent with the notion that the fishing industry has been a base industry in that economy.

Our objective is to test the existence of a long-run relationship between the GDP of a region, the inputs of the primary factors labor and capital in the region, and the output of the economic base — here the fishery. One way to do this is through the definition of a vector autoregressive (VAR) model incorporating these variables (actually, their logarithmic transformations) into a 4 × 1 vector $\mathbf{z}_t = [Y_t \;\; L_t \;\; K_t \;\; F_t]$ and relating these variables to the k lagged values of these variables:[9]

$$\mathbf{z}_t = \mathbf{A}_1 \, \mathbf{z}_{t\text{-}1} + \ldots + \mathbf{A}_k \, \mathbf{z}_{t\text{-}k} + \mathbf{u}_t \, , \;\; \mathbf{u}_t \sim IN\,(0, \Sigma) \qquad (12)$$

where the k 4 × 4 matrices $\mathbf{A}_i$, for $I = 1,\ldots,k$ are matrices of coefficients relating the 4 variables in $\mathbf{z}_t$ to their lagged values. This type of VAR model has been advocated most prominently by Sims (1980) as a way of estimating dynamic relationships among jointly endogenous variables without imposing strong *a priori* restrictions. The system is in reduced form with each variable in $\mathbf{z}_t$ regressed only on lagged values of itself and all the other variables in the system. In the absence of restrictions on the parameters, Ordinary Least Squares (OLS) efficiently estimates the equations in (12), since the right-hand side of each equation in the system constitutes a common set of lagged (and thus predetermined) variables (Sims 1980).

By the Granger Representation Theorem (Engle and Granger 1987, p 255-56), if all variables are cointegrated of order 1 [$I(1)$], Eq. (12) can be reformulated into a vector error-correction (VECM) form, as follows:

$$\Delta\mathbf{z}_t = \mathbf{\Gamma}_1\,\Delta\mathbf{z}_{t-1} + \ldots + \mathbf{\Gamma}_{k-1}\,\Delta\mathbf{z}_{t-k+1} + \mathbf{\Pi}\,\mathbf{z}_{t-k} + \mathbf{u}_t \qquad (13)$$

where $\mathbf{\Gamma}_i = -\,(\,\mathbf{I} - \mathbf{A}_1 - \ldots - \mathbf{A}_i)$, $i = 1,\ldots, k-1$, and $\mathbf{\Pi} = -\,(\,\mathbf{I} - \mathbf{A}_1 - \ldots - \mathbf{A}_k)$ are all 4×4 matrices. This specification usefully decomposes the autoregressive relationships in Eq. (12) into their dynamic (short-run) and equilibrium (long-run) components, capturing these in the matrices $\mathbf{\Gamma}_i$ and $\mathbf{\Pi}$ respectively. The dynamic (i-period) multipliers relate changes in the variables in $\mathbf{z}_t$ to changes in these variables i periods in the past and are contained in the matrix $\mathbf{\Gamma}_i$. The long-run equilibrium adjustments in these variables are captured in the term $\mathbf{\Pi}\,\mathbf{z}_{t-k}$; in long-run equilibrium, $\Delta\mathbf{z}_t = 0$ for all t, and therefore it must be true that $\mathbf{\Pi}\,\mathbf{z}_{t-k} = 0$ in equilibrium as well. Such a 4×4 homogeneous linear system depends on the existence of at least one independent long-run relationship among the variables in the model (the number of such relationships being equal to the rank of the matrix $\mathbf{\Pi}$).[10] Presumably the long-run relationship that we seek between GDP and the economic base, if it exists, is reflected in one of these relationships. The existence of such a relationship ensures that the variables in the vector $\mathbf{z}_t$ are cointegrated (provided that they are in fact integrated, and therefore are characterized by stochastic trends) (Engle and Granger 1987).

The model can be characterized as an error-correction model, because the term $\mathbf{\Pi}\ \mathbf{z}_{t-k}$ captures the response of the variables in the model to the development of discrepancies or "errors" in the r equilibrium relationship(s) connecting these variables. These discrepancies are specified as the $r \times 1$ vector $\boldsymbol{\varepsilon}_t = \boldsymbol{\beta}'\mathbf{z}_t$, where $\boldsymbol{\beta}$ is a $4 \times r$ matrix of coefficients of the r equilibrium relationships (Engle and Granger 1987).

Suppose that the 4 variables in $\mathbf{z}_t$ respond in an error-correcting way to these discrepancies at rates of change represented in the $4 \times r$ matrix $\boldsymbol{\alpha}$, where α_{ij} is the rate of response of the j^{th} variable in $\Delta\mathbf{z}_t$ to a change in the error ε_i in the i^{th} equilibrium relationship in the vector $\boldsymbol{\varepsilon}$. The error-correction that takes place in the variables in $\mathbf{z}$ is therefore $\boldsymbol{\alpha\varepsilon} = \boldsymbol{\alpha\beta}'\mathbf{z}$, which is captured in Eq. (13) as $\mathbf{\Pi z}_{t-k}$. Thus, the long-run coefficients in $\mathbf{\Pi}$ can be decomposed into two components as $\mathbf{\Pi} = \boldsymbol{\alpha\beta}'$. $\boldsymbol{\beta}$ is the $4 \times r$ matrix of coefficients on the vector $\mathbf{z}_{t-k}$ such that the term $\boldsymbol{\beta}'\mathbf{z}_{t-k}$ represents r long-run cointegration relationships in the multivariate model. These cointegration relationships ensure that $\mathbf{z}_t$ converges to its long-run equilibrium solution (around any deterministic trend), as the 'error' in the r long-run cointegration relationships in the system is 'corrected' in the system dynamics. The $4 \times r$ matrix $\boldsymbol{\alpha}$ represents the rate at which each of these 'errors' results in a 'correction' in the corresponding elements of $\mathbf{z}_t$, and so can be interpreted as a matrix of speed-of-adjustment parameters.

This presentation is predicated on the assumption that there is only one base industry F_t. Additional base industries can easily be accommodated by increasing the dimensionality of the analysis through expansion of the vector $\mathbf{z}_t$, to include the output of all such industries. Any long-run relationship between GDP and the several economic base industries would then be captured in one of the relationships in the error-correction vector $\boldsymbol{\varepsilon}_t = \boldsymbol{\beta}'\mathbf{z}_t$. Moreover, if there were to exist economic base industries that have not been incorporated in the empirical analysis, the effect of such industries would be included in this error term. If these effects were more than transitory, they would possess a unit root, and this unit root would then be incorporated in the corresponding error term. But then the relationship in question would no longer be recognized as a cointegration relationship, since such a relationship must have an error term that is stationary. What this suggests is that the cointegration tests implemented in this paper not only test whether an industry acts as an economic base, but also indirectly test whether there are any other industries, unaccounted for in the analysis, that also act as an economic base. On the basis of the tests discussed below, we conclude that the fishery was the only base industry in the Newfoundland economy during the period in question.

4. Data

We use annual data on real Gross Domestic Product, employment, net capital stock, and real value of landings of marine products, for the province of Newfoundland over the period 1961-1994. The span of this period is constrained by that of the net capital stock series that is used.[11] However, it does incorporate a period that saw the modernization of the fishing industry, the expansion of Canadian fisheries jurisdiction to the 200 mile limit, and the moratoria on the cod fisheries, while excluding the beginning of offshore oil production on the Grand Banks (which is potentially an emerging base industry).

The GDP series is obtained from Statistics Canada (1988, 1989-2001), and is deflated by the GDP deflator for Newfoundland beginning in 1981, when that deflator first became available.

For previous years this deflator was chained to the GDP deflator for Canada (Statistics Canada 1989). Employment is taken from the Statistics Canada Labour Force Survey, as reported in Statistics Canada (1995); unfortunately, a series based on this definition is not available before 1966. We obtained data for the period 1961-1975 based on the previous definition from Statistics Canada (1983), and found a consistent discrepancy in the range 3-4% in the two series over the overlap period. Therefore we extended the newer series back to 1961 by regressing the newer series on the older for the overlap period (obtaining $R^2 = 0.9988$), and using the regression to project estimates of the newer series for the period 1961-65. We are confident that any error so induced is well within the precision of the original survey instrument. Net capital stock is obtained from Statistics Canada (1994), using the geometric depreciation assumption. Production of the fisheries sector is based on value of landings as reported in Dominion Bureau of Statistics (1962-1977) up to 1976, and in Fisheries and Oceans Canada (1979-2003) thereafter. The series is deflated by a custom Divisia index (Tornqvist approximation) based on the implicit price for each species derived from the landings data.

5. Statistical Analysis

5.1 Testing the Order of Integration of the Variables

The determination of the order of integration of the variables is based on both augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The null hypothesis of a unit root can be accepted for all four variables. For fish landings, we can accept the hypothesis that there is neither a drift term nor a deterministic trend; for capital, we can do so with the ADF test but not the PP test. For the other variables, a deterministic trend is statistically significant under both tests. We can reject the hypothesis of a unit root in all the first differences, although the ADF tests are somewhat ambiguous in the case of capital and marine landings. We conclude from this analysis that all four variables have a unit root, but only one unit root, and so are integrated of order 1 [*I*(1)].

5.2. Tests of the Appropriate Specification of the VAR

To test for the appropriate lag length in the VAR model in Eq. (12), we initially estimated the model with lag length $k = 3$ (following Enders 2004, p 358), and then utilized the likelihood ratio test statistic recommended by Sims (1980). Alternatively, lag length can be selected using a multivariate generalization of an information criterion such as the Akaike (AIC). The presence of a deterministic trend in the vector autoregressive (VAR) process can be tested using the same methods. The results can be summarized as follows:

(1) The hypothesis that time trends are absent from the VAR is strongly rejected by the Sims test (*p*-value= 0.010). This result is supported by the Akaike, Schwartz, and Hanna-Quinn information criteria.

(2) The hypothesis that $\mathbf{A}_3 = \mathbf{0}$ (no three-period lags in any variable) cannot be rejected at any reasonable level of significance (*p*-value=0.36). However, the hypothesis that $\mathbf{A}_2 = \mathbf{A}_3 = \mathbf{0}$ (no two *or* three period lags in any variable) is rejected (*p*-value=0.019). The two results together imply that $\mathbf{A}_2 \neq \mathbf{0}$ while $\mathbf{A}_3 = \mathbf{0}$. As well, the information criteria are all minimized when the lag length is 2. The VAR was reestimated with a lag length of 2. These results were confirmed in the

context of the new model. On the basis of these results, we test for cointegration in the context of the VECM

$$\Delta \mathbf{z}_t = \boldsymbol{\Gamma}_1 \Delta \mathbf{z}_{t-1} + \boldsymbol{\Pi}\, \mathbf{z}_{t-2} + \boldsymbol{\delta} t + \boldsymbol{\mu} + \mathbf{u}_t \tag{14}$$

which is Eq. (13) with $k = 2$ and including a constant and time trend.

5.3. Testing for the Existence and Number of Cointegration Relationships

Johansen (1988) has developed procedures to test for the rank of $\boldsymbol{\Pi}$ in Eq. (14) and therefore for the number of cointegrating relationships in the data, by testing for the number of eigenvalues λ_i, derived from a related positive semidefinite matrix, that are greater than zero. His λ-*trace* statistic is used to test the null hypothesis that there are at most r non-zero eigenvalues (and therefore at most r cointegration vectors in the data), r being a fixed parameter. An alternative test is based on the λ-*max* statistic which is used to test the null hypothesis that there are exactly r cointegration vectors, against the alternative that there are r+1. Note that the λ-*max* test has more specific null and alternative hypotheses than does the *λ-trace* test. While this characteristic sharpens the test, it is possible that both the null and alternative hypotheses are false, in which case the test results are ambiguous.

Insert Table 1 around here.

The results of the two tests for various values of r are presented in Table 1. For $r = 0$, the tested hypothesis is that there are no cointegration vectors in the system, so that $\boldsymbol{\Pi} = \mathbf{0}$ and therefore the matrix has rank 0.[12] The λ-trace test strongly rejects this hypothesis; the λ-max test also rejects the hypothesis, but less decisively. This makes perfect sense, because the alternative hypothesis in the λ-max test is that there is exactly one non-zero eigenvalue (i.e. one cointegration vector) while, as shown in Table 1, the two largest eigenvalues are almost the same size. It would be difficult to conclude that one is zero while the other is not, and this is what the λ-max test is telling us. When we test the hypothesis that there is no more than one cointegration vector $r = 1$), both tests reject, the max test strongly (being the sharper test) and the trace test more tepidly. Both tests support the null hypothesis that there are no more than two cointegration vectors $r = 2$). We conclude that the Johansen tests provide the strongest support for the hypothesis that there are two cointegration vectors, and so we estimate the VECM on that basis.

5.4. Identification of the cointegration relationships

The results of the cointegration tests suggest that among the four variables in the model, there are two long-run relationships (incorporated in the matrix $\boldsymbol{\beta}$ in the VECM) that are sufficiently persistent that deviations from this relationship are stationary. Unfortunately, disentangling distinct cointegrating relationships from integrated time series is not always easy (Johansen and Juselius 1992, 1994). The eigenvectors corresponding to the two significant eigenvalues in the Johansen analysis can help in doing this, however, because a cointegration relationship must lie in the vector space spanned by these eigenvectors[13].

The two eigenvectors corresponding to the significant eigenvalues (normalized on the numerically largest element) are as follows:

Y_t	-0.023	1
L_t	1	-0.441
K_t	-0.261	-0.249
F_t	-0.039	-0.089

The first eigenvector appears to be at least a part of an expansion-path type growth relationship between labor and capital, whereby additional capital induces demand for additional labor (and/or vice versa). The other two variables make very little contribution here; in fact, we cannot reject the null hypothesis that a vector with zeroes corresponding to these variables spans the cointegration space (the log-likelihood ratio, which is asymptotically $\chi^2(4)$, is 1.65, which has a p-value of 0.80). Thus the evidence strongly suggests the existence of a cointegration relationship between labor and capital alone, and we can identify this relationship by the imposition of the overidentifying restrictions $\beta_{Y1} = \beta_{F1} = 0$ on the first column $\boldsymbol{\beta}_1$ of the cointegration matrix $\boldsymbol{\beta}$.

The second eigenvector appears to reflect a long-run relationship (possibly a production relationship) among GDP, the two primary factors, and fisheries production. All four variables contribute reasonably strongly to the relationship, although the labor parameter is somewhat smaller than we would expect from a production relationship. Unfortunately, such a production relationship in all four variables is not fully identified. The reason is that it is not possible to distinguish between the true structural relationship $\boldsymbol{\beta}_2$ (the second column of the cointegration matrix $\boldsymbol{\beta}$), which hypothetically consists of all non-zero elements, and a linear combination of the two structural relationships $\boldsymbol{\beta}_2$ and $\boldsymbol{\beta}_1$. Therefore, while the second eigenvector may contain the production relationship $\boldsymbol{\beta}_2$, it may also incorporate elements from $\boldsymbol{\beta}_1$ as well. The unexpectedly small value of the element corresponding to labor (0.441) suggests that this may in fact be the case.

Because of the identifying restrictions $\beta_{Y1} = \beta_{F1} = 0$ on the first relationship $\boldsymbol{\beta}_1$, the corresponding elements in $\boldsymbol{\beta}_2$ are not affected, and so the parameter β_{F2} (which reflects the contribution of fisheries production as an economic base to GDP) *is* identified. However, the same cannot be said for the remaining elements of $\boldsymbol{\beta}_2$, β_{L2} and β_{K2}, which remain unidentified unless further identifying restrictions can be imposed.[14] We can force identification by utilizing the close association of the production elasticities of the primary factors with their shares of the product. The share of labor in net national income at factor cost averaged 0.75 (with standard deviation 0.029) over the sample period.[15] The restriction $\beta_{L2} = 3\beta_{K2}$ is (almost[16]) sufficient to identify all the parameters in the production relationship. It must be emphasized that *only the otherwise unidentified parameters —* β_{L2}, β_{K2}, *and the* α_{i1} *— depend on this restriction*. The estimates of the other parameters are not affected.[17]

5.5. Model Estimation

Upon incorporating the identifying restrictions, we can express the cointegration equations $\boldsymbol{\beta}'\mathbf{z}_t$, net of any embedded constant terms and time trends[18], as follows:

$$
\begin{aligned}
L_t &= \beta_{K1} K_t + \varepsilon_{1t} \\
Y_t &= \beta_{L2} L_t + \beta_{K2} K_t + \beta_{F2} F_t + \varepsilon_{2t} \qquad (15) \\
\beta_{L2} &= 3\beta_{K2}
\end{aligned}
$$

and the dynamic vector error-correction model (VECM) as:

$$\Delta Y_t = \gamma_{YY}\,\Delta Y_{t\text{-}1} + \gamma_{YL}\,\Delta L_{t\text{-}1} + \gamma_{YK}\,\Delta K_{t\text{-}1} + \gamma_{YF}\,\Delta F_{t\text{-}1} + \alpha_{Y1}\varepsilon_{1,t\text{-}2} + \alpha_{Y2}\varepsilon_{2,t\text{-}2} + \delta_Y\,t + \mu_Y + u_{Yt}$$

$$\Delta L_t = \gamma_{LY}\,\Delta L_{t\text{-}1} + \gamma_{LL}\,\Delta L_{t\text{-}1} + \gamma_{LK}\,\Delta K_{t\text{-}1} + \gamma_{LF}\,\Delta F_{t\text{-}1} + \alpha_{L1}\varepsilon_{1,t\text{-}2} + \alpha_{L2}\varepsilon_{2,t\text{-}2} + \delta_L\,t + \mu_L + u_{Lt} \qquad (16)$$

$$\Delta K_t = \gamma_{KY}\,\Delta K_{t\text{-}1} + \gamma_{KL}\,\Delta L_{t\text{-}1} + \gamma_{KK}\,\Delta K_{t\text{-}1} + \gamma_{KF}\,\Delta F_{t\text{-}1} + \alpha_{K1}\varepsilon_{1,t\text{-}2} + \alpha_{K2}\varepsilon_{2,t\text{-}2} + \delta_K\,t + \mu_K + u_{Kt}$$

$$\Delta F_t = \gamma_{FY}\,\Delta Y_{t\text{-}1} + \gamma_{FL}\,\Delta L_{t\text{-}1} + \gamma_{FK}\,\Delta K_{t\text{-}1} + \gamma_{FF}\,\Delta F_{t\text{-}1} + \alpha_{F1}\varepsilon_{1,t\text{-}2} + \alpha_{F2}\varepsilon_{2,t\text{-}2} + \delta_F\,t + \mu_F + u_{Ft}$$

This equation system is estimated jointly by maximum likelihood after substituting the cointegration equations (15) directly into the error-correction model (through the $\varepsilon_{i,t\text{-}2}$). The system does contain non-linear cross-equation restrictions on the β_{ij} parameter estimates, but is otherwise linear.

(i) Cointegration model

The cointegration model (15) is estimated as:

$$L_t = \underset{(0.050)}{0.264}\,K_t + \varepsilon_{1t} \qquad (17)$$

$$Y_t = \underset{(0.049)}{0.612}\,L_t + \underset{(0.016)}{0.204}\,K_t + \underset{(0.020)}{0.088}\,F_t + \varepsilon_{2t} \qquad (18)$$

Estimates of the parameters in the error-correction model (16) are presented in Table 2 and discussed below.

The estimated Eq. (18) suggests that the fishing industry plays a significant role as an economic base for the economy of Newfoundland and Labrador, quite independent of the returns to the factors of production it employs. While the output elasticity which can be ascribed to this effect, at 0.088, is not large, it is nonetheless impressive given that the total value of fish landings in Newfoundland accounts for only about 3 percent (0.03) of Gross Domestic Product, and actual value-added in the harvesting sector about half that,[19] so the leverage these landings provide appears to be considerable.[20]

The implications of Eq. (17), while not part of the focus of this paper, are also of interest. The estimate suggests that capital investment in the economy of Newfoundland and Labrador is not accompanied by a proportionate increase in employment; specifically, a 10 percent increase in capital stock is associated with only a 2.6 percent increase in employment. The model as presently constituted cannot speak to why this is the case, but the result is consistent with the observed tendency of the economy of Newfoundland and Labrador to import capital and export labor, and may shed some light on why most attempts to create employment in Newfoundland and Labrador by attracting investment have not been successful.

Two hypotheses involving the cointegration parameters in the equilibrium relationships (17) and (18) are of particular interest. The first is $H_0 : \beta_{F2} = 0$ — fishing makes no contribution to GDP independently of the primary factors it utilizes. This hypothesis is decisively rejected in a likelihood ratio test, with a p-value of 0.0024.[21] The second is $H_0 : \beta_{K1} = 1$ — changes in capital stock bring forth proportionate changes in employment. We could not actually test this hypothesis, because we could not successfully estimate a model incorporating this restriction due to non-convergence (a maximum for the likelihood function could not be located — often an indicator that the model is seriously inconsistent with the data). We *were* able to test the hypothesis that $\beta_{K1} = 0.8$, and were able to reject this hypothesis with a p-value of 0.000038.

(ii) Error-correction Model

The parameter estimates of the vector error-correction model (16) are reported in Table 2 along with the asymptotic standard errors. For the purposes of this study, the key equation is the first one, controlling the GDP variable Y, whose results are reported in the first column of numbers in Table 2. The parameters can be categorized into three classes: the short-run multipliers γ_{ij}, the cointegration adjustment-speed parameters α_{ij}, and the time trends δ_i.

Insert Table 2 around here.

The short-run multipliers measure one-period Granger-causal effects among the variables in the model that may exist outside the error-correction process. In the estimated model, these short-run effects do not contribute much to the dynamics of the system. Most of the estimated parameters are small and statistically insignificant. GDP and capital stock are autoregressive but stable. A change in fisheries production has a small ($\gamma_{YF} = 0.102$) but highly significant positive impact on the change in GDP one year later, which is consistent with expectations.

The importance of the long-run equilibrium effects depend on the size of the adjustment parameters α_{ij} attached to the error-correction terms ε_{ij}. Most of these parameters are statistically significant, the exceptions being the adjustment parameters in the capital equation. This is not too surprising, given the lack of malleability of capital and the fact that the capital series used takes no account of capital utilization, which might be expected to play a substantial role in the adjustment process. Notwithstanding this consideration, the joint hypothesis H_0: $\alpha_{K1} = \alpha_{K2} = 0$ (both error-correction terms are absent from the capital equation) cannot be rejected by a Wald test at any reasonable level of significance ($W = 2.12$, p-value = 0.35), so we cannot reject the hypothesis that capital is exogenous to the error-correction process and plays no role in that process.

The second set of error correction terms α_{i2} control the adjustment of the model variables to the long-run production relationship. These estimates imply that deviations from this relationship are self-correcting. An economy that is producing more than can be sustained in the long-run with existing factor utilization will respond by reducing GDP and increasing both employment and (at 10% significance) capital stock. The opposite happens to an economy with underutilized production factors. All of this is as would be expected, and indicates that GDP and the primary factors of production behave in a stabilizing manner.

On the other hand, the substantial role played by fisheries production in this error-correction process is a surprise. The economic-base theoretical model outlined in Section 2 implies that the base activity (here, fish production) has a significant impact on economic activity generally, but there is nothing to suggest that there is any feedback from economic activity to the base. Economic base theory is generally predicated on the presumption that the base activity is exogenous, and the direction of causation is unidirectional from the base activity to GDP.

The estimates of the error-correction model, by contrast, imply a substantial (α_{F2} = 2.258) and certainly statistically significant feedback relation from the long-run production relationship to fisheries production, suggesting that the base activity not only has an important leverage effect on GDP, but also plays a role in the adjustment process. For example, an economy that is producing more than can be sustained in the long run with existing factor utilization responds not only by reducing GDP and increasing both employment and capital stock, but also by expanding the base activity — which in turn enhances the production capacity of the economy. Therefore, the relationship between the base and non-base industries is not unidirectional; the two sectors feed on one another in a mutually reinforcing way.[22] This is a provocative result, not previously suggested in economic base analysis, and it would be worthwhile to examine whether this result is repeated in other economies, or whether it is an anomaly specific to this economy.

The time trends are mostly significant but small. The largest is a *negative* 3 percent trend in fisheries production, and probably reflects the effect of resource depletion over the sample period.[23]

In summary, once error-correction effects are incorporated into the model, the variables in the model are closely intertwined, all variables Granger-causing one another. Only capital may be an exception; at a 5% (but not 10%) level of significance, none of the other variables Granger-cause capital stock.

5.6. Model diagnostics

Diagnostic tests of the model are briefly summarized here. There is no evidence of autocorrelation in the residuals of any of the equations in the error-correction model, suggesting that the model has adequately captured all the dynamic effects. The hypothesis that the residuals are normally distributed cannot be rejected for any of the equations. There is some evidence of heteroskedasticity (except in the fish production equation), but the evidence is spotty and unsystematic; there is no evidence of a consistent pattern of heteroskedasticity. As it happens, the presence of heteroskedasticity does not affect the limit distributions of the estimates in this model (Rahbeck et al. 2002). These results all support the characterization of the model estimates as maximum likelihood.

Model specification and stability tests do not reveal any concerns regarding model misspecification or parameter shifts, with the possible exception of the capital equation, which may have experienced a (possibly transitory) structural shift in the early 1970s. It is unlikely that such a shift would have significantly affected our results; Campos et al. (1996), for example, have documented that shifts in the levels of integrated variables do not affect the size of the test of the null hypothesis of no cointegration, so long as the shift has not affected the cointegrating relationship itself.

5.7. Model Reduction

The error-correction results reported in Table 2 contain many estimates that are statistically insignificant, and have a weak theoretical base for inclusion; this is particularly the case with respect to the short-run multipliers γ_{ij}. Most researchers proceed by eliminating such parameters from a final parsimonious version of the model. In our case, sequentially dropping the most statistically insignificant (at a 5% level) variables eliminates 16 parameters, and results in the model presented in Table 3.[24]

Insert Table 3 around here.

The implications of the parsimonious model are roughly the same as those of the reduced model. None of the parameters that remain change very much, and the statistical significance of most parameters improves. There is no strong theoretical case to be made for the inclusion of any of the removed parameters, although the removal of both error-correction terms from the capital equation does imply that this variable is exogenous.

6. Conclusion

While the fishery has historically been the mainstay of the economy of Newfoundland and Labrador, its importance has declined precipitously over the last century. The boom-or-bust character of the economy of Newfoundland and Labrador is nonetheless mirrored in the chronic instability of the fishery, both on the resource side and the market side, raising the possibility of a relation between the two that goes beyond the direct contribution of the fishery to value added.

This direct connection is consistent with the notion that certain industries act as an economic base for the rest of the economy. The idea of an economic base has a long history, but it is not an idea that is particularly well-formed. In section 2, we attempted to incorporate the concept into a macroeconomic model, in order to extend in a modest way our understanding of how an economic base industry could be expected to work in impacting the broader economy. In the latter part of the paper, beginning with section 3, we tested the hypothesis that the fishery has an impact on the broader economy in Newfoundland and Labrador over and above its contribution to value added. The hypothesis was tested using cointegration analysis, establishing the existence of a long-run cointegrated relationship between gross domestic product, inputs of primary factors of production, and the size of the fishery.

The conclusion from this analysis is that the size of the fisheries sector in Newfoundland and Labrador has a direct impact on the size of the economy, over and above its contribution to value added (which would be reflected in its employment of the primary factors of production). An effect of this nature is consistent with a role for the fishery as an economic base for the economy of Newfoundland and Labrador.

The elasticity of this direct effect, at 0.088 (0.102 in the parsimonious model) is not large; however, it is about three times the direct contribution of the harvesting sector to the GDP. Moreover, the model does predict that, for example, the expansion in the crustacean fishery in the period between 1994 and 2004 would have contributed 8-9 percentage points to the 44 percent growth in the economy of Newfoundland and Labrador that occurred during this period as a result of this leverage effect.

Were there other base industries in this economy? While a direct test of this possibility would be desirable, we can tentatively conclude that there were not. If such industries existed, we would expect their effects to enter into the estimated cointegration relationship along with GDP, the primary factors of production, and the fishing industry. Since these have not been explicitly accounted for in the analysis, these non-transitory effects would be incorporated into the residual term, which would introduce a unit root into the residual. Since there is no unit root here (otherwise the variables would not be cointegrated), we can conclude that there is no evidence of any economic base industries in this economy in this period, other than the fishery. A direct test of this proposition would be useful, but must await further research.

The error-correction model estimated in section 5 provided a number of additional interesting implications.

(1) The implicit 'expansion path' of the economy of Newfoundland and Labrador appears to be strongly biased toward capital and away from labor, making it difficult to resolve through capital investment the deep-seated unemployment problems that have characterized this economy for generations;

(2) Standard economic-base theory is a static analysis, but the direction of causality is implicitly assumed to flow from an autonomous economic base to general economic activity. In contrast, the relationship between the two in this economy is apparently bidirectional and mutually reinforcing (but still convergent), so that an increase in economic activity acts to expand the economic base as well as vice-versa. While not inconsistent with economic base theory, this feedback relationship adds a new dimension to the effects usually implied in such models.

(3) The variables in the model are closely intertwined, and all (with the possible exception of capital, which may be exogenous) Granger-cause one another.

However, we would like to emphasize that our methodology merely shows that the data are consistent with fisheries being a base industry; it does not conclusively prove that this is so. It would strengthen the empirical evidence for the existence of base industries if the existence of these other (non-base) industries was empirically verified. To do that the first step would be to test our methodology on these other industries. The second step would be to develop tests specifically designed to identify non-base industries.

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Table 1. Johansen Tests of Cointegration Rank

H_0 :	λ_i	λ_{trace}	$\lambda_{\max}$
$r = 0$	0.556	55.9^{***}	26.0^{*}
$r = 1$	0.531	29.9^{*}	24.2^{***}
$r = 2$	0.148	5.7	5.1
$r = 3$	0.017	0.5	0.5

*** , **, and * represent rejection of the null at 5%, 10%, and 20% levels of significance respectively.

Table 2. Maximum-Likelihood Estimates of Error-Correction Model Eq. (16), with Asymptotic Standard Errors

$i =$	Y	L	K	F
γ_{iY}	-0.873^{***}	0.097	0.114	0.521
	(0.159)	(0.158)	(0.185)	(0.694)
γ_{iL}	-0.238^{*}	-0.094	-0.159	-1.450^{**}
	(0.165)	(0.164)	(0.186)	(0.738)
γ_{iK}	-0.379^{***}	-0.115	0.466^{***}	-2.283^{***}
	(0.150)	(0.143)	(0.164)	(0.629)
γ_{iF}	0.102^{***}	-0.010	-0.063	0.062
	(0.045)	(0.045)	(0.051)	(0.203)
α_{i1}	-0.380^{***}	-0.432^{***}	0.115	-0.806^{*}
	(0.100)	(0.100)	(0.124)	(0.481)
α_{i2}	-0.453^{**}	0.399^{**}	0.293^{*}	2.258^{***}
	(0.174)	(0.184)	(0.216)	(0.795)
δ_i	0.007^{**}	-0.001	-0.007^{**}	-0.033^{**}
	(0.003)	(0.003)	(0.004)	(0.015)
μ_i	2.419^{***}	-0.074	-1.099^{*}	-4.337^{*}
	(0.642)	(0.666)	(0.751)	(3.079)
R^2	0.7	0.64	0.66	0.54

***, **, and * represent rejection of the null at 1%, 5%, and 10% levels of significance (one-tailed) respectively.

Table 3. Maximum-Likelihood Estimates of Parsimonious Model,

with Asymptotic Standard Errors

i =	Y	L	K	F
β_{i1}			0.255	
			(0.048)	
β_{i2}		0.599	0.200	0.102
		(0.046)	(0.015)	(0.019)
γ_{iY}	-0.952^{***}	—	—	—
	(0.149)			
γ_{iL}	—	—	—	—
γ_{iK}	-0.306^{**}	—	0.665^{***}	-1.958^{***}
	(0.151)		(0.097)	(0.527)
γ_{iF}	0.114^{***}	—	—	—
	(0.039)			
α_{i1}	-0.346^{***}	-0.392^{***}	—	—
	(0.105)	(0.075)		
α_{i2}	-0.539^{***}	0.309^{***}	—	2.286^{***}
	(0.180)	(0.063)		(0.527)
δ_i	0.008^{***}	—	—	-0.042^{***}
	(0.003)			(0.009)
μ_i	2.624^{***}	0.100	0.086^{*}	-6.522^{***}
	(0.616)	(0.115)	(0.006)	(1.793)

***, **, and * represent rejection of the null at 1%, 5%, and 10% levels of significance (one-tailed) respectively.

Legend Figure 1: Marine Landings as percent of Gross Domestic Product, Newfoundland, 1961-1994.

Notes

1.Innis argued that Canadian economic development was driven by the exploitation of staple commodities: fish, fur, lumber, agricultural commodities, and minerals. The idea has since been used to study the economies of other countries that are dependent on natural resource development. See the Wikipedia entry at http://en.wikipedia.org/wiki/Staples_thesis for additional information.

2.According to the 1901 census, 61 percent of the labor force worked in a fishing occupation (Copes 1970, Table 3).

3.It works just as well but is slightly more complicated to assume an initial positive level of GDP.

4.Actually, even imports normally require some local importation and distribution services.

5.As is easy to check, it makes almost no qualitative difference to assume that this output is consumed locally.

6. For simplicity capital is left out of this model.

7.For instance, the harnessing of a water reservoir in an arid but otherwise favorable area is often the foundation for a local economy.

8. For example, some conventional economic base theory (e.g., Schaffer 1999, ch. 2) models the base activity as acting through a simple Keynesian multiplier, and so working only through demand rather than supply.

9.For simplicity, constant terms and deterministic regressors such as dummy variables and time trends have been suppressed in Eq. (12).

10. However, there can be no more than three such relationships in a 4-variable model, since otherwise the homogeneous system $\mathbf{\Pi}\, \mathbf{z}_{t-k} = 0$ would be non-singular and so would have no non-trivial solution. The problem here is that 4 independent relationships would completely determine

the 4 variables in the system, so that a unique *stationary* solution would exist, leaving no room for stochastic trends. For example, the VAR represented in Eq. (12) has a steady-state solution ($\mathbf{z}_{t-i} = \mathbf{z}_t$ for all i) if the matrix $\mathbf{I} - \mathbf{A}_1 - ... - \mathbf{A}_k$ (which, as noted in the derivation of Eq. (13), is equal to $-\mathbf{\Pi}$) is invertible (and therefore non-singular). The existence of such a stationary solution is inconsistent with the presence of non-stationary stochastic trends (and therefore cointegration) in the data. In other words, $\mathbf{\Pi}$ can be non-singular only when the variables in $\mathbf{z}$ are all $I(0)$ (i.e., stationary). Otherwise, Eq. (13) would consist of an inconsistent mixture of $I(0)$ (the $\Delta\mathbf{z}$'s) and $I(1)$ ($\mathbf{\Pi}\, \mathbf{z}_{t-k}$) variables.

11.A data redefinition in Statistics Canada's capital stock estimates after 1994 renders subsequent estimates inconsistent with this series.

12. In this case, Eq. (13) becomes an ordinary VAR in first differences; because all variables are $I(0)$, the VAR can be estimated efficiently by OLS.

13.However, because eigenvectors are orthogonal, they are not themselves likely to be the structural relationships embodied in $\boldsymbol{\beta}$.

14.Since the decomposition of $\mathbf{\Pi}$ into $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}'$ depends on identifying $\boldsymbol{\beta}$, a failure to identify $\boldsymbol{\beta}_2$ means that the first column of the adjustment-speed matrix $\boldsymbol{\alpha}$ is not identified either.

15.This statistic is obtained from Statistics Canada (1988, 1989-2001), by dividing Wages, Salaries and Supplementary Labor Income by Net Domestic Income at factor cost.

16. The rank condition $\beta_{K1}\, \beta_{L2} + \beta_{K2} \neq 0$ must also be satisfied. This condition will be satisfied if these parameters are all positive, as theory suggests they should be.

17. The restriction only *just*-identifies the parameters, and so it cannot itself be tested, because it is not nested within a more general model that is itself identified.

18.Constant terms and time trends specific to the cointegration equations cannot be identified, and so are not estimated. They are instead incorporated into the constant terms and time trends in the error-correction model (16). Nothing in our model turns on the identification of these parameters.

19.Statistics Canada (2005) uses an input-output table to estimate that the “direct impact” of $100 million in new spending on Newfoundland by fishing, hunting and trapping in 2000/2001 was only $46 million. Government of Newfoundland and Labrador (2002) estimates that the direct economic impact of fish harvesting over the period 1997-1999 averaged $244 million, which, based on landings averaging $426 million, implies a direct impact ratio of 0.57. The harvesting industry incurs significant expenditures on fuel and on repair and maintenance, much of this originating from outside the province.

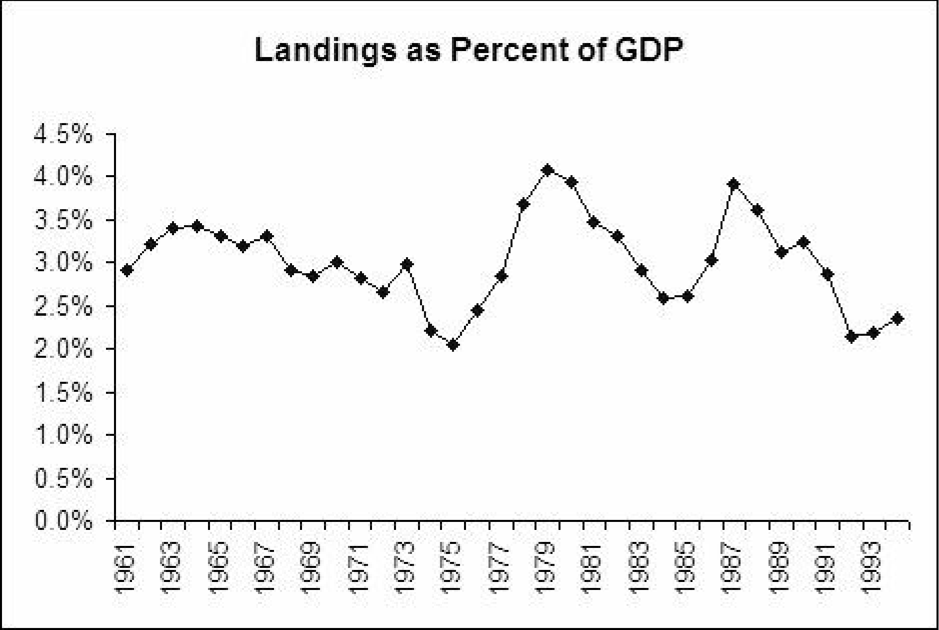
20.An output elasticity of 0.088 implies an output multiplier of 2.96, based on the average values for GDP and fish landings over the sample period, and assuming that utilization of primary factors of production does not change. This value is considerably larger than estimates derived using other methods. For example, Government of Newfoundland and Labrador (2002) uses an input-output model and a conventional econometric model to estimate a total economic impact of fish harvesting and processing in 1997-99 averaging $808 million, about 1.9 times the average value of landings in this period.

21.Because the estimate of the cointegrating vector $\boldsymbol{\beta}$ converges to a mixed Gaussian distribution, the associated *t*-, *F*-, and Wald statistics require a scaling factor that differs from the inverse of the standard deviations reported in Eqs. (17) and (18), and so the conventional test statistics cannot be used (Johansen 1996). However, the parameter estimates are maximum-likelihood, and likelihood-ratio tests remain valid, and are distributed asymptotically as χ^2 (Johansen 1996).

22.The size of the adjustment parameter (2.258) may lead to concerns that this feedback process is not stable. In fact, what determines stability is not the size of α_{F2}, but that of $\alpha_{F2}\ \beta_{F2}$, which is about 0.2. This reflects the strength of the error-correction which acts directly through F_t, and while not trivial, is nowhere near the size needed to create instability.

23.Groundfish stocks in particular were continually depleted over the period of our sample, and by the end of the sample, most groundfish fisheries had been closed to exploitation (Schrank 1995). Biomass in the important Northern Cod stock complex, for example, is estimated to have declined from about 3 million tonnes in the early 1960s to less than 100,000 tonnes in the early 1990s (Fisheries and Oceans Canada 2007; Walters and McGuire 1996). However, some of the associated fishing effort was diverted into an expanding crustacean fishery.

24.At each stage in the reduction process, we confirmed by a likelihood-ratio test that the reduced model was not significantly different from the original, unreduced model. At no time did the likelihood ratio test yield a *p*-value below 0.6.



Landings as Percent of GDP
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
1961
1963
1965
1967
1969
1971
1973
1975
1977
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1981
1983
1985
1987
1989
1991
1993