GROWING THE SEAFOOD SECTOR: TECHNICAL CHANGE AND INNOVATION

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ABSTRACT

The scope for fishing firms operating in an output controlled fishery, with tradable rights, and facing world prices, to augment profit is limited inter alia to a search for alternative input configurations that lower harvesting costs. This paper provides evidence of technical change in the New Zealand rock lobster fishery. Industry response to a declining allowable harvest is seen in the percentage of harvesting rights exercised increasing over the 1992-2000 period. Over this period the total lobster fleet has steadily declined. Average output per firm, output per labour unit, and the capital-labour ratio have all increased. Econometric analysis finds the rate of technical change to have steadily increased over the period. The contribution of improving vulnerable biomass to lower harvesting costs is controlled for. Another innovation is seen in the seasonal shift of fishing effort, timed to coincide with better market prices. Clearly new technologies will continue to offer scope for lowering harvesting costs. Given the harvest constraints facing this industry economic growth in the future will also depend on innovations occurring through organizational design and contracting at various points along the chain of supply to market. Well-defined harvesting rights provide not only a degree of certainty over access to fish stocks they also provide a platform for contracting product supply that matches demand. Historically, seafood companies with an export focus have shown a preference for research and innovation aimed at increasing production and quality of production, rather than developing new product opportunities.

Keywords: Technical change; innovation; economic growth of seafood sector

INTRODUCTION

The scope for fishing firms operating in an output controlled fishery, with tradable rights, and facing world prices, to augment profit is limited inter alia to a search for technologies and innovations that lower harvesting costs. Cost reductions ceteris paribus could also flow from improvements in the vulnerable biomass over time. Aside from biological sustainability, technical change and innovation will have great influence on the capacity of industry to sustain economic growth.

In this paper we tackle the empirical challenge of estimating technical change while controlling for changes in the vulnerable biomass. The paper is organized as follows; firstly we provide an overview of technological change and innovation, secondly we describe trends in harvest levels, catch per unit effort, changes in the within season distribution of effort, and summary statistics on employment and capital within the rock lobster fishery. The results of pooled time series estimation of a cost function are summarized, from which we derive estimates of the rate of technological change occurring over the 1992-2000 period. Finally, the paper concludes with a general discussion.

TECHNOLOGICAL CHANGE AND INNOVATION

Standard cost minimisation sees a firm with a given production relation responding to changes in relative prices. Technical change alters the mapping of inputs into output. The classification scheme provided by Hicks (1946) sees a labour-saving (capital-saving) innovation as one that raises the marginal product of capital (labour) relative to that of labour (capital) at a given capital-labour ratio employed in producing a

* We acknowledge support of the Foundation for Research Science and Technology, the Ministry of Fisheries, the New Zealand Seafood Industry Ltd, and Statistics New Zealand. We alone are responsible for any remaining errors.
given output. Profit is seen as a return on innovation. However, Dosi (1997) claims that there is a lack of evidence supporting the hypothesis that the intensity of the search for innovation grows monotonically with the expected value of the resultant rent stream. In the following sections we identify areas that might fuel technological change and innovation.

**Regulatory Environment**

According to Porter and Linde (1995) the notion that environmental regulation is a burden on industry arises out of an incorrect framing of the issue. Rather than adopting a static view of environmental regulation they suggest competitiveness arises out of a dynamic framework based on innovation. Turning to rock lobster, limiting annual harvest levels to an operational definition of sustainability is a central plank in rights based management. This system of governance can work to foster innovation by:
1. Signaling likely resource inefficiencies and potential technological improvements.
2. Reducing uncertainty by ensuring that investments in sustainable utilization will ultimately add value.
3. Foster continuous innovation rather than locking in technology.
4. Endogenising innovation within industry rather looking to government.
5. Creating a level playing field where fishing firms cannot gain advantage by avoiding conservation.

**Government Incentives and Innovation**

Reid’s (1998) study of the British herring fishery highlights the adverse impact that government policy can have on innovation. The Herring Industry Council focused on modernising the herring fleet using a range of instruments viz. (1) research and development (R&D) into new fishing technologies; (2) grants and loans to subsidise investment; (3) minimum price and vessel subsidies to support incomes and encourage participation in the industry. Unfortunately, the incentives created for achieving this transition resulted in over-fishing and the increase in supply was short-lived.

Davis et al. (1987) utilize the history of whaling to observe the effects of technical change and government policy on the process of economic change. By choosing whaling they aimed to sort out pure productivity effects, including capital and human resources, and the institutional structure that regulated and constrained whaling. The North Atlantic was chosen for their study because it was here that competition between the British and American fleets was most intense. Four factors contributed to the British loss in the competition with the Americans: failure in vessel design, failure of seamen, high cost of vessels and changes in government policy.

**Organisational Structure**

Firm size is often considered a factor in technological adaptation. This of course is the Schumpeterian thesis that, other things being equal, large firms are more adept at making technological innovations than small firms. This proposition is testable. In the fishing sector Floc’h and Fuchs (2001) suggest that small and medium-sized firms are more adept at making technical innovations because their size allows them more flexibility in designing new capturing techniques or processing. However, when organisational structure is endogenous, as in the Aghion and Tirole (1994) model, the relationship between R&D input (or output) and parameters such as scale, scope or monopoly power is not clear.

Early models of vertical integration are based on the inability to write complete contracts between a single supplier producing an input for a single buyer (Williamson, 1985). Bolton and Whintson (1993) extend the model into a multilateral trading arrangement. Determining the scope of the firm in a multilateral trading system is more complex because of interactions arising with other firms. In a bilateral setting a
move from non-integration to vertical integration is optimal when network externalities exist (David, 1985). In a multilateral setting non-integration may be optimal where transaction costs are high and concerns over supply assurance are great. Their results stand in contrast to empirical findings that often attribute integration to supply assurance concerns.

**Process and Product Innovation**

Process innovations are defined as any adopted improvement in technique that reduces average costs at given input prices (Blaug, 1988). Product innovations alter the output itself. The distinction between process and product innovation may blur in practice.

Athey and Shmuzler (1995) describe demand enhancing (product) and cost reducing (process) innovations as complementary because they work together to increase the firm’s net revenue in the short run. Returns to implementing a product innovation are highest when the firm also implements a process innovation. For example, if a firm implements a product innovation (e.g. fillets) that shifts out the demand curve, then the firm will increase output. But returns from process innovation (e.g. special filleting machinery) will also work to lower unit costs. Thus the firm will implement both innovations together. Capon et al. (1992) find firms that engage in mainly process innovation performed worse relative to firms that engaged in both types of innovation. Market structure is also a relevant consideration because product flexibility allows the firm to strategically locate its product in a wider range of products in the market (Eaton and Schmidt, 1993).

**NEW ZEALAND ROCK LOBSTER FISHERY**

The Ministry of Fisheries is directed by legislation to set the total allowable catch (TAC) in the direction of maximum sustainable yield. The TAC is further partitioned into a total allowable commercial catch (TACC) and an allowance made for non-commercial use. Only commercial rights are tradable as individual transferable quota (ITQ). Nine quota management areas (QMAs) cover the entire New Zealand fishery. Stocks within these QMA are generally managed separately within the QMS.

**Industry Organization**

The NZ Rock Lobster Industry Council is an umbrella agency representing the commercial fishery interests of New Zealand’s nine regional rock lobster stakeholder groups (http://www.seafood.co.nz/industry/otoz/rlcoun/). Membership comprises fishing and non-fishing quota owners, quota holders, permit holders, processors and exporters from within the nine designated management areas. Each regional group contributes to the Council's operational budget in proportion to the region's TACC. The Council provides a range of technical, administrative, research, science, and management services.
Table 1: Biomass, TACC and Commercial Harvest 1992-2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Vulnerable biomass (t)</th>
<th>TACC (t)</th>
<th>Catch (t)</th>
<th>Caught (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>360</td>
<td>3,616</td>
<td>3,066</td>
<td>85</td>
</tr>
<tr>
<td>1993</td>
<td>475</td>
<td>3,265</td>
<td>2,644</td>
<td>82</td>
</tr>
<tr>
<td>1994</td>
<td>590</td>
<td>2,913</td>
<td>2,755</td>
<td>95</td>
</tr>
<tr>
<td>1995</td>
<td>713</td>
<td>2,913</td>
<td>2,622</td>
<td>90</td>
</tr>
<tr>
<td>1996</td>
<td>925</td>
<td>2,913</td>
<td>2,536</td>
<td>87</td>
</tr>
<tr>
<td>1997</td>
<td>1083</td>
<td>2,954</td>
<td>2,645</td>
<td>90</td>
</tr>
<tr>
<td>1998</td>
<td>1102</td>
<td>2,865</td>
<td>2,553</td>
<td>89</td>
</tr>
<tr>
<td>1999</td>
<td>1041</td>
<td>2,927</td>
<td>2,718</td>
<td>93</td>
</tr>
<tr>
<td>2000</td>
<td>963</td>
<td>2,849</td>
<td>2,748</td>
<td>96</td>
</tr>
</tbody>
</table>

Source: Clement and Associates (2001), Breen et al. (2001), Annala et al. (2001)

**Trends**

Estimates of vulnerable biomass for each of the nine quota management areas are not available. The data presented in Table 1 are an average of the median vulnerable biomass over five QMAs for which estimates are available. One possible interpretation of these data is that they represent the vulnerable biomass facing fishers in any one of the management areas. Table 1 shows the vulnerable biomass increasing over the period. On the other hand, the TACC available to industry (aggregated over all quota management areas) has generally declined; the TACC in 2000 was 78% of TACC in 1992. Industry response to a declining TACC is seen in the percentage of harvesting rights exercised increasing from 85% to 96% over the same period.

The national lobster fleet has been decreasing since the 1980’s probably due to a variety of reasons, including declining available biomass in the 1980’s. The fleet has shown its most rapid and consistent decline from the mid-1990’s to the turn of the century. In the period of interest 1989-1990 to 2001-2002 the fleet reduced in estimated size from 586 to 322 vessels, a decrease of 45%.

![Number of vessels](image_url)
Figure 1 shows the estimated number of vessels targeting rock lobster whose primary method was potting (the overwhelmingly predominant method) and landed more than 1 tonne during the fishing year. The data do not correct for individual vessels fishing in more than one QMA.

The estimated national catch per unit effort was calculated from standardized mean CPUE values estimated for each QMA, weighted by the contribution of the catch from the QMA to the national total landings for the fishing year. In the period of interest for which we have data 1990-1991 to 2001-2002 the estimated mean CPUE increased from 0.58 to 1.0 kg/pot. This indicates a strong upward trend, although a small proportion of this increase is probably due to the CPUE standardization procedure which tended to upwardly adjust the CPUE due to the shift in fishing effort to the autumn-winter season, because catch rates are lower on average during this period. Sustained increases in CPUE support independent evidence that the overall biological state of the fishery has improved quite markedly over the period. Increases in the CPUE could have also come about from technical change. In this paper we attempt to separate these two effects and attribute efficiency gains – in terms of lower costs – to improvements in the biomass and technical change.

![Figure 2: Estimated mean national CPUE in kg/potlift](image)

In the period of interest for which we have data 1990-1991 to 2001-2002 there was a marked shift in the seasonality of fishing effort. This was estimated by aggregating catch-landing records by month for each QMA. The majority of the national catch is now landed in June, July, August, September and October. In 2002-2003 this period accounted for 63% of the catch, compared to 43.5% in 1990-1991.

The seasonal shift runs against the ease of seasonal fishing conditions and has probably been in response to market prices which are depressed when the season for the main competing spiny lobster fishery in Western Australia, for *Panulirus cygnus*, opens from 15 November to 31 June each year. The closed season from 16 August to 14 November was proclaimed in 1962 and was extended from 1 July to 14 November in 1978. Figure 3 shows how the seasonality of the New Zealand lobster catch has shifted markedly in the last decade.
Econometric Evidence

The Annual Enterprise Survey in New Zealand provides financial information by industry groups. To be included in the population, enterprises must have annual revenue of at least $30,000. Statistics NZ (SNZ) supplied data on Class A0411, Rock Lobster Fishing. Observations on firms within the rock lobster fishing industry are available over nine years, from 1992 through 2000. Unfortunately, data on individual firms over this period are not contiguous. Thus conventional panel data models are not appropriate. The data are confidential and the results had to meet SNZ output rules.

Summary statistics presented in Table 2 highlight three trends. First, average harvest per enterprise has increased over the period. This lines up with the earlier observation that vessel numbers have declined. However, there is no obvious pattern in output per unit of capital. Second, output per unit of labour has increased by over 70 per cent. Third, capital per labour unit has more than doubled. The latter two observations suggest that gains in productivity have come about through capital-labour substitution. Although the capital-labour ratio, on average, has increased the industry-wide constraint metered out by the TACC (which was reduced over the period) means that relatively more capital intensive firms may not be able to fully exploit latent economies associated with capital unless they acquire more quota.
Table 2: Summary Statistics for New Zealand Rock Lobster Industry

<table>
<thead>
<tr>
<th>Year</th>
<th>Cases (N)</th>
<th>Quantity per labour unit</th>
<th>Capital ($000) per labour unit</th>
<th>Output per unit capital ($000)</th>
<th>Output per unit Labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>55</td>
<td>6.84 (4.36)</td>
<td>2.96</td>
<td>65.11 (61.20)</td>
<td>0.2260 (1.248)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.53 (1.49)</td>
</tr>
<tr>
<td>1993</td>
<td>72</td>
<td>6.74 (5.09)</td>
<td>2.96</td>
<td>65.41 (57.05)</td>
<td>0.0676 (0.0796)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.36 (1.34)</td>
</tr>
<tr>
<td>1994</td>
<td>73</td>
<td>6.48 (3.72)</td>
<td>2.89</td>
<td>79.73 (91.37)</td>
<td>0.0691 (0.0833)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.35 (1.15)</td>
</tr>
<tr>
<td>1995</td>
<td>51</td>
<td>8.09 (6.06)</td>
<td>3.22</td>
<td>72.91 (72.08)</td>
<td>0.0589 (0.0540)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.57 (1.41)</td>
</tr>
<tr>
<td>1996</td>
<td>58</td>
<td>10.35 (20.01)</td>
<td>3.68</td>
<td>76.73 (78.74)</td>
<td>0.1091 (0.3522)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.76 (2.68)</td>
</tr>
<tr>
<td>1997</td>
<td>47</td>
<td>7.64 (5.13)</td>
<td>3.08</td>
<td>71.11 (68.50)</td>
<td>0.0970 (0.2030)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.67 (1.63)</td>
</tr>
<tr>
<td>1998</td>
<td>90</td>
<td>10.30 (19.05)</td>
<td>2.50</td>
<td>132.88 (178.88)</td>
<td>0.0805 (0.1929)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.11 (2.49)</td>
</tr>
<tr>
<td>1999</td>
<td>96</td>
<td>8.11 (11.84)</td>
<td>2.70</td>
<td>125.29 (168.26)</td>
<td>0.0544 (0.0594)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.39 (2.81)</td>
</tr>
<tr>
<td>2000</td>
<td>101</td>
<td>9.09 (15.43)</td>
<td>2.47</td>
<td>145.35 (195.64)</td>
<td>0.0853 (0.1776)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.05 (3.59)</td>
</tr>
</tbody>
</table>

Source: Annual Enterprise Survey (Statistics New Zealand). Capital is measured as $10,000 per unit.

Turning to the econometric analysis, we use a translog function to represent the cost function.

\[
\log(c(w, q, b, t)) = \alpha_0 + \alpha \sum_{i=1}^{2} w_i + \alpha^* \ln B + \left( \frac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \alpha_{ij} \ln w_i \ln w_j + \beta_1 \ln q + \left( \frac{1}{2} \beta_2 \ln q \right)^2 \right. \\
+ \left. \sum_{i=1}^{2} \beta \ln q \ln w_i + \beta_1 t \ln q + \sum_{i=1}^{2} \psi_i t \ln w_i + \phi t + \left( \frac{1}{2} \phi \right)^2 \right)
\]

(1)

where \( \alpha_{ij} = \alpha_{ji} \), \( w_i = \) labour wage, \( w_2 = \) capital price, \( q = \) harvest, and \( b \) is the vulnerable biomass in the fishery at time \( t \). Using Shephard’s Lemma, the \( i \)th input’s cost share is given by

\[
S_i = \alpha_i + \sum_{j=1}^{2} \alpha_{ij} \ln w_j + \beta_{it} \ln q + \psi_i t
\]

(2)

which, together with equation (1), provide the basis for estimation. Given estimation of the parameters in equations (1) and (2) we follow Ohta (1974) to compute the rate of technical progress as

\[
\epsilon_t = -\frac{\partial \ln C(q, w, b, t)}{\partial t} = -\left( \phi_1 + \phi_2 t + \beta_{it} \ln q + \sum_{i=1}^{2} \psi_i t \ln w_i \right)
\]

(3)
If there is no technological change effect then
\[ \beta_{It} = \psi_{Li} = \psi_{Ki} = \psi_{Pi} = \phi_i = \phi_{2t} = 0 \] (4)

Technological change is neutral at a non-constant exponential rate of
\[ \phi_1 + \phi_2 t + \beta_{It} \ln(q) \text{ if } \psi_{Li} = \psi_{Ki} = \psi_{Pi} = 0 \] (5)

Technological change is ith factor saving if \( \frac{\partial S_i}{\partial t} < 0 \), ith factor using if \( \frac{\partial S_i}{\partial t} > 0 \), and \( \frac{\partial S_i}{\partial t} = 0 \) implies neutrality. Elasticity of scale is given by
\[ \varepsilon = \frac{\partial \ln c}{\partial \ln q} = (\beta_1 + \beta_2 \ln q + \sum_i \beta_{1i} \ln w_i + \beta_{1t}) \] (6)

\( \varepsilon < 1 \) implies diseconomies of scale, \( \varepsilon > 1 \) implies economies of scale, and \( \varepsilon = 1 \) implies constant returns to scale. An indication of minimum efficient firm size (MES) is given by
\[ \frac{\partial \varepsilon}{\partial t} = \beta_{1t} \] (6a)

If \( \beta_{1t} > 0 \) then MES can be achieved at a lower level of output, if \( \beta_{1t} < 0 \) then MES can be achieved at a higher level of output, and \( \beta_{1t} = 0 \) implies no change in MES.

We use equations (1) and (2) as the unrestricted model and impose the set of restrictions summarised in Table 3. The overall statistical significance of technical change is measured by a likelihood ratio test with \( L_R \) and \( L_U \) as the maximum likelihood values of the restricted and unrestricted model, respectively. Space limitations do not permit a complete report on each of the models estimated. The results suggest that: (1) we can reject the null hypothesis that there has been no technological effect; (2) reject the null hypothesis that technical change has been neutral; and, (3) we find no evidence to reject the null hypothesis that there is a scale bias. The sign on the MES parameter (equation 6a) is negative indicating that MES can be achieved at a higher level of output. The latter result warrants comment because it adds some support to an earlier comment that quota holdings might be limiting the ability of firms to benefit from scale economies. It might be that firms are investing with an expectation that the TACC will be increased in the near term.

Table 3: Models Tested

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unrestricted model, equation (1) &amp; (2)</td>
<td>D.W. = 1.94, Log-L = -402.81</td>
</tr>
<tr>
<td>2</td>
<td>No technological effect, equation (4)</td>
<td>Reject H_0 ; 1% level</td>
</tr>
<tr>
<td>3</td>
<td>No factor-Input bias, equation (5)</td>
<td>Reject H_0 ; 1% level</td>
</tr>
<tr>
<td>4</td>
<td>No scale bias, equation (6a)</td>
<td>Can’t reject H_0 at 5% level</td>
</tr>
</tbody>
</table>

We use equations (1) and (2) as the unrestricted model and impose the set of restrictions summarised in Table 3. The overall statistical significance of technical change is measured by a likelihood ratio test with \( L_R \) and \( L_U \) as the maximum likelihood values of the restricted and unrestricted model, respectively. Space limitations do not permit a complete report on each of the models estimated. The results suggest that: (1) we can reject the null hypothesis that there has been no technological effect; (2) reject the null hypothesis that technical change has been neutral; and, (3) we find no evidence to reject the null hypothesis that there is a scale bias. The sign on the MES parameter (equation 6a) is negative indicating that MES can be achieved at a higher level of output. The latter result warrants comment because it adds some support to an earlier comment that quota holdings might be limiting the ability of firms to benefit from scale economies. It might be that firms are investing with an expectation that the TACC will be increased in the near term.
Table 4: Percentage annual rate of technical progress

<table>
<thead>
<tr>
<th>Year</th>
<th>Technical Progress</th>
<th>Elasticity of cost</th>
<th>Elasticity of Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>-6.60 (0.01)</td>
<td>0.24 (0.07)</td>
<td>4.73 (3.17)</td>
</tr>
<tr>
<td>1993</td>
<td>-5.26 (0.01)</td>
<td>0.23 (0.07)</td>
<td>4.72 (2.03)</td>
</tr>
<tr>
<td>1994</td>
<td>-3.82 (0.01)</td>
<td>0.24 (0.06)</td>
<td>4.48 (1.52)</td>
</tr>
<tr>
<td>1995</td>
<td>-2.47 (0.01)</td>
<td>0.23 (0.07)</td>
<td>5.01 (3.16)</td>
</tr>
<tr>
<td>1996</td>
<td>-1.15 (0.01)</td>
<td>0.24 (0.07)</td>
<td>4.73 (2.45)</td>
</tr>
<tr>
<td>1997</td>
<td>0.03 (0.01)</td>
<td>0.23 (0.07)</td>
<td>5.10 (3.52)</td>
</tr>
<tr>
<td>1998</td>
<td>1.93 (0.01)</td>
<td>0.24 (0.06)</td>
<td>4.36 (1.42)</td>
</tr>
<tr>
<td>1999</td>
<td>3.00 (0.01)</td>
<td>0.22 (0.06)</td>
<td>4.91 (1.94)</td>
</tr>
<tr>
<td>2000</td>
<td>4.69 (0.01)</td>
<td>0.23 (0.07)</td>
<td>4.75 (1.75)</td>
</tr>
</tbody>
</table>

Note: mean estimates, standard deviation in parenthesis.

Table 4 shows an estimated annual rate of technical progress improving over the period, from -6.60% to 4.30%. The rate of technical progress is controlled for the annual vulnerable biomass that has been increasing over the period. The results point to technological regression early in the period. Proximity to the 1990 entry of rock lobster into the QMS might explain regression and we draw attention to the steady improvement through 2000.

DISCUSSION AND CONCLUSIONS

Rock lobster were introduced into the QMS in 1990. Our data set begins in 1992 and runs through to 2000, a period during which the TACC declined. Independent estimates of the vulnerable biomass generally increased over this period. Data from the Ministry of Fisheries show the percentage of the TACC caught increasing, the CPUE increasing, the number of vessels decreasing, and a changing pattern of harvest.

We draw the following conclusions using the four broad areas associated with technological change and innovation:

1. The QMS has provided both a platform and a mechanism that has facilitated a continuous increase in technical change over the period; improvements in the vulnerable biomass have contributed to increased CPUE. Although we could not reject the null hypothesis on scale bias, we can report that the sign of the estimated coefficient is positive, indicating that minimum efficient firm size can be
achieved at a higher level of output. In the short run, at least, it would appear that the full benefits of
capital investment will not be realized unless the TACC is increased.

2. The rock lobster industry receives no subsidies, contributes to the cost of management, compliance
and research. The absence of government subsidy and limited devolution has clearly unleashed a
dynamic that has achieved economic growth within the constraints of sustainability.

3. Apart from the observation that the number of vessels has decreased and capital per enterprise has
increased, we can not comment on vertical integration.

4. There is evidence supporting the notion that process and product innovations are complementary.
Product innovation is seen in the evidence that rights to harvest are being exercised during months
when market prices are highest. Process innovation is most evident in the steady reductions in costs
over the period.

In this paper we used the standard time trend approach to modeling technical change. As noted by Baltagi
and Griffin (1988) pure technical change \((\phi + \phi^* t)\) was increasing at a constant rate with the effect of
dominating the other components of equation (3). In future work, we intend to extend our analysis to
include a more general index of technical change and examine the impact of trading in the quota market
as a means of achieving cost economies.

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