TECHNOLOGICAL SWITCHING IN THE FISHERIES SECTOR

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ABSTRACT

Technological switching and re-switching has been the subject of debates within economics. Under assumptions of malleable capital in economies with multiple sectors, the wage-rent envelope can show multiple re-switching. The interest of technological change and switching behavior for fisheries economists and managers stems from the fact that the control of effective effort remains one of the central management problems for that sector, and for many managers, the most elusive. In the fisheries, the trawling technique has been largely promoted in the seventies and eighties. Consequently, path-dependency was developing in such a way that the preferred choice of new entrants into the fishery was this technology to produce wild fish. In this context, it can be argued that technological lock-in has occurred on the trawling technique, making it the most used technique in the French fisheries sector in Atlantic, to the detriment of alternatives, called passive techniques. However, it must be questioned why technical switching, from trawling to passive methods, has not been accelerated due to poorer economic performance for the former technology. This paper addresses the diffusion process of trawling, accompanied by state subsidies. Even if trawling has been commonly defined as a major innovation in fisheries, its potential for technological adaptations or minor innovations is questionable when faced with an increasing energy price, especially in the absence of State aid. JEL : fishery, switching, technological change, capital

Keywords: fishery, switching, technological change, capital

I. INTRODUCTION

Many fisheries world-wide are over-exploited mainly because of declining stocks and growing effective fishing effort, often helped along by subsidies and jobs programs offered by governments. Considering this unsustainable behaviour by the private and the public sector, economists have every reason to expect that their recommendations would be seriously taken; usually a shift towards techniques and practices which are more resource conserving, and a systematic control on effort, possibly using market forces. There is some global evidence (Sumaila *et al.*, 2008) that this is in fact happening. However, there are also other cases where the practices and the techniques adopted in the past have managed to hang on, even though there is mounting evidence that, even from the standpoint of very practical criteria such as fuel efficiency, these technologies should be on their way out. This paper discusses that phenomenon by reviewing information on the costs of passive gear versus the production costs of trawls, or mobile gear, in the French fishery and comparing that to their exit and switching behavior. All countries have examples of unfair and inefficient subsidies, and government-caused technological lock-in. But we can say that the French case demonstrates more clearly than most how an active role by the State may actually impede normal processes of technical switching, thus making the sustainable management of fisheries more difficult.

There are policies which can encourage sustainable or unsustainable trajectories of technological change. An example of this is taken from the French fisheries, where we find evidence that the subsidy policies in place for fuel may have comparatively favored mobile gear technologies and large scale fishers. Over a long period of time, the "bending" of the trajectory in this direction by subsidy policies, along with passive technology adoption, learning behavior, and the influence from the general economy, exhibits inertia that can only be overcome by large exogenous shocks. In this case, that large shock was the rising costs of fuel; but also at issue is whether a fuel subsidy policy in this case really is sustainable.

The paper presents a general overview of the standard neoclassical arguments for re-switching. Then, the empirical evidence of fuel price induced switching from mobile to fixed gears is presented. Finally, we show that the presence of the subsidy policy for fuel would dampen the readjustment to the alternative (and seemingly dominant) technical pathway. We conclude the paper by discussing some of the reasons why policy makers in France as elsewhere may be motivated to enact these subsidies, even though it is generally understood that doing so is neither sustainable nor efficient.

RE-SWITCHING MODELS AND THE MALLEABILITY OF CAPITAL

Technological switching and re-switching and the conditions under which it happens has been the subject of at least three debates within economics, starting with the famous Cambridge debates (see for example Han and Shefold, 2006). These debates arose in part from the divergent views as to the theoretical implications of capital, or produced intermediate goods. Sraffa (1960) predicts that, under assumptions of malleable capital in economies with multiple sectors, the wage-rent envelope can show multiple re-switching.

The neoclassical position is that despite its numerous shortcomings, being able to explain switching behavior is not one of them (Stiglitz, 1973). The process is easily explained as a function of changing relative factor prices and marginal productivities subject to underlying changes in technology.

Third and most interesting is the emerging research agenda of evolutionary economics. These researchers (Nelson and Winter, 1982; Dosi, 1988) sought to ground explanations of growth in the micro-behavior of the firm. Technical change was presented as adaptations which are fundamentally evolutionary in nature (Nelson and Winter, 1982). These are, then, the three related stories about technical switching.

All of them suggest processes which seem to be lodged within the firm and abstracted from the intrusions of policy makers in an economy. However, capital is often not fungible, the firm and firm managers are not always easily described by the neoclassical representations of technology, and firm managers are well-aware that spending resources for coercion and lobbying can at times be a substitute for innovation and internal change.

The interest of technological change and switching behavior for fisheries economists and managers stems from the fact that the control of effective effort remains one of the central management problems for that sector, and for many managers, the most elusive. It is well-known (Le Floc'h and Fuchs, 2001), that technical change in fisheries is largely passive, and may occur for reasons which are related to growth in the general economy.

Metcalfe and Steedman (1972) examine the effects of a positive return on capital on the question of technique choice. Using a simple expository model for their analysis, the production of commodities is within an input/output framework, where net outputs in the economy are produced using, among other factors, capital goods, or goods in process. It is assumed that a positive rate of profit is earned on the value of capital. Further, they assume an economy in autarky with two homogeneous primary inputs, land (L) and labor (l) both of which are fully employed. In this simple model, these factors are not produced by the economy, and are thus constraints on production. The simple economy produces two commodities, which are both capital goods and goods for final consumption.

To produce the two commodities the economy uses a number of technically efficient fixed coefficient processes, all of which are known at the beginning of the process. The production is on an annual cycle. All capital stocks are used up and must be replaced at the beginning of each production period. Each technique is either land intensive in the production of commodity 1 or labor intensive for commodity 2.

Variations in the consumption patterns of members of the economy and owners of factors are not captured in this model. Aggregate consumption patterns depend only upon relative commodity prices, and perfect competition is assumed. These early authors assumed that the economy in question is in a state of stationary long term equilibrium, and that comparisons between techniques are being made in this context. They add one unorthodox assumption with regard to the perfect competition assumption; that the rate of profit on capital goods reflects payments to that factor, and that these values are positive. Finally, a higher ratio of rents to wages does not necessarily lead to using a more labor-intensive technique of production, but rather can lead to the use of a more land-intensive technique.

Following again Metcalfe and Steedman, the formalization of the fixed factor production model of commodities 1 and 2, C1 and C2;

$$C1 = a11*C1 + a21*C2 + a1*l + A1*L \quad (1)$$

$$C2 = a12*C1 + a22*C2 + a2*l + A2*L \quad (2)$$

Which, with the constraints…

$$A1 + A2 = L \quad (3)$$

$$a1 + a2 = l \quad (4)$$

forms the basic analytical structure of the problem. Prices of the commodities in competition are given by:

$$P1 = (a11*p1 + A21*p2)(1+r) + w*a1 + W*A1 \quad (5)$$

$$P2 = (a12*p1 + A22*p2)(1+r) + w*a2 + W*A2 \quad (6)$$

The relative prices of the commodities are given by:

$$\frac{P1}{P2} = \frac{(1 - a22(1+r))(a1 + A1\, W/w) + a21(1+r)(a2 + A2\, W/w)}{(a12(1+r))(a1 + A1\, W/w) + (1 - a11(1+r))(a2 + A2\, W/w)} \quad (7)$$

In other words, the output price ratios of the commodity are a function of the input price ratios, as well as r, the payments to capital. After differentiating this with respect to W/w, and rearranging terms, we obtain a linear wage rent frontier, with the additional argument, r.

$$w2 = \left[\frac{\det(I - (1+r)A)}{a2(1 - a11(1+r)) + a1a12(1+r)}\right] - \left[\frac{A2(1 - a11(1+r)) + A1a12(1+r)}{a2(1 - a11(1+r)) + a1a12(1+r)}\right] W2 \quad (8)$$

I is a 2X2 identity matrix and A is the matrix of fixed factor coefficients.

The intuitions of these relations are relatively direct. Payments to labor in the production of commodity two is a decreasing function of those payments made to land and to capital. When r tends towards 0, the relation becomes more simplified still, with values of W2 and w2 attaining maximum values. This theoretical framework is used in Figures 1-2.

Open access fishing, at least in theory, results in payments to capital and labor, but not to land. If resource rents do indeed dissipate into the economy, such a result would imply that W=0 for this economy. This is an even simpler problem, because it reduces to looking at technique choice as a relation between the wage rate for the production in question, and the payment rate to capital, r. In these cases, the wage-profit frontier suggests switching in a less ambiguous way. This is shown in Figure 2. In this case the capital intensive technique (**a**) dominates ***outside*** of the range of r1 to r3.

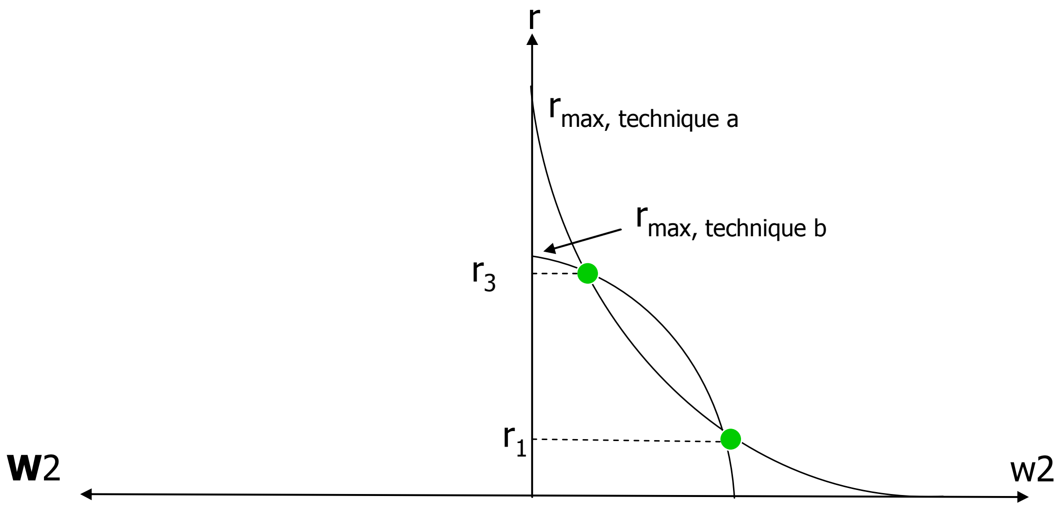

Figure 1. Technique choice in the production of commodity 2, assuming open access fishing.

Using this simplified model with malleable capital, we explore the impacts of a subsidy favoring the capital intensive technique, in this case the trawl technology. In Figure 3, the situation of no subsidies (solid lines) and subsidies (dotted lines) is explored with the framework developed by Metcalfe and Steedman. The dotted lines are the wage-rent frontiers with fuel subsidies for trawls (**a**) and fixed gear (**b**) compared to the case without subsidies. If fuel subsidies comparatively favor the capital intensive technique (in this case trawling), then the range over which capital intensive techniques dominate will be enlarged, even though both techniques benefit from the subsidy. This is exemplified by the reduction of the switching zone where technique b, or the fixed gear, would dominate (from r2-r1 to r1s to r2s). The implications of this are that the malleable capital will be nevertheless fixed within techniques which may not be efficient or sustainable.

There are even more complications to this model in real life, however. Whereas the preceding analysis of technical switching assumes malleable capital, the problem in fisheries as in other sectors is that capital comes into production and is durable. The durability of that capital may pose a number of problems to the investor, especially in the face of changing costs of other factors. As will be seen in the case of the French fishery and elsewhere, policies of rationalization revealed that the actual residual value of capital fixed in the trawl fleet was far lower than the owners of that capital had expected. Since markets for excess capital are not fluid either, we can imagine that there was a strong incitation to younger members of the fleet and owners of newer vessels to petition their government for relief. That relief came in the form of subsidies aimed at counter-balancing the high price of fuel. Such subsidies have the effect of pushing the date at which this non-malleable capital is disposed of into the future. Therefore, it may be that technological lock-in may not be just the result of shifting wage-price frontiers, but rather a political-economic result of producers trying to preserve the values of their capital investments by affecting the competitive conditions of factor markets. A proactive government was enlisted to this end. Therefore, in real economic sectors, there may be several techniques operating at once, although one technology may be dominant from one time to the next. In this way, non-malleability of capital may be one reason why subsidy programs seem persistent. However, subsidy programs help to ensure technological lock-in which may not ultimately be sustainable.

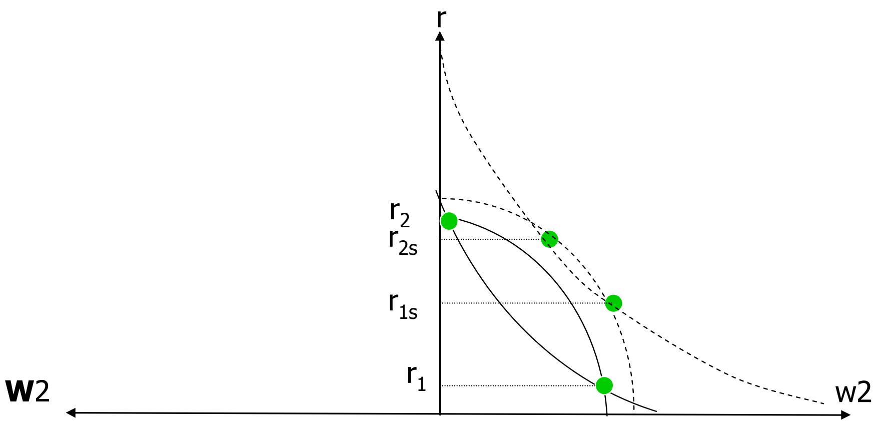

Figure 2. Technique choice in the production of commodity 2, assuming open access fishing and subsidies.

The subsidy therefore has two effects. It masks or occults techniques which may be more efficient over prevailing rates of r and w, thereby slowing down switching. Second, and more importantly in more realistic context, it helps to fix non-malleable capital onto development pathways for the sector which are difficult to change, because of technological lock-in.

The next section presents a case study, and the following section discusses the real-life implications of these policies.

FRENCH FISHERIES OF THE ATLANTIC COAST

Depending on the fleet and the year, buyback policies reduced vessel numbers by 44% from 1990 to 2005. The size of the commercial fishing fleet located on the Atlantic coast has decreased, from 3675 vessels in 1990 to 2053 in 2005, with a severe drop in 1991 due to the implementation of the first decommissioning scheme by the French State to reduce potential fishing capacity. The largest percentage reduction over the period was among vessels using the trawling technique, (46%), whereas the number of users of alternative fishing techniques decreased by 43%. The trawl technique represents 40 to 47% of the total vessels, depending on the year, and reciprocally, passive methods were used on the greater number of fishing vessels.

Measured from engine power in kW (Figure 3), which is directly related to fuel consumption, the reduction in capacity appears less dramatic for the largest trawlers (-8%), isolated from other segments of trawlers, compared to smaller trawlers under 20 meters of length (-47%). Overall, decommissioning schemes explain a large proportion of the reduction in the size of the fleet, although other motives led vessels to exit. Hence, fleet buyback policies contributed significantly to the reduction in size of these fleets. During the study period, the contribution of the entire fleet of trawlers in terms of kW declined from 64% to 60% of the total capacity. Only the largest trawlers increased their relative capacity (or fishing effort) from 17% in 1990 to 24% in 2005, despite the buyback schemes implemented by the French government (Guyader *et al.* 2007).

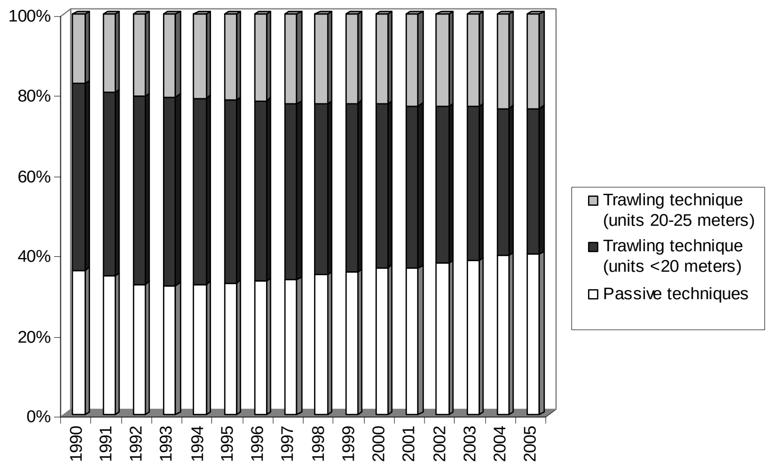

Figure 3. Evolution of fleets in kW, expressed in percentage, from 1990 to 2005. (*Source: IFREMER*)

Structural measures to encourage exit from the fishery implemented during the nineties seem to have had limited effects on reducing the fishing capacity operated by the larger trawler vessels. Fishers do not respond identically to management measures, such as buyback programs, or other external factors like rising fuel costs. If fishermen are assumed to behave rationally, the number of adopters of the trawling technique should have been declining in the face of expected high levels of fuel cost, because the trawl technique is more energy intensive than passive techniques. For this reason, analyzing fishers' behavior with regard to increasing fuel costs provides new insights into the understanding of technical change, especially between trawlers and users of passive fishing gears.

Bookkeeping databases provided landings value, operating and financial costs. These data cover the 1998-2005 period for a constant sample of fishing vessels (trawlers and alternative techniques), classified according to length classes, (four classes for trawlers and two for vessels using passive techniques). Trawlers over 20 meters are very sensitive to fuel costs and are considered in this research as the reference units. For the year 2005, costs and earnings data are available for a constant sample of 180 units (Table 1).

We studied fishers' behavior with regard to the fuel consumption component. To do this, an econometric model was estimated, which represents fisher fuel consumption by fleet class, in the context of increasing energy costs. Fishers' behavior with regard to increasing fuel costs is dependent on the fishing method used. Moreover, the potential production capacity is constrained by energy requirements. Length and fishing method are assumed to be relevant standards to study the path dependency of each fleet segment *vis à vis* fuel consumption. The aims of the econometric work was then to measure the gaps between fleet classes and the larger trawlers of 20-25 meters, assuming these are more dependent on the energy input.

Stepwise regression methods were used to select the model. The choice criterion is based on Akaike and Bayesian information criteria (Greene 2003). We explain fuel consumption in quantity (litres), expressed in log ($\log(fuel_t)$), as a function of gross revenue computed one and two years before ($\log(GR_{t-1})$ and $\log(GR_{t-2})$), technical characteristics (deviation from average gross tonnage, GT, and engine power, kW, building year, and dummy variables for fleet segments with "trawlers <12 m" =1 and 0 otherwise, "trawlers 12–16 m" =1 and 0 otherwise, "trawlers 16–20 m" =1 and 0 otherwise, "passive <12 m" =1 and 0 otherwise, "passive >12 m" =1 and 0 otherwise.

Table 1. Technical characteristics of the French commercial fleet of the Atlantic coast in 2005. Mean values of the population and variation coefficients in brackets are given for the age (years), length (metric meters), engine power (kW). (Source: IFREMER-SIH and Observatoire économique régional des pêches)

Constant Samples		Number of vessels in the population (in 2005)	Size of samples (2005)	Age in 2005 (years)	Length (meters)	Engine power (kW)
Trawlers	<12m.	371	27	26 (39%)	10 (14%)	101 (37%)
	12-16m.	140	39	20 (38%)	14 (9%)	229 (24%)
	16-20m.	125	21	20 (31%)	18 (8%)	321 (19%)
	>20m.	176	34	17 (33%)	22 (7%)	405 (17%)
Passive	<12m.	1100	49	21 (50%)	8 (24%)	76 (66%)
	>12m.	140	10	19 (51%)	17 (23%)	265 (39%)
All vessels		2053	180	21 (46%)	11 (45%)	147 (84%)

The segment of "trawlers 20-25 m" as the reference segment is in the intercept. Stepwise methods were used to test the full model for six years (from 2000 to 2005). The best model, expressed through a semi-logarithmic equation, includes the explanatory variable gross revenue one year before (GR_{t-1}) in log, deviation from kW and all dummy variables (Equ.9):

$$\log(Fuel_t) = \alpha + \beta \log(GR_{t-1}) + \gamma d_{kW} + \lambda_1 trawlers < 12m + \lambda_2 trawlers\, 12-16m + \lambda_3 trawlers\, 16-20m + \lambda_4 Passive < 12m + \lambda_5 Passive > 12m + \varepsilon \quad (9)$$

As the model associates explanatory variables expressed in log (GR_{t-1}) and others in linear form (deviation from kW and dummies), we are cautious in the interpretation of the semi-logarithmic equation results. Hence, β is an elasticity coefficient of $Fuel_t$ with respect to GR_{t-1}, as the percentage change in $Fuel_t$ for a percentage change in GR_{t-1}. One can expect a positive coefficient, meaning an increase in fuel consumption when gross revenue has progressed the year before. Concerning linear variables, their coefficients ($\gamma, \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5$) give the instantaneous growth rate and are not directly elasticity coefficients as β.[1]

[1] Halvorsen and Palmquist (1980) suggest taking the antilog of the linear coefficients and subtracting the value of 1 from them to obtain elasticity measures.

DISCUSSION

Fishers in this study have had their fuel costs affected in three ways. First, fuel costs have experienced temporal fluctuations related to world demand and supply. Secondly, fuel costs confronted by fishers are lower, because of their tax exemption. Third, fuel costs have been affected by emergency measures resulting from the fishermen lobbies. The evolution of monthly fuel prices (Figure 4) excluding taxes shows two peaks occurring in 2000 (€0.31 per litre for the fishing fuel price) and in 2005 (€0.40 per litre).

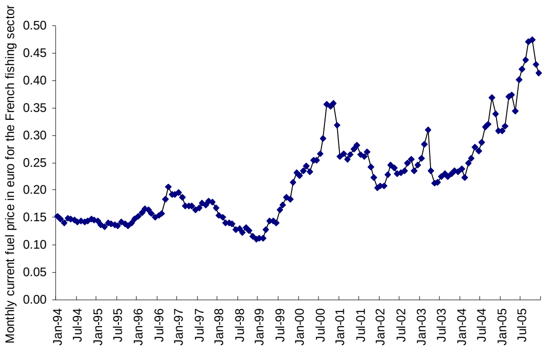

Figure 4 Monthly tax exempt fuel price per litre for the French fishing sector, in current Euros, from 1994 to 2005. (Source: Coopérative Maritime du Pays Bigouden)

Rising fuel prices could have enhanced the substitution effect between fishing techniques in 2000 and more particularly in 2005 due to the higher dependence of trawlers on fuel compared to boats using passive techniques. If taxes were to be included, reflecting what a typical consumer in France would pay for fuel, then prices would be two or three times higher than shown. Therefore fuel prices paid by the fishing as well as the agricultural sectors in France are already subsidized, and have been throughout this study. In addition, the French government has also implemented state aid programs as a result of pressure from fishermen's lobbies. This double scheme of subsidies is therefore composed of more standard measures and the emergency measures put in place in 2000, as well as more recently in 2005 and 2006.

During the study period, from 1998 to 2005, nominal fuel prices increased by 10% a year. However, these prices already account for a fuel subsidy. Fuel cost as a percentage of turnover or gross revenues, increased from 16% in 2004 to 23% in 2005 for the trawlers (Observatoire Economique regional des Pêches de Bretagne, 2006). However, if we consider emergency state aid as well, the effect of that price increase was largely neutralized (17% in 2005). The impact on passive gears was less severe, ranging from 5% in 2004 to 8% in 2005. With emergency state aid, these costs too were largely neutralized (6%). However, the technology that benefits most, not only from tax exemptions but also emergency aid, is the trawl technology[2].

A permanent increase in fuel price might change fishers' behavior by reducing fishing time (Ward *et al.*, 2005) or inducing a technique switching. In the short term, however, fishers did not change their fuel consumption. The results derived from the econometric model confirm this.

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[2] This is because the governance system in the French fishery treats the larger (20-24 meters) trawlers as the "white mice". When a fuel crisis occurs, the impacts on this segment are measured carefully. During the 2005 fuel crisis, the break-even for trawlers ran between 0.3-0.4 Euro/liter, whereas the break-even for passive technologies on vessels under 12 meters was estimated at 2.18 Euro/liter (Van Marlen, 2009).

The best model, selected with a stepwise method, includes gross revenue (gr_{t-1}) the year before, deviation from kW, and dummy variables (Table 2). All variables, apart from the intercept and the dummy "trawlers16–20 m", are significant at a 1% level. That means that there is different behavior in terms of fuel consumption between the largest trawlers (over 16 meters) and other segments of the fleet. The 16-20 meter trawlers serve as the reference segment (trawlers of 20-25 meters), particularly from 2003, since the dummy variables are insignificant.

Table 2. Results of the econometric model (dependent variable; log of fuel consumption). ***Significant at a 1% level, **Significant at a 5% level, *Significant at a 10% level.

	Year 2000	*Year 2001*	*Year 2002*	*Year 2003*	*Year 2004*	*Year 2005*
R^2	0.94	0.94	0.94	0.94	0.93	0.88
n	178	179	188	180	184	180
Intercept	0.77	1.43	-0.95	-0.69	-0.13	-1.76
t-value	*(0.9)*	*(1.7)*	*(1.1)*	*(0.8)*	*(0.1)*	*(-1.1)*
$\log(gr_{t-1})$	0.98***	0.86***	0.89***	0.91***	0.95***	1.09***
t-value	*(14.1)*	*(13.8)*	*(13.8)*	*(14.8)*	*(13.0)*	*(10.9)*
$Dev(e_{kw})$	0.61***	0.61***	0.57***	0.57***	0.44***	0.53***
t-value	*(7.2)*	*(7.5)*	*(6.9)*	*(7.1)*	*(4.7)*	*(4.1)*
Trawlers16-20m	-0.17*	-0.18*	-0.19**	-0.15	-0.09	-0.04
t-value	*(-1.7)*	*(-1.8)*	*(-1.9)*	*(-1.5)*	*(-0.8)*	*(-0.2)*
Trawlers12-16m	-0.53***	-0.50***	-0.54***	-0.48***	-0.43***	-0.51***
t-value	*(-5.2)*	*(-5.0)*	*(-5.5)*	*(-4.9)*	*(-3.7)*	*(-3.3)*
Trawlers<12m	-1.35***	-1.28***	-1.28***	-1.26***	-1.16***	-1.15***
t-value	*(-9.2)*	*(-9.2)*	*(-8.9)*	*(-8.9)*	*(-6.9)*	*(-5.3)*
Passive >12m	-1.43***	-1.25***	-1.33***	-1.31***	-1.33***	-1.11***
t-value	*(-10.3)*	*(-9.3)*	*(-9.9)*	*(-9.9)*	*(-8.4)*	*(-5.3)*
Passive <12m	-1.62***	-1.69***	-1.76***	-1.68***	-1.49***	-1.40***
t-value	*(-10.9)*	*(-12.0)*	*(-12.5)*	*(-12.2)*	*(-8.9)*	*(-6.2)*

Expressed in logarithms, the influence of gross revenue is positive and proportional to the fuel consumption the year after. An increase of 10% in gross revenue, or landings value, leads to a higher fuel consumption of between 9%-11% the following year. As expected, fuel needs are lower for smaller trawlers and passive units. In this sense, the hierarchy according to fishing gears (trawling *versus* passive) and potential production capacity (length segments) is well ordered.

We do see that trawlers were negatively affected by higher oil prices due to their dependence on fuel consumption. Fleet contribution to total earnings could then be reassessed in the future if the technical change from trawling technology to fishing passive techniques is confirmed. The impact of fuel costs on the comparative desirability of alternative technological trajectories should be considered when evaluating policy choices. In the current economic situation however, one could ask why a switching phenomena has not been more apparent or accelerated away from trawling techniques, which are more capital and energy intensive, especially compared to passive methods, even with all the subsidies. The reason why technical change has not really affected the biggest units is because subsidy policies for fuel comparatively favor trawling technologies and large scale fishers.

CONCLUSIONS

Our analysis shows that fuel support regimes could delay the technical change process by slowing down the exit of vessels or encouraging them to keep fishing with trawl gear. However, it is likely that trends in the fuel market will be similar to those observed in 2005 (Brook *et al*. 2004). If this is the case, another fuel price crisis will again raise challenges for the bigger trawlers, which will likely incite vessel owners to lobby harder for more aid. In situations where a “political-economic” solution is not possible, the economic viability of trawling would decline, leading to switching. However, that assumes economic processes that are not affected by coercive political action by interest groups and proactive governments. The French government is proactive, especially as it concerns agricultural producers and fishers (Mesnil, 2008). So persuasive are these particular pressure groups in France that they have even caused their administrations to adopt policies that appear to be at odds with EU policy.

Fishers in this particular case took an early interest in upholding a special regime designed to limit the impact of high fuel prices. The fund as originally conceived was to have been a type of insurance partnership, where fishers were to make contributions to a common fund that would have paid out during periods of high fuel prices. This tool has been used in dealing with other risky markets. However, the scheme was ultimately prone to market failure. The financial contributions from fishermen were relatively low, compared to the compensation that was ultimately given to stakeholders. The French government then stepped in, and has been the main contributor to this fund, which was originally created by fishermen. In a sense, fishers have forced the French government to protect them, even though that same government knows very well that their policy is neither sustainable nor is it likely to be upheld as legal. In this case, there is a financial side to the question, since state aid is not permitted to support such a compensation mechanism (European Commission 2006).

In cases like this, the State encourages technological lock-in through *ad hoc* policymaking, often, as Olson (1965) has argued, in favour of a small, well-organized group who has a lot to lose or gain. In this case, that group is represented by the more capital intensive technique, which is not necessarily the most profitable. This option can be socially sustainable as long as other fishermen using alternative techniques also benefit from subsidies. It also requires that the larger public, often unaware of the policy or unconcerned about it, are willing to tacitly or overtly accept the inequities that might occur with the policy. However, the more serious problem with *ad hoc* policy-making is that an artificially induced technological lock-in is provoked, which can be non-sustainable in the long run (ecologically and economically). In this case, the trawling technique should by this time have been an inferior technique because it wastes economic resources. Also at issue is whether fuel subsidy policies to any sector can be justified, given what is known about the broader effects of fossil fuel use. There might be justifiable cases, but we suspect that they will not be wide-spread. And if they are not, then our discussions about capital non-malleability and the relation that has with technological trajectories highlights a crucial question: “…how can new lock-ins of inefficient or undesired technologies be avoided?” (Van den Bergh, 2007).

One way of avoiding or minimizing these effects might be for fisheries economists to explore more broadly the literature in economics, especially relating to theories of collective action, public choice, and evolutionary economics (Wilson, 2007), and then to build these into our policy recommendations. The development of fisheries governance structures that take account of both the positive effects, as well as the negative effects, of coercion and lobbying needs critical attention as well as the question of technological trajectory. Certainly, changes in governance that force discussions of policies through public hearings assisted by the press cannot hurt. On the other hand, government assistance in the areas of promoting education and entrepreneurial innovation among fishers that is necessary for new and sustainable technologies should be favored.

More generally and over a longer time period, public agencies everywhere played a major role in promoting technological lock-in on the trawling technology from the beginning of the 1960’s, which turned out to be highly fuel-dependent compared to passive gears. Trawling has often been cited as a major innovation in fisheries (Standal, 2007; Meuriot, 1986; Whitmarsh, 1978). However, its potential for technological adaptations or even minor innovations is now doubtful without State aid, especially during periods of increasing energy prices.

This paper showed evidence of the relative technical disadvantage of the trawling technology for certain segments of the French fleet in analyses of fleet rationalization statistics. But the paper also showed how direct subsidies provided to fishermen by the French State, in order to offset increasing fuel prices, may have caused resistance either to their exit or to technical change in the sector. Such a system has resulted in increased usage of energy by larger high-powered vessels, because the State aid had effectively reduced operating costs, thus indirectly off-setting increased fuel prices paid by fishermen. In these cases, policies of this type may well subvert other important policies aimed at sustainability and fleet rationalization.

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