Welfare properties of network bypass*

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Abstract

One result of the deregulation of utilities in New Zealand has been the bypass of existing networks. We investigate two cases of bypass in the distribution of natural gas, and compare the welfare properties of regulation vs. the 'laissez-faire' equilibrium. We demonstrate that installing a redundant bypass can be simultaneously profitable and socially undesirable. Bypass is costly, but it reduces market power and increases the variety of goods available to consumers. Regulation is an alternative mechanism to discipline the behavior of the incumbent, but provides no variety to consumers. We find that desirability of the two regulatory regimes depends critically on the degree of differentiation between the existing and potential network. Both marginal and average cost price regulation are considered.

Key Words: regulation, entry, welfare, efficiency, CES
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1 Introduction

The deregulation of the transmission and distribution of natural gas in New Zealand provides the opportunity to study an industry where 1) there are significant returns to scale, 2) the only constraint on firm behavior is a threat that the government will intervene if accounting profits are deemed to be excessive, 3) incumbent firms must disclose their pricing and accounting records. One interesting aspect of the adoption of light handed regulation is that the excess profits in the distribution of natural gas has lead to the bypass of the incumbent's network, most notably by Nova Gas in Auckland and the Hutt Valley, New Zealand. The combination of mandatory information disclosure by the incumbent and the entry of a new distributor allows for the study of how the incumbent's pricing behavior changes when faced with competition.

Oligopoly theory provides a number of predictions as to how the behavior of the incumbent should respond (*ex post*) to entry. At one extreme, the supergame literature following Rubinstein (1979) suggests that if both firms are sufficiently patient, and the firms interact indefinitely, then the monopoly price can be sustained in duopoly using some form of trigger strategies. At the other extreme, static models of price competition in the spirit of Bertrand (1883) predict that prices will be driven down to marginal cost, given the firms are not capacity constrained.[1]

In reality, incumbent prices decreased in the markets where they faced competition (potential or actual), but still remained significantly higher than marginal cost. For instance, customers in Auckland within 1km of a gate or the Nova bypass received a 28% discount (on distribution charges) relative to customers greater than 5km away.[2] Thus, one is left with a puzzle. If the incumbent chose an optimal price schedule prior to entry, and we believe that firms are colluding, then why did the incumbent's price drop by 28% when bypass occurred? The Folk theorem, as formalized by Fudenberg and Maskin (1986) suggests that *any* price above marginal cost

[1]Edgeworth (1897) solved the Bertrand paradox by demonstrating that its extreme result depends on firms being able to serve the entire market. If firms are capacity constrained, then prices will not be driven down to marginal cost.

[2]Distribution line charges reported by Vector 2003, in accordance with the New Zealand Gas (Information Disclosure) Regulations 1997.

can be supported in a subgame perfect Nash equilibrium, when sufficiently patient players interact indefinitely. However, if the price chosen prior to entry was optimal for the incumbent, then it is unlikely that a price 28% lower is maximizing the joint profits of the two firms. If the firms are colluding, why have they failed to pick the joint profit maximizing price, which one could argue is focal?

On the other hand, if firms are competing in price, the Bertrand-Nash prediction is that prices should be driven down to marginal cost, given that firms are not capacity constrained[3], and fixed costs are sunk. However, after entry occurred, the price only decreased by 28%, and remains significantly above marginal cost.[4] Thus, the price decrease associated with entry cannot be reconciled with simple models of cooperation or competition in price.

One possible explanation for this apparent puzzle is that the good being provided is differentiated in some respect.[5] Indeed, the 'gas' distributed by Nova Gas is a mixture of natural gas and landfill (methane) gas: it is non-spec. We posit a model where consumers value variety; for example having access to different specifications of gas. We assume the reason why the incumbent's post-entry price is lower than the monopoly price, but higher than marginal cost, is because the service being provided is differentiated. Differentiation creates market power, and allows for price to remain above marginal cost when firms compete in prices.

We make a number of simplifying assumptions, which allow us to focus on the welfare properties of regulation when bypass results in some degree of product differentiation. First, we assume that the regulator has complete information concerning the incumbent's cost structure. In this case, regulation does not have to be incentive

[3] "By world standards [New Zealand's] gas distribution pipelines are under-utilised, presenting an excellent opportunity for growth as existing and new gas customers take advantage of natural gas now sourced from competing gas traders." KC Johnson, Enerco New Zealand Limited (1998) at 1998 New Zealand Petroleum Conference. This implies that capacity constraints can not be used to explain equilibrium prices above marginal cost, as in Edgeworth (1897), and Kreps and Scheinkman (1983).

[4] In New Zealand, it could be argued that the marginal cost of distributing natural gas is close to zero. Pressure from the transmission network is sufficient to propel the gas through the distribution network.

[5] See the extensive literature on product differentiation following Launhardt (1885) and Hotelling (1929).

compatible, as in Baron and Myerson (1982). Furthermore, complete information on cost allows for direct price regulation. Thus, the distortion in investment associated with rate of return regulation described by Averch and Johnson (1962) is not an issue. We assume that the incumbent's service is perfectly reliable, so there are no gains associated with having access to two networks, as mentioned by MacAvoy, Spulber, Stangle (1989). We also assume that firms can not alter the characteristics of their products, as in Chamberlin (1953). Consumers in this model are are assumed to be homogenous, so that issues of 'cream skimming' do not arise, as in Laffont and Tirole (1990) and Curien, Jullien and Rey (1998). Finally we assume that bypass is the only method by which the entrant can provide its service. It is either technically infeasible to utilize the incumbent's network to deliver a differentiated service, or equivalently the entrant is denied access or faces an exorbitant access fee.

The entrant's decision of whether to bypass the existing network depends on the behavior of the regulator. If the regulator chooses 'heavy handed' regulation of the industry, bypass does not occur. The entrant rationally anticipates that the regulator would choose to extend the price regulation from the incumbent to both the incumbent and the entrant, as this would maximize *ex post* social welfare. Alternatively, 'heavy handed' price regulation could be coupled with a restriction on entry. On the other hand, if the regulator chooses 'light handed' regulation, then bypass of the incumbent network will occur whenever positive (net) economic profits are anticipated. All other things being equal, the lower the fixed cost of bypassing the network, and the greater the degree of product differentiation/market power, the more likely it is that entry will occur.

If entry does occur, there is some downwards pressure on price, as there is a degree of substitutability between the incumbent's good, and the entrant's. Furthermore, consumers benefit from the increase in variety of goods available. However, these benefits must be weighed against the potentially significant resource cost associated with duplicating the network. The installation of a bypass pipeline can be simultaneously profitable and socially undesirable. In these cases, bypass is profitable because consumers can be bid away from the existing network; the 'business stealing' effect described in Mankiw and Whinston (1986).

In contrast, the welfare tradeoff when considering bypass depends on 1) whether it is socially more desirable for a regulator or a potential competitor to discipline the incumbent firm's pricing behavior, 2) whether the bypass creates a degree of differentiation that consumers value. In the cases where bypass results in a small degree of differentiation, bypass can be profitable but socially undesirable. If the degree of differentiation is sufficiently large, then even perfect price regulation will decrease welfare. The remainder of the paper is organized as follows. Section 2 outlines the model. Section 3 presents the results. Section 4 is a case study of the New Zealand gas market.

2 The model

2.1 Timing

The model is cast in a world of perfect information. The solution concept is Subgame Perfect Nash Equilibrium. The first mover is the regulator R, who decides whether or not to regulate the differentiated sector. The next move is made by the entrant, who chooses whether or not to bypass the incumbent network. If the industry is regulated, the price(s) are set by the regulator. In the absence of regulation, if bypass does not occur the incumbent chooses price as a monopolist. In the absence of regulation, if bypass does occur, then the firms choose prices simultaneously and non-cooperatively. Finally, the representative consumer maximizes his utility, taking as given wealth and prices. We begin by looking at the behavior of the representative consumer.

2.2 Utility and Demand

The representative consumer has a utility function $U(\mathbf{x};\xi)$, where $\mathbf{x} = (x_0, x_1, x_2)$, and ξ measures the elasticity of substitution between x_1 and x_2. The representative consumer maximizes utility over a compact budget set $B = \{\mathbf{x} \in \mathbb{R}^3_+ : \mathbf{x} \cdot \mathbf{p} \leq M\}$, where $\mathbf{p} = (p_0, p_1, p_2)$, and M is the representative consumer's wealth. Let good x_0 be the numeraire ($p_0 = 1$), which is produced competitively. We make the following assumptions about U.[6]

Assumption 1 *$U : B \to \mathbb{R}$ is a continuous function on B.*

Assumption 2 *U is strictly quasiconcave.*

Assumption 3 $\frac{\partial U}{\partial x_0} = 1$.

Assumption 4 $\lim_{x_1 \to 0} MRS_{01} = \lim_{x_2 \to 0} MRS_{02} = 0$.

Assumption 1 ensures that U attains a maximum on B. Assumptions 1 and 2 ensure that the set $\arg\max\{U(\mathbf{x})|\mathbf{x} \in B\}$ is a singleton. Assumptions 2 and 3 ensure that the Kuhn-Tucker conditions for a maximum are both necessary and sufficient for a global maximum. Assumption 3 also implies that utility is quasilinear (in good x_0). Given $p_0 = 1$, the representative consumer's indirect utility function is money metric. Assumption 4 ensures that the solution to the utility maximization problem is interior with respect to the nonnegativity constraints on goods x_1 and x_2.

We also assume that M is large enough so that the solution is also interior with respect to the nonnegativity constraint on x_0. If bypass occurred, then maximization of utility on the budget set yields the demand vector

$$\mathbf{x}_D^\star = (x_0^\star(M, p_1, p_2; \xi), x_1^\star(p_1, p_2; \xi), x_2^\star(p_1, p_2; \xi)) \tag{1}$$

If bypass did not occur, we impose the additional constraint that $x_2 = 0$. Maximization of utility on this compact subset of the budget set yields the demand vector

$$\mathbf{x}_M^\star = (x_0^\star(M, p_1; \xi), x_1^\star(p_1; \xi), 0) \tag{2}$$

[6] An example of a family of utility functions that satisfy assumptions 1-4 is the CES utility function used in Spence's (1976) paper on monopolistic competition.

2.3 Prices and Gross Profits

Moving backwards one step in the game, we look at the behavior of the two firms, anticipating the utility maximizing behavior of the representative consumer in the final period, having observed the regulator's decision of whether or not to regulate, and the entrant's decision of whether or not to bypass. If the regulator chooses to regulate, $p = c$ and gross profits are zero. If the regulator decides to forego regulation, and bypass does not occur, then the incumbent chooses price as a monopolist. If the regulator decides to forego regulation, and bypass does occur, then firms simultaneously and non-cooperatively choose prices. Firm i's objective is to maximize $\pi^i = (p_i - c)x_i^\star(p_i, p_j, \xi)$ with respect to p_i, where p_j is the other firm's price. We make the following assumptions about the profit function of firm i.

Assumption 5 $\pi^i_{ii} < 0$.

Assumption 6 $\pi^i_{ij} > 0$.

Assumption 7 $\pi^i_{ii}\pi^j_{jj} - \pi^i_{ij}\pi^j_{ij} > 0$.

Assumption 5 ensures that the firm's first order conditions are both necessary and sufficient for a global maximum, and that the solution is unique. Assumption 6 states that prices are strategic compliments. Assumption 7 ensures that the equilibrium in this subgame is strategically stable. Let the strategy profile $\mathbf{p}^\star = (p_1^\star(c, \xi), p_2^\star(c, \xi))$ constitute the Nash equilibrium in this subgame. Let $\Pi_2 = (p_2^\star(c, \xi) - c)x_2^\star(\mathbf{p}^\star; \xi)$ be the entrant's gross profits.

2.4 Bypass

Moving back one more stage in the game, we study the bypass behavior of the entrant, rationally anticipating the rest of the game, having observed whether the regulator has chosen to regulate. We assume that there is a sunk cost associated with installation of a network, f. If the regulator chooses to regulate, then bypass will result in a maximum of zero profits. If the regulated price is set to marginal cost, the entrant earns net profits of $-f$. If regulated (maximum) price is set to average cost, the best the entrant can do is earn zero profits. We assume that the entrant chooses not to bypass if the regulator regulates, and earns 0. If the regulator foregoes regulation, then the entrant will choose to bypass when net profits are positive: $f < f_e(\xi) = \Pi_2(\xi)$, where $f_e(\xi)$ is the entry frontier. In words, the entry frontier tells us the maximum bypass cost the entrant would be willing to pay, for a given ξ.

2.5 Regulation

The regulator chooses to regulate if it increases welfare relative to the laissez-faire outcome, rationally anticipating the outcome in all subsequent subgames. First, note that regulation will always be desirable when in the absence of regulation, bypass does not occur. This is the standard case where regulation will reduce the deadweight loss associated with monopoly pricing. Now consider the regulator's optimal choice if, in the absence of regulation, bypass would occur. To begin with, we consider perfect price regulation. Welfare under perfect price regulation, W_R, is equal to the money metric utility level of the representative consumer $V_r = U(x_0^\star(M, c, \xi), x_1^\star(c, \xi), 0; \xi)$, because $p_1 = c$, and the incumbent's fixed cost is sunk. Next consider the laissez-faire welfare associated with bypass. The laissez-faire welfare W_N is the sum of the representative consumer's money metric utility

$$V_d = U(x_0^\star(M, \mathbf{p}^\star; \xi), x_1^\star(\mathbf{p}^\star; \xi), x_2^\star(\mathbf{p}^\star; \xi); \xi) \tag{3}$$

plus the (symmetric) gross duopoly profits of the two firms $\Pi_1 + \Pi_2 = 2\Pi$, minus the bypass cost incurred by the entrant f. Thus $f_w(\xi) = V_d - V_r + 2\Pi$ is the welfare frontier, for which welfare is equal under both regimes, for a given ξ. If $f > f_w(\xi)$, then welfare is higher under regulation than under an unregulated duopoly.

2.6 Equilibrium

Let p_m be the monopoly price, R and NR stand for the decision to regulate or not respectively, B and NB stand for the decision to bypass or not respectively. The unique subgame perfect Nash equilibrium strategy combination is $\mathbf{s} = (s_1, s_2, s_R, s_C)$, where s_i is the equilibrium strategy of firm $i = \{1, 2\}$, s_R is the regulator's equilibrium strategy[7], and s_C is the consumer's equilibrium strategy.

$$\begin{array}{ll} s_1 = & p_m \text{ if } NR \text{ and } NB, p_1^\star \text{ if } NR \text{ and } B \\ s_2 = & NB \text{ if } R, NB \text{ if } NR \text{ and } \Pi_2 - f \leq 0, B \text{ if } NR \text{ and } \Pi_2 - f > 0, p_2^\star \text{ if } NR \text{ and } B \\ s_R = & R \text{ if } W_R > W_N, NR \text{ if } W_R < W_N \\ s_C = & x_D^\star \text{ if } B, x_M^\star \text{ if } NB \end{array}$$

3 Results

Lemma 1 *If the entry frontier is above the welfare frontier, then for intermediate values of f bypass is profitable in the absence of regulation, yet welfare is higher under a regulated monopoly, than under an unregulated duopoly.*

This lemma is true by the definitions of f_e and f_w. If $f < f_e$, in the absence of regulation the net profits associated with bypass are positive. If $f > f_w$, welfare is higher under a regulated monopoly than under an unregulated duopoly. Thus, a welfare maximizing regulator will choose to regulate when: 1) in the absence of regulation, bypass would not occur, and 2) in the absence of regulation, bypass *would* occur, but welfare would be higher under a regulated monopoly than an unregulated duopoly. This occurs when $f_e > f > f_w$. In this region bypass is profitable, yet is socially undesirable. What remains to be seen is when will $f_e > f_w$.

Lemma 2 *The entry and the welfare frontier are both equal to zero when goods one and two are perfect substitutes.*

[7] Note that the regulator has only one information set. However, the regulator's optimal choice at this information set depends on the parameter values (ξ, f, c).

First consider the entry frontier. If the goods are perfect substitutes, a potential entrant will not be willing to incur a positive fixed cost of bypass, because it anticipates that Bertrand competition will drive prices down to marginal cost. Next consider the welfare frontier. The consumer derives no benefit from variety when goods are perfect substitutes. Furthermore, the duopoly price is equal to the regulated price c, which implies that both regimes are free of deadweight loss. Welfare under both regulation and duopoly will be the same if the fixed cost is zero. In other words, both the entry frontier and the welfare frontier pass through $(f, \xi) = (0, \infty)$.

Lemma 3 *If* $\frac{\partial(f_w - f_e)}{\partial \xi}|_{\xi=\infty} > 0$*, then the entry frontier is above the welfare frontier when goods one and two are close substitutes.*

If this derivative is positive, it means that the entry frontier descends more steeply to $(f, \xi) = (0, \infty)$ than the welfare frontier. Thus, at least locally, the entry frontier is above the welfare frontier.

Proposition 1 $\frac{\partial(f_w - f_e)}{\partial \xi}|_{\xi=\infty} = \frac{\partial U(x_0^\star, x_1^\star, x_2^\star, \xi)}{\partial \xi} - \frac{\partial U(x_0^\star, x_1^\star, 0, \xi)}{\partial \xi} - \frac{\partial p_1(c,\xi)}{\partial \xi} - \frac{\partial p_2(c,\xi)}{\partial \xi}$

First, note that $f_w - f_e = V_d - V_r + \Pi$. We begin by looking at the derivative of V_d. The envelope theorem states that the indirect effect (through x) of marginal changes in ξ are zero because the gradient of the lagrangian function is zero at the optimum: $\nabla \mathscr{L}(x^\star) = 0$. Furthermore, 1) assumption 3 implies that the lagrangian multiplier associated with the budget constraint $\lambda_b = 1$, and 2) assumption 4 ensures that lagrangian multipliers associated with the nonnegativity constraints $\lambda_{x_i} = 0$ for $i = \{1, 2\}$. Thus, the envelope theorem implies that $\frac{\partial V_d}{\partial \xi} = \frac{\partial U(x_0^\star, x_1^\star, x_2^\star, \xi)}{\partial \xi} - \frac{\partial p_1(c,\xi)}{\partial \xi} - \frac{\partial p_2(c,\xi)}{\partial \xi}$. Next we differentiate V_r. Under regulation, changes in ξ have no direct effect on the constraints because none of the prices change with ξ. Thus the envelope theorem implies that $\frac{\partial V_r}{\partial \xi} = \frac{\partial U(x_0^\star, x_1^\star, 0, \xi)}{\partial \xi}$. Now consider Π. The reason why $\frac{\partial \Pi}{\partial \xi}|_{\xi=\infty} = 0$ is the envelope theorem and the fact that $p(c, \xi)|_{\xi=\infty} = c$. The envelope theorem ensures that the indirect effects of change in ξ acting on the firm's choice variable $p_i^\star$ are zero. The fact that $p(c, \xi)|_{\xi=\infty} = c$ ensures that the direct effect of shifts in demand are zero as well.

Next we attempt to sign $\frac{\partial(f_w - f_e)}{\partial \xi}|_{\xi=\infty}$. It is easy to tell that $\frac{\partial p_1(c,\xi)}{\partial \xi} = \frac{\partial p_2(c,\xi)}{\partial \xi} < 0$. As the elasticity of substitution between two goods increases, price competition intensifies, driving price down towards marginal cost. Signing the other two terms is a little more tricky. First off, recall that we are holding the bundles consumed under both regimes constant. Note that when $\xi = \infty$, the representative consumer attains the same level of utility under both regimes. Under regulation, the consumer does not suffer because he is constrained by $x_2 = 0$. The reason why is that x_1 is a perfect substitute, and is available at $p_1 = c$. Now consider an example. Suppose for argument's sake that in the unregulated regime, the consumer chooses a bundle where $x_2 > 0$. Of course, when $\xi = \infty$, he is indifferent between any combination of x_1 and x_2 that add to some constant k. In the regulated regime, the consumer would choose $x_1 = k$ because good two is not available, and $p_1 = c$ as it was under duopoly.

Now consider what happens when the utility function changes in some arbitrary way that 1) maintains symmetry in the preferences between goods one and two[8] and 2) results in an incremental reduction in the elasticity of substitution. Holding the bundles constant, the $x_2 = 0$ constraint that is placed on the consumer under regulation begins to bind. This constraint drives a wedge between the utility attained by a more balanced bundle, and the bundle where $x_2 = 0$. Thus, $\frac{\partial U(x_0^\star, x_1^\star, x_2^\star, \xi)}{\partial \xi} - \frac{\partial U(x_0^\star, x_1^\star, 0, \xi)}{\partial \xi} \leq 0$, implying that the sign of $\frac{\partial(f_w - f_e)}{\partial \xi}|_{\xi=\infty}$ is indeterminate.

Duopoly becomes less attractive when the goods become less than perfect substitutes, because the duopoly prices rise above marginal cost. On the other hand, regulation becomes less attractive when the goods become less than perfect substitutes because the $x_2 = 0$ constraint begins to bind. Whether or not regulation can improve welfare when bypass would occur in the absence of regulation depends on the tradeoff between these two effects. For instance, if duopoly prices rise sufficiently quickly as differentiation increases, it can be the case that bypass is profitable, yet socially undesirable. Thus, 'facilities based competition' is no panacea, as it can result in a reduction in welfare. However, if duopoly prices rise sufficiently slowly as differentiation increases then whenever bypass is profitable, it is also socially desir-

[8] Graphically, indifference curves are reflections through the 45 degree line.

able. If this is the case, regulation would only be desirable in situations where bypass would not occur in the absence of regulation.

We now consider average cost regulation instead of marginal cost regulation. Average cost regulation allows the incumbent to earn a return on the sunk investment. Denote the average cost welfare frontier as f_{AC}.

Corollary 1 *If* $\frac{\partial(f_{AC}-f_e)}{\partial\xi}|_{\xi=\infty} > 0$ *then the entry frontier is above the welfare frontier when goods one and two are close substitutes.*

Note that under marginal cost regulation, the entry and welfare frontiers both pass through $f = 0$ as $\xi \to \infty$. Thus, average cost regulation changes no aspect of the proof, because when $f = 0$ then $AC = c$. However, average cost regulation reduces the set $F \times \Xi = \{(f, \xi)|f_w < f < f_e\}$ for which entry would occur but welfare would be higher under a regulated firm. This is due to the distortion created by price being higher than marginal cost, which implies that $V_{AC} \leq V_r$, where V_{AC} is the representative consumer's utility associated with price being set to average cost. Thus, regulating price to average cost instead of marginal cost shifts the welfare frontier upwards by an increasing degree as f increases. We now return to marginal cost pricing, but demonstrate that even if regulation involves incurring a fixed cost c_r, regulation can still increase welfare by deterring profitable yet socially undesirable bypass. Let the welfare frontier associated with costly regulation be denoted f_{cr}.

Corollary 2 *If* $\frac{\partial(f_w-f_e)}{\partial\xi}|_{\xi=\infty} > 0$*, and the cost of regulation is sufficiently small, it is still feasible for the entry frontier to be above the welfare frontier.*

In the absence of regulation costs, the entry and welfare frontiers both pass through $(f, \xi) = (0, \infty)$. In the case of costly regulation, the welfare frontier is shifted upwards relative to f_w: $f_{cr} = f_w + c_r$. Thus, if the shift upwards in the welfare frontier is sufficiently small, then costly regulation can still increase welfare by deterring profitable, yet socially undesirable bypass. We now turn our attention to the other end of the spectrum, where the goods become perfect compliments.

Proposition 2 *As* $\lim \xi \to 0$*, then whenever entry would occur in the absence of regulation, regulation will decrease welfare.*

As the elasticity of substitution approaches zero, goods one and two become perfect compliments. Good one is not of value to consumers in the absence of good two. If good two is not provided, the consumer's level of money metric utility is $U^{\star} = M$. The consumer chooses to consume only the numeraire good. If goods one and two are consumed, it must be the case that the consumer is better off, because the original bundle where $x_0 = M$ is still available, but not chosen. Furthermore, bypass will only occur if the net profits are positive. Thus, when bypass occurs, all parties are made better off. As a result, whenever bypass would occur in the absence of regulation, regulation decreases welfare.

4 Case Study: New Zealand Gas Market

We now turn to the specifics of the two cases of bypass alluded to in the introduction. In both cases, the bypass was undertaken by Nova Gas Ltd. In South Auckland, the bypass occurred in 1998. In Wellington, Nova's Porirua landfill gas extraction has been operating since 1996. The network was connected to the natural gas transmission system in Tawa in late 1997.

In both Auckland and Wellington, the incumbent network has changed hands several times in recent years. The incumbent network in Auckland was purchased by United Networks from Orion in March, 2000. Orion was formerly part of Enerco New Zealand Limited. Then in November 2002, then network was sold to Vector. In Wellington (the Hutt Valley) prior to bypass, the incumbent network was owned by TransAlta New Zealand Limited, a subsidiary of TransAlta Energy Corporation of Canada. The incumbent pipeline was sold in March 1999 to The Australian Gas Light Company, who then sold the network to Powerco Limited in June 2001.

One might wonder what comparisons can be made in an environment where ownership and control changes so frequently. An additional problem is that Nova Gas has an exemption from the New Zealand Gas (Information Disclosure) Regulations 1997. Nova Gas does not disclose its pricing, and its customers must sign nondisclosure agreements as part of the terms of service. We take two different approaches to get around these issues. In Auckland, Vector has adopted an explicit zonal pricing scheme, which allows us to compare the deals available to customers that have potential or actual access to the bypass network, with customers for which bypass is not a viable option. See figure 1 for a graphical depiction of Vector's line charges.

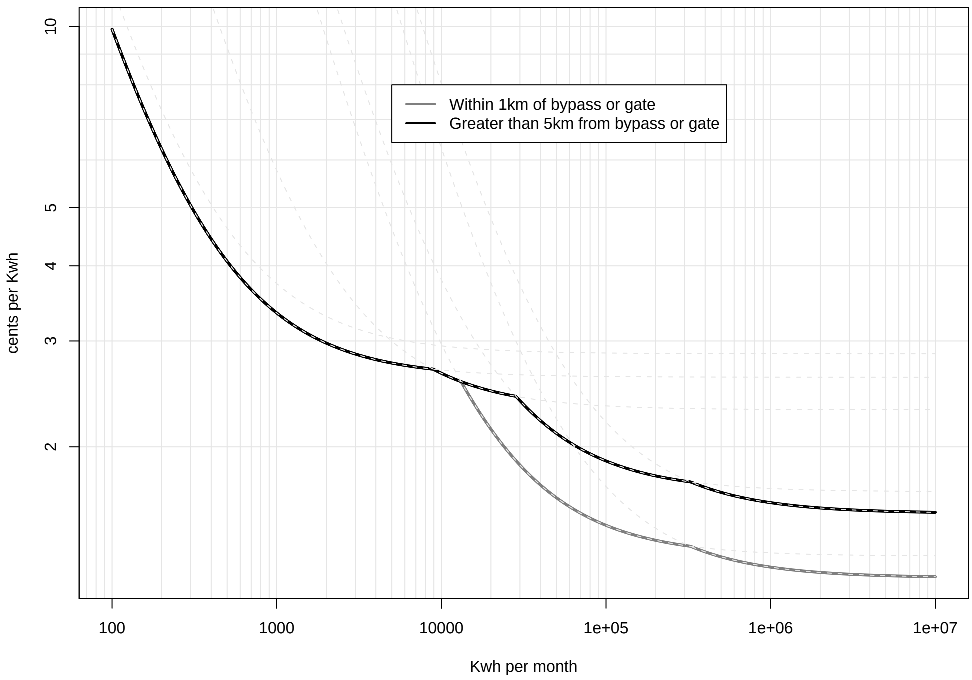

Figure 1: Vector line charges for Auckland area, 2003.

In Wellington, we compare the standard price schedule offered by Transalta in 1997, to the standard price schedule offered by Powerco in 2002, after adjusting for inflation. We find remarkable stability in the standard contract lines charges, despite the bypass. Where the effect of bypass becomes apparent is in the custom contracts, that are negotiated case by case. While in this case the difference in price is not explicitly linked to the existence of bypass (as it is in the zonal pricing of Vector), but it does give an indication of the rents that are being extracted by the standard contract. See figure 2 for a graphical depiction of Transalta's and Powerco's line charges.

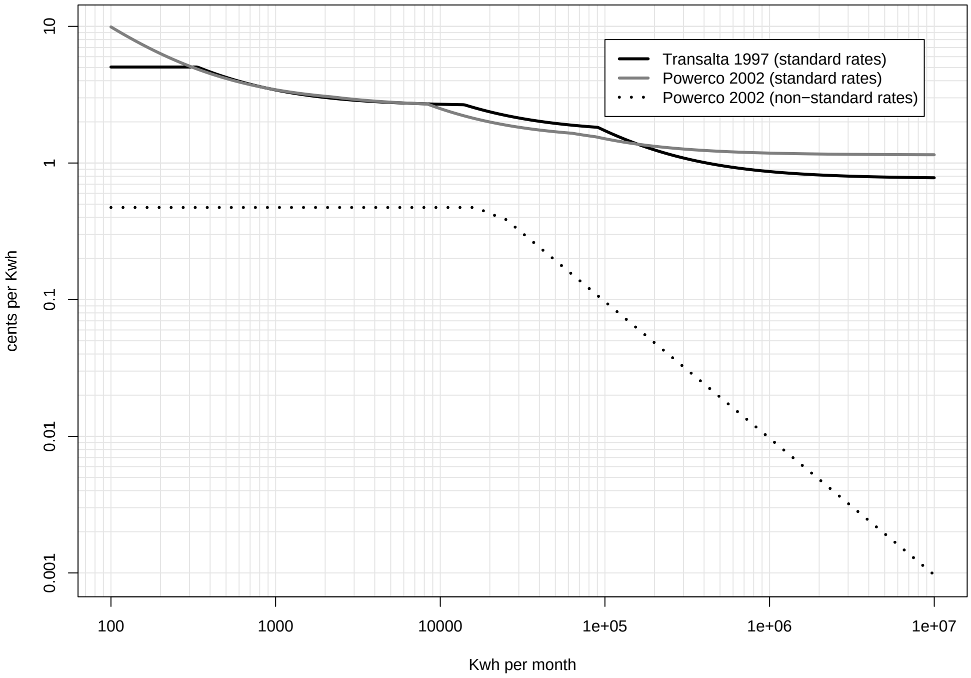

Figure 2: Transalta 1997 vs. Powerco 2002 lines charges for Hutt Valley/Porirua Network (1997 dollars).

4.1 Calibration

For the purpose of calibration, we specify the following utility function for the representative consumer: $U = x_0 + (x_1^\rho + x_2^\rho)^{\frac{\delta}{\rho}}$, when $0 < \delta \leq \rho < 1$. This utility function features a constant elasticity of substitution between goods x_1 and x_2: $\xi = \frac{1}{1-\rho}$ where $\rho < 1$. For this utility function, the demand functions are:

$$x_m(p, M) = \begin{cases} x_1^* = \left(\frac{\delta}{p_1}\right)^{\frac{1}{1-\delta}} \\ x_2^* = 0 \\ x_0^* = M - p_1 x_1^* \end{cases} \tag{4}$$

in the case of monopoly, and

$$x_d\left(p, M\right) = \begin{cases} x_1^* = \left(\frac{\delta}{p_1}\right)^{\frac{1}{1-\delta}} \left[1 + \left(\frac{p_1}{p_2}\right)^{\frac{\rho}{1-\rho}}\right]^{\frac{\rho-\delta}{\rho(\delta-1)}} \\ x_2^* = \left(\frac{\delta}{p_2}\right)^{\frac{1}{1-\delta}} \left[1 + \left(\frac{p_2}{p_1}\right)^{\frac{\rho}{1-\rho}}\right]^{\frac{\rho-\delta}{\rho(\delta-1)}} \\ x_0^* = M - p_1 x_1^* - p_2 x_2^* \end{cases} \tag{5}$$

in the case of duopoly. The monopoly price is $p_m = \frac{c}{\delta}$, whereas the duopoly price is

$$p_1 = p_2 = \frac{c\left(-2 + \rho + \delta\right)}{-\delta + 2\delta\rho - \rho} \tag{6}$$

Note that when $\rho \rightarrow 1$, $p_1 = p_2 = c$. Also, if $\rho = \delta$, then $p_1 = p_2 = p_m$. The entry frontier is

$$f_e = \left(\frac{c\left(-2 + \rho + \delta\right)}{-\delta + 2\delta\rho - \rho} - c\right) \left(\frac{\delta\left(-\delta + 2\delta\,\rho - \rho\right)}{c\left(-2 + \rho + \delta\right)}\right)^{\left(\frac{1}{1-\delta}\right)} 2^{\left(\frac{\rho-\delta}{\rho\,(\delta-1)}\right)} \tag{7}$$

For values of $f < f_e$, bypass will occur in the absence of regulation, because it results in strictly positive net profits. The welfare frontier is

$$f_w = c\left(\tfrac{\delta}{c}\right)^{\left(\frac{1}{1-\delta}\right)} - \left(\tfrac{\delta}{c}\right)^{\left(\frac{\delta}{1-\delta}\right)} - 2\,c\left(\tfrac{\delta\,(-\delta+2\,\delta\,\rho-\rho)}{c\,(-2+\rho+\delta)}\right)^{\left(\frac{1}{1-\delta}\right)} 2^{\left(\frac{\rho-\delta}{\rho\,(\delta-1)}\right)} + 2^{\left(\frac{\delta}{\rho}\right)} \left(\left(\tfrac{\delta\,(-\delta+2\,\delta\,\rho-\rho)}{c\,(-2+\rho+\delta)}\right)^{\left(\frac{1}{1-\delta}\right)} 2^{\left(\frac{\rho-\delta}{\rho\,(\delta-1)}\right)}\right)^{\delta} \tag{8}$$

Refer to figure 3 for a graphical example, where $c = 1$ and $\delta = .5$.

We take the following approach to calibrate the model. The price before bypass (monopoly price) is known. The marginal cost of transporting natural gas is unknown. However, it is most likely between zero and the known duopoly price. For arbitrary marginal costs within this range, we impute the value of δ that would generate the observed monopoly price: $p_m = \frac{c}{\delta}$. Given our estimate of δ for each c, we then use the observed duopoly price to impute a value of ρ that is consistent with c, δ, p_m. With our conjecture of c, and our calibrated estimates of δ and ρ, we derive the welfare and entry frontiers. The calibration estimates are presented in Figure 4 for the zonal pricing of Vector.

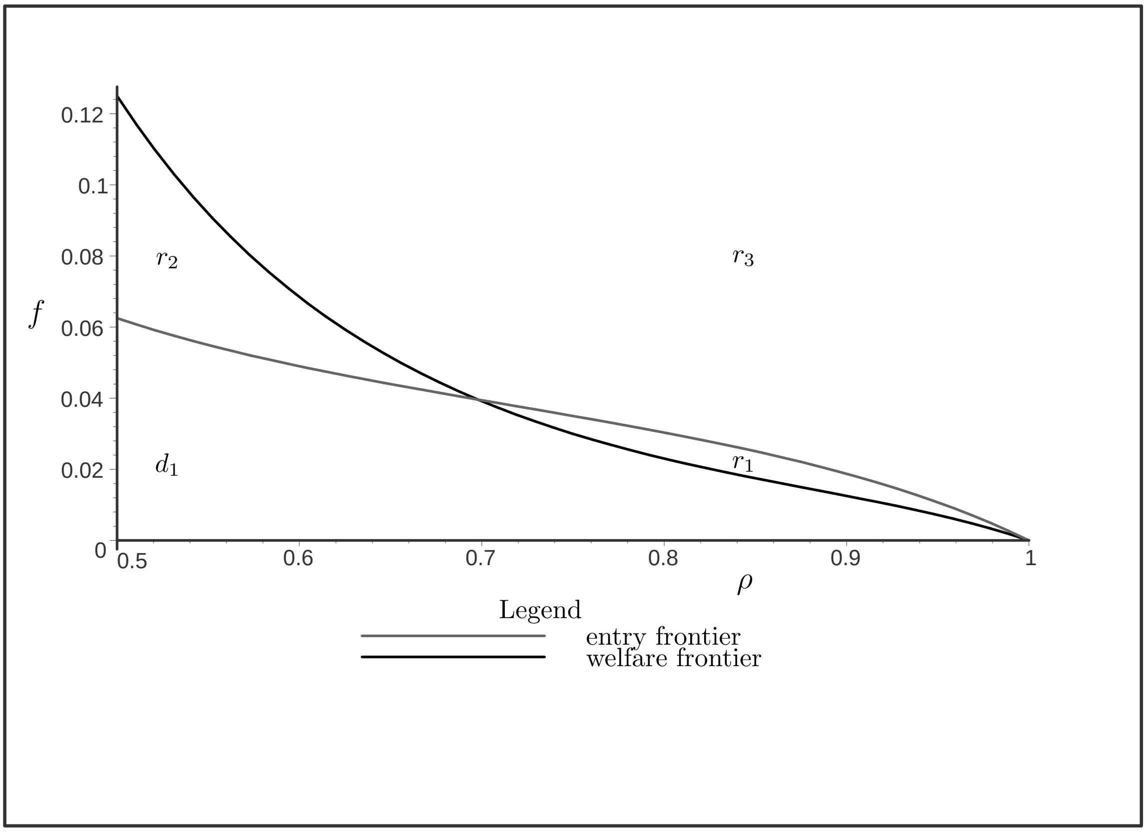

Figure 3: The two curves are the entry frontier f_e and the welfare frontier f_w. These two curves define four regions: r_1, r_2, r_3, d_1. In region r_1, regulation improves welfare, and deters profitable yet socially undesirable bypass. In region r_2 and r_3, bypass would not occur in the absence of regulation, and regulation is preferable to an unregulated monopoly. In region d_1, bypass would occur in the absence of regulation, and an unregulated duopoly is socially preferable to a regulated monopoly.

p_m	c	δ	p_d	ρ	f_e	f_w
0.01684	0.001	0.059382423	0.01316	0.092017136	0.046467119	0.468802966
0.01684	0.002	0.118764846	0.01316	0.182774221	0.102855814	0.477615955
0.01684	0.003	0.178147268	0.01316	0.272085742	0.180812847	0.530680147
0.01684	0.004	0.237529691	0.01316	0.359727896	0.298994788	0.634541736
0.01684	0.005	0.296912114	0.01316	0.445428162	0.494118419	0.8175342
0.01684	0.006	0.356294537	0.01316	0.52885129	0.846845639	1.145950138
0.01684	0.007	0.41567696	0.01316	0.609580147	1.555693308	1.779417315
0.01684	0.008	0.475059382	0.01316	0.687089091	3.181804005	3.151281252
0.01684	0.009	0.534441805	0.01316	0.760706236	7.622043256	6.663063913
0.01684	0.01	0.593824228	0.01316	0.829558788	23.02496496	18.08512438
0.01684	0.011	0.653206651	0.01316	0.892491886	98.09644226	70.71132774
0.01684	0.012	0.712589074	0.01316	0.947944636	685.7043516	468.6483348
0.01684	0.013	0.771971496	0.01316	0.993754473	4617.704782	3172.000826

Figure 4: Calibration Results

Consider the case where the marginal cost of transmission of natural gas is less than .8 cents per KWH. If this is the case, and bypass occurred, then the fact that the welfare frontier is higher than the entry frontier implies that deregulation and the resulting bypass improved welfare. Note that this is true even in the absence of all the well known distortions associated with regulation. However, attributing the fact that duopoly prices remain above marginal cost completely to product differentiation most likely overstates the welfare benefits associated with deregulation.

If the marginal cost of transmission of natural gas is greater than .8 cents per KWH, then we do not get a clean result. If this is the case, the welfare frontier will be below the entry frontier, which means that whether or not heavy handed regulation is desirable depends on the size of the fixed cost f. Because bypass occurred when the industry was deregulated, we know that $f < f_e$. It could be the case that f is lower than both the entry frontier and the welfare frontier, in which case deregulation would improve welfare, as in the case above. However, it is also possible that f could be below the entry frontier, but above the welfare frontier. In this case, deregulation would have decreased welfare.

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