Price Squeezes and Imputation Tests on Next Generation Access Networks (*)

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Abstract: A vertically integrated firm that wholesales to its retail rivals can, if it has sufficient market power, set the margin between its retail and wholesale prices so as to harm its rivals. Conventionally, an imputation test is used to determine whether such behavior is being undertaken. Such tests are common in electronic communications, and the EC calls for their potentially intensive *ex ante* application in the supply of NGANs. This paper shows that while imputation tests are helpful analytical tools for understanding the nature of price squeezes, difficulties associated with implementation, which are sharp in an NGAN context, can make them misleading in practice. Instead, price squeezes are best dealt with through the rigorous comparison of expected outcomes, given the alleged anticompetitive behavior, with the outcomes expected in that behavior's absence. Such analysis is not suited to *ex ante* application.

Key words: price squeeze; imputation tests; next generation access networks; vertical discrimination; electronic communications; regulation.

■ Vertical integration, price squeezes and imputation tests

A next generation access network (NGAN) is a necessary input in the supply of high-speed broadband services. NGAN suppliers typically self-supply the NGAN input at the wholesale layer, and retail to purchasers who

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do not supply electronic communications (hereafter "end-users"), so are vertically integrated.

Vertical integration is ubiquitous. All firms are, to some extent or another, vertically integrated. Moreover, vertical integration is usually efficient, arising when vertically coordinated actions are more productive than exchanging goods and services through arm's length (or horizontal) market-based transactions. Indeed, the empirical record suggests that even where antitrust concerns have been raised, commercial agreements to vertically integrate are commonly beneficial (LAFONTAINE & SLADE, 2007). Some vertically integrated NGAN suppliers can or will be able to act to a significant extent independently of actual or potential rivals, and hence can expect profits that more than recover the efficiently incurred costs of their operations. Such firms are said to have substantial (or in the EU, significant) market power (SMP) [1].

Vertically integrated electronic communications carriers with SMP are often required to wholesale services to carriers who have not made access network investments (hereafter "unintegrated carriers"). For example, regulated unbundling of copper loop deployed by incumbents with SMP is common, while a draft European Commission (EC) recommendation calls for mandated wholesaling of SMP carriers' NGANs [2].

The capacity of unintegrated firms to effectively compete with wholesaling vertically integrated suppliers in part depends on whether unintegrated competition is efficient. Despite the almost certain presence of substantial vertical economies of scope in NGAN provision, unintegrated provision may still be efficient. For example, some unintegrated firms may be excellent niche marketers, reaching customers at lower costs than those that the NGAN provider would have to incur.

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[1] A firm without market power can only make sales at the market price, which is beyond its capacity to influence (that is, the market price would not be changed if the firm withdrew from the market or maximized its output). In contrast, a firm with market power can make sales at a range of prices, but chooses the price that maximizes its profit. In practice, many firms have market power, for example, because of product differentiation, but still operate in effectively competitive environments (that is, their competitors' responses constrain them to recover, in expectation, their efficiently incurred costs).

[2] Draft Commission Recommendation on regulated access to Next Generation Access Networks (NGA), 12 June 2009.
http://ec.europa.eu/information_society/policy/ecomm/doc/library/public_consult/nga_2/090611_nga_recommendation_spc.pdf (hereafter "the draft EC recommendation").

If the vertically integrated firm has wholesale SMP, then it might be able to and wish to harm an efficient unintegrated carrier when it buys the vertically integrated firm's input. (Without SMP, any anticompetitive action would be defeated by competitive responses, for example, wholesale supply from another firm.) One means of harming rivals would be to set a margin between the vertically integrated firm's retail and wholesale prices that it is too small for even efficient, but unintegrated, rivals to recover their costs. This practice is known as a price or margin squeeze.

This paper is concerned with how one might detect a price squeeze. In what follows: The 2nd Section shows that the conditions that must hold for a price squeeze are rigorous. When wholesale prices are set by regulation, objecting to a price squeeze is a call for higher retail prices. Given that, and the difficulty of effecting a squeeze, prosecution should only occur against a high burden of proof. The 3rd Section illustrates, in a highly simplified environment, a means of detecting a price squeeze - imputation testing. The 4th Section shows that in reality imputation tests are complex to implement. If such tests are to be meaningful, then they must be applied over the arena in which firms compete, and should provide a coherent comparison of the expected outcomes under the squeeze and in its absence. Further, such analysis requires sophisticated modeling and sensitivity testing and so is likely to be meaningless if undertaken rapidly or following a rote process. Yet, in many jurisdictions, regulation of electronic communications calls for frequent imputation testing. The Section after demonstrates that in realistic settings, like those for NGANs, imputation testing is also not conceptually simple, but rather a choice must be made among divergent tests, each of which does not clearly identify whether anticompetitive harm is being effected. Accordingly, careful analysis of the case with and without the alleged behavior is the best way to identify whether prices embody a squeeze. The last Section concludes.

■ The mechanics of a price squeeze

A simple illustration of the basic mechanics of a price squeeze can be provided by assuming that:

- all retail output is identical across the competing firms and the market is contestable (so all active retail firms have set the equal lowest price, and a sale by one firm displaces an identical sale by another);

- the per unit retail and wholesale prices do not vary with volumes purchased;
- the vertically integrated firm supplies a wholesale input that must be used to supply retail output (that is, no bypass substitution), and must be used in fixed proportions with the retail output (that is, no substitution by buying less of the input and augmenting it, for example, as one might do with broadband by purchasing a lower broadband speed wholesale, and using data compression to supply the customer with what appears to be a faster link than its physical specifications);
- the unit costs of producing wholesale and retail inputs do not change with volumes (constant returns-to-scale);
- the actions of suppliers do not change the size of the retail market by shifting consumer demands; and
- the relevant markets are not "two-way" or "two-sided" (as will be explained below).

Under these assumptions, a price squeeze occurs if the vertically integrated firm's retail prices are not sufficient to recover the price of the wholesaled input plus the efficient costs of combining the wholesale input with other inputs and producing the competing retail output (that is, the retail transformation costs). Thus, there is a price squeeze if the retail price, *P*, is less than the sum of the wholesale price, *W*, and the efficient transformation costs of going from wholesale to retail supply, *C*, that is, if $P<W+C$. The effect presumably would drive even efficient unintegrated carriers from the market.

At the risk of stating the obvious, it must be the case that the firm engaging in the squeeze has sufficient market power over a wholesale input to harm existing and potential competition (otherwise unintegrated firms would simply purchase the input from a different firm).

While a price squeeze makes unintegrated supply unprofitable, it also reduces the profits of the squeezing firm by $W-P+C$. To see this, let c represent the per unit wholesale costs of the integrated firm. Thus, a squeezing firm has chosen to earn $P-C-c$ on every retail sale it makes, when it could earn $W-c$ on every unit wholesaled. The difference between profit on retailing and wholesaling is therefore $P-C-W$. But, if there is price squeeze, then $P<W+C$, which implies $P-C-W<0$.

Accordingly, if a price squeeze is to be a plausible anticompetitive strategy, then, as with predatory pricing, the squeezing firm must eventually expect to more than recover the revenues foregone during the squeeze [3]. This is so, even if during the squeeze, the vertically integrated firm makes positive profits - that is, if $P-C-c>0$ - because the firm could have made even greater returns if it had not engaged in the squeeze. Moreover, if the profits lost during the squeeze are to be recovered, then the profits made during the later recoupment phase must be substantially greater than the nominal loss so as to compensate for the time-cost of money, the risks that something might change thereby preventing recoupment, and the risk of antitrust proceedings and penalties. Consequently, after competition has been harmed, there must be sufficient barriers to retail entry or service (re)expansion, that the vertically integrated firm can raise prices for a sufficiently long period to recoup the revenues given up during the squeeze.

Recoupment means a successful squeeze must harm end-users: any end-user gains during the squeeze (when $P<W+C$) are more than lost in the profit recovery phase. However, it also means that if the recoupment of profit foregone during an alleged price squeeze is not possible, then it is unlikely a price squeeze has occurred (CROCIONI & VELJANOVSKI, 2003). Rather, the observed behavior, which after all amounts to setting lower prices, is just like any other competitive action, necessarily harming rivals and benefiting end-users.

Since an anticompetitive price squeeze is only profitable in unlikely circumstances, and is difficult to distinguish from pro-competitive behavior, banning squeezes raises the real probability that legitimate behavior will be mistakenly punished, chilling competition. For example, rather than risk being accused of a squeeze, a supplier of an input may over-price its retail outputs, or simply refuse to produce the input where there is no duty to supply (CARLTON, 2008). Consequently, any prohibitions on price squeezes should be subject to strict conditions of proof, so as to avoid the possibly high social costs of "false positives". This leads to the question of how to detect price squeezes.

[3] Non-price vertical discrimination also harms rivals, but potentially at little direct cost to the vertically integrated firm. Consequently, one would expect such activity in conjunction with a squeeze, or an explanation for its absence.

■ Detecting price squeezes: imputation tests in the simple case

Price squeezes are typically identified through imputation tests. A simple example was already implicitly provided above: check whether $P \geq W+C$. The imputation test is passed, that is, finds no price squeeze, if $P \geq W+C$.

In applying such a test, the vertically integrated firm's transformation cost is often used as an estimate of C. This has the advantage that the vertically integrated firm does not have to guess what efficient transformation costs are when setting prices, but can instead rely on its own cost information. Moreover, if the vertically integrated firm incurs unduly high transformation costs, C, then an efficient rival will undercut it, forcing the vertically integrated firm to reduce its costs or lose its market share.

Under the assumptions of the previous section, an imputation test is not only simple to express, but is, as the rest of this section explains, conceptually compelling. In that case, passage of the simple imputation test, $P \geq W+C$, demonstrates three separate facts:

- Unintegrated firms can profitably replicate the vertically integrated firm's prices: that is, the margin between the vertically integrated firm's wholesale and retail prices, $P-W$, is sufficient to allow an efficient unintegrated supplier to cover its costs of transforming the wholesale service and other inputs into the retail output, C. This is the 'replication' interpretation of the test.

- The vertically integrated firm is properly accounting for the opportunity cost of wholesale revenues. As discussed, a price squeeze is costly to the squeezing firm, since it foregoes more revenues upstream than it gains downstream. Hence, a squeezing firm is behaving as if the opportunity cost of wholesaling does not matter. Passage of the test shows its prices are consistent with recognition of this opportunity cost. This is 'opportunity cost' interpretation of the test.

- The vertically integrated firm's behavior is, on its face, profit maximizing. In the simple case under examination, this is so exactly because the vertically integrated firm accounts for the opportunity costs of wholesaling, so the second and third understandings are essentially identical. This is the 'profit maximization' interpretation of the test. Failing this test suggests that the firm might have an anticompetitive purpose that makes the behavior profit maximizing. Thus, this aspect of the test is closely linked to the 'but for' test often used in competition law. That test asks

whether the firm would have engaged in the behavior 'but for' having an anticompetitive intent. In short, in the simple case of the previous section, passing the imputation test suggests efficient rivals can profitably compete with the vertically integrated firm, and the vertically integrated firm is behaving as any competitive profit-maximizing firm would. Conversely, failure of the test suggests that competition would be harmed and that the vertically integrated firm may well be behaving anticompetitively.

■ Implementation complexity and its implications

In practice, imputation testing is more complex than the simple test outlined above. This section considers examples of this complexity as it arises in the cases of bundling and other forms of joint supply (for example, offering separate telephony and broadband services over the same infrastructure), contracts with different time commitments, 'teaser-rates' and loss leaders, nonlinear pricing, and economies of scale.

Each of the discussed examples is highly simplified, but the required analysis is not. In particular, the examples show that to demonstrate a price squeeze requires identifying (1) the arena over which firms compete [4], (2) the outcomes that can be expected given the squeeze must be elucidated, that is, the factual must be identified (this is like estimating *P*-*C*-*c*, but also would show how the squeezing firm is able to behave after the squeeze phase is over), and (3) the outcome that would be expected given competitive behavior, that is, a counterfactual must also be demonstrated (this is like estimating *W*-*c*). Comparing the factual with the counterfactual amounts to a complex form of an imputation test. To find a squeeze, the comparison must demonstrate that the factual, because it prevents efficient competition, is more harmful to consumers and more profitable to the squeezing firm.

Such analysis is necessarily time-consuming and expensive. It cannot practically be undertaken, for example, for routine tariff filings or changes in circumstances, and produce meaningful results. Yet, in the regulation of electronic communications casual imputation testing is surprisingly common.

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[4] This arena will generally be the market, or a segment of the market that is crucial for sustained competition. In all cases, the test should use the retail costs incremental to supplying the identified arena.

Bundling and joint supply

A vertically integrated firm might offer a special discount on telephony service if the customer also buys other services from them. In electronic communications, bundling is common as it typically lowers costs (that is, provides economies of scope) in both provision and consumption. To provide a simple example, consider a telephony and broadband bundle. Applying an imputation test to the telephony service alone [5] might show a price squeeze (as might a test that focuses on the broadband price), but since the broadband and telephony services must be bought together, this may be misleading. If an efficient unintegrated firm can purchase a wholesale service, say unbundled local loop, and profitably supply both telephony and broadband at the vertically integrated firm's combined retail prices for these services, then there is no squeeze. Here, then, the arena of supply must include both telephony and broadband.

Bundling alone does not capture the fullness of competition in many markets, notably those for electronic communication. For example, it may cost less to produce two or more services jointly even when not bundled. If so, commercial reality may dictate that efficient carriers sell the full range of services that deliver those economies. However, this can lead to prices that would fail an inappropriately narrow imputation test.

In electronic communications, incremental costs tend to fall as the number of services provided and service volumes rise. Consequently, incremental cost pricing typically does not allow recovery of total costs.

Allowing different markups above cost can maximize end-users benefits while still ensuring overall cost recovery. Thus, the market might deliver certain services at rates that just cover their incremental costs, and other services at rates that more than do so. While such a pricing strategy may be efficient, an imputation test narrowly applied to the lower priced services may fail, suggesting a squeeze. Yet, this is likely to be incorrect. An appropriate imputation test would identify the services over which costs are efficiently shared and determine whether an efficient competitor purchasing the necessary wholesale inputs to supply the efficient aggregation of services faces a price squeeze. It may be that when the returns from supplying an efficient service range are considered, there is no squeeze.

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[5] For example, the prices might be listed, but only available if the bundle is purchased. Alternatively, if there is only a single bundle price, then an implied price of telephony might be obtained by subtracting the market rate for standalone broadband service from the bundle price.

Explicit and implicit time commitments

Long-term contracts (and also bundling) are likely to allow risk sharing. Suppliers with large sunk costs may grant wholesale purchasers and end-users discounts and price certainty in return for gaining commitments to broad and ongoing use, thereby reducing the risks sunk investments necessitate.

As an example, a vertically integrated firm might offer a special discount on telephony for the first year of service, but a two-year contract is required. While the initial discounted price might fail an imputation test, this need not indicate a squeeze. What is relevant is whether an efficient unintegrated firm could profitably make a similar retail offer. That is, the correct retail price in the imputation test is the full price of the contract. Equally, if unintegrated firms can get wholesale discounts if they commit to a two-year contract, then the two-year wholesale price should be used in the imputation test. Further, contract lengths may not be the only relevant determinant of the appropriate timeframe for an imputation test. For example, the time-profile of customers' stays with an efficient carrier is also likely to be relevant.

Loss-leaders

A vertically integrated firm may introduce a new, say, extremely high speed broadband service at temporarily low rates as a means of attracting attention to the service and allowing users to discover its true value. Similarly, a vertically integrated firm may offer a low priced low bandwidth service knowing a significant number of purchasers will learn the value of the service, but upgrade as they become frustrated with the service's limitations.

Both approaches amount to loss leading and are likely to be particularly important in the context of NGANs. Many new services are likely to be available on an NGAN and these may be difficult for potential end-users to value without trying them, but, having not tried the service, end-users may not be willing to pay their full cost. Such goods are referred to as experience goods, and suppliers often seek to kick-start consumption of such goods through the use of loss leaders and teaser rates.

In both cases, an imputation test might fail if it was narrowly applied to the temporary rate or "teaser" offering. However, if cost-based prices (that is, prices consistent with a narrowly defined imputation test) were required, then innovative services might never take-off. Further, an efficient unintegrated

carrier might be able to profitably replicate the vertically integrated firm's strategies. For example, this would be so if initial losses on the temporary sales are made up by profits on later higher priced sales, and if losses on the teaser service are recovered as customers move from the low to higher bandwidth and so from the low to higher priced packages. Thus, the narrow imputation test would be misleading. An appropriate imputation test would look at the true arena of competition and account for demand shifts over time and across service offerings.

Nonlinear prices and economies of scale

Nonlinear pricing is not merely ubiquitous in electronic communications retailing, but is likely necessary for efficient cost-recovery (for the reasons given above). Efficiency likely also requires nonlinear wholesale rates (KENNET & RALPH, 2007), though these are often regulated to be linear. In either case, the P or W of the simple imputation test are not well-defined unless a volume of sales is also specified. Accordingly, to make statements about profitability and whether account of opportunity costs is taken, it is not enough to identify the arena of competition. The volume of firms' sales and purchases must be estimated. In particular, outcomes in the case of the alleged squeeze (the factual) and outcomes in its absence (the counterfactual) must be specified, with the comparison of the two determining how the vertically integrated firm's actions in the factual could be said to maximize profits, and whether competition was harmed. It goes without saying that the outcome of such comparisons will be sensitive to the underlying assumptions.

A similar effect occurs when the unit costs of supplying retail services (beyond those of the wholesale input, if it is priced linearly) vary with output levels, meaning *c* and *C* are also not defined until output volumes are specified.

An example of regulatory error in this respect is AGCOM's requirement (Resolution 152/02/CONS Annex E) that the regulatory accounts, which contain average costs, be used in conducting imputation tests. This forces Telecom Italia's prices, if they are to pass an imputation test, to exceed average costs, regardless of the specific costs of supply in any given case. In some market segments, this prevented Telecom Italia from competing, since its rivals were already pricing below average costs.

The implications of imputation testing complexity

These simple examples illustrate that, to be appropriate, an imputation test must cover the arena of competition that a squeeze is said to hamper. An imputation test on a narrow service, such as calls on weekends, given competition occurs more broadly than that, at best provides limited and inconclusive information on the impact on competition. This is particularly the case if that service is not sold separately, or if no viable business model can be based on only selling that service separately. Rather, firms compete in markets, which in turn have many dimensions (such as product, geographic, customer, vertical position, and time). If a squeeze is alleged, it must be capable of preventing an efficient, but unintegrated, firm from competing in some market or markets.

When nonlinearities enter the analysis, the imputation test's results will vary depending on what volumes of supply are assumed. To determine the correct volumes amounts to showing how the vertically integrated firm's prices prevent an unintegrated rival from profitably engaging in efficient supply over an identified arena of competition. That requires demonstration of the outcomes under the squeeze (the factual), and how that compares with the case that would have been obtained if the alleged squeeze had not been undertaken (the counterfactual).

Developing a robust factual and counterfactual requires much time and expense, and all the more so because the counterfactual is necessarily speculative (as the factual also must be if the squeeze is examined prior to final recoupment). A pertinent example occurs when unintegrated firms enter a market. Many retailing costs in the supply of electronic communications to mass-market customers are fixed (as is common in virtually any mass market). This means that at sufficiently low sales volumes, unit costs are high. Yet, entry inevitably initially occurs with low volumes, even (or especially) in highly competitive markets. Consequently, in the early phases of entry, a new firm incurs losses. As these losses are normal, it would be inappropriate to estimate unit retail costs, C, in the imputation test on the basis of initial volumes. Rather, *C* should be based on an estimate of the expected market share an efficient carrier would achieve. But determining what that share should be is likely to be analytically and empirically demanding as the following dispute about the factual and counterfactual hopefully makes clear:

> Consider a situation in which unintegrated entry occurs, and the vertically integrated firm responds by cutting its retail prices sharply. The entrant claims this effects a squeeze - given the incumbent's

> prices, the entrant believes its market share will stabilize at an unprofitable level (the factual; in the entrant's counterfactual, the incumbent's retail price cuts are more muted). The incumbent responds that in the factual an efficient entrant would achieve a higher market share and turn profitable in four years (so there is no squeeze). The entrant says, in the factual, it will be out of business by then, and the incumbent will simply raise prices back to where they were. The incumbent says it is not required to set prices at any minimum level should the entrant go out of business, and it is not its problem if the entrant is inefficient and goes out of business, but in any case, it does not believe that the entrant will fail, merely that the entrant is trying to get a court enforced leg-up at the incumbent's expense.

Such an argument cannot be settled by pointing to imputation test results. One result based on low volume shows a squeeze, the other based on higher volumes says there is none. Instead, the actual claims about the factual and counterfactual must be carefully analyzed to come to a judgment.

A key implication of all the preceding is that determining what the arena of competition is, and then developing a factual and counterfactual, cannot be done well quickly. Not surprisingly then, in most industries, imputation tests are applied under competition law proceedings, and hence are infrequent, and when applied, they are thoroughly tested in a legal setting. This is as it should be: when it is difficult to assess whether a certain behavior has occurred it is better to discourage the behavior with high fines on discovery, rather than substantial effort attempting to discover the behavior (STIGLER, 1970).

Despite this, in electronic communications, where imputation tests are likely to be anything but simple, many jurisdictions impose imputation tests through regulatory proceedings. Indeed, imputation tests applied prospectively to tariffs before they are implemented can become routine, as has long been the case in Australia and Italy. Such regulation would likely be even more damaging if applied to NGANs, for at least two reasons:

- NGANs allow quality-of-service variation, which in turn allow substantial product differentiation not available under traditional telephony and broadband supply, hence imputation testing will be considerably more complex in this environment than in traditional telephony. On a traditional copper network voice services, including services like call-forwarding, answering services and similar, are hard to differentiate (though customer service and similar can and often is differentiated). Somewhat more differentiation is possible through broadband service on an all-copper

network, largely by means of bandwidth availability and download caps, but these amount to vertical more than horizontal quality differences [6]. Consequently, different carriers typically offer very similar variations in service, implying homogeneity of overall offerings, but in any case, the product differentiation is relatively limited. In contrast, on an NGAN, quality-of-service control makes substantial horizontal product differentiation possible.

- A wide range of new services and applications are likely to be supplied on NGANs, in part due to quality-of-service controls, making it difficult for regulators (and indeed the market) to forecast outcomes. This makes conducting imputation tests considerably more difficult than in a more well understood environment, raising the likelihood and the cost of error (costs increase, for example, because intervention is more likely to distort or prevent market-oriented solutions to problems that otherwise would arise).

Given this, it is of concern that the draft EC recommendation directs (paragraphs 25 and 39) that if wholesale NGAN prices are not required to be cost-based, then national regulatory authorities (NRAs), "at the request of an operator enjoying rights of access or on their own initiative, should verify the SMP operator's pricing behavior by applying a properly specified margin-squeeze test". This seems like a recipe for frequent, and hence likely poor quality, tests. Frequent testing can be expected to arise because the cost to unintegrated firms of obtaining an imputation test is low (a request just need be made), while the benefits to unintegrated firms are likely to be material. The benefits to unintegrated firms of imputation testing include two that are efficiency enhancing: deterring squeezes; and catching and preventing squeezes early, even if only accidentally. The other benefits to the unintegrated consumer are harmful to efficiency: delaying the vertically integrated firm's competitive responses; discouraging competitive retail price responses from vertically integrated firm; and raising the integrated carrier's costs (because such regulatory proceedings are time, data and attention-consuming exercise). To these costs must be added the regulator's costs and the costs, already discussed, of finding there is a squeeze when there is none.

[6] When all customers agree that one service is better than another (5 *versus* 2 Mb/s broadband), then the difference is vertical; when customers have different preferences for different services (higher bandwidth fixed *versus* lower bandwidth mobile broadband) the difference is horizontal.

In sum, routine and rapid imputation testing of prospective tariffs in real world environments is likely to lead to frequent regulatory errors, a conclusion which applies *a fortiori* to NGAN services.

■ In practice, the imputation test is not conceptually simple

The 2nd and 3rd sections above suggest that, at least conceptually, the imputation test - $P \geq W+C$ - is simple (even if the 4th section shows that implementation is complex). This conceptual simplicity is misleading, being a result of the restrictive assumptions of the 2nd section. As these assumptions are relaxed, the simple imputation test becomes much less useful [7]. Indeed, relative to the opportunity cost, replication and profit-maximizing interpretations of the test, the simple test may give both false positives and false negatives, even when there are no errors in empirical measurement. Of greater concern, these three interpretations are typically no longer congruent, raising the question as to whether it makes more sense to directly ask whether the behavior of concern harms competition and ultimately consumers (as compared with a counterfactual). That being said, (1) arguably, the opportunity cost test could be applied without undertaking a full analysis of the factual, so would be less costly than undertaking either the replication or the profit-maximizing test (each of these essentially would require full analysis of the factual); and (2) since passage of the opportunity cost test is not as rigorous as passing the profit-maximization test, this would also help prevent false positives, especially if coupled with a requirement that the material likelihood of more efficient outcomes be demonstrated in the counterfactual. The rest of this section discusses relaxing some of 2nd section's assumptions, and in so doing also explains these points.

Retail contestability

The assumption of retail contestability is highly simplifying. It ensures that all firms act, in the retail market, as price takers, so strategic interactions are ruled out. A somewhat weaker assumption commonly employed in the

[7] There is a close analytical relationship between the imputation test and the efficient component pricing rule. Analysis of that rule in Armstrong, Doyle and Vickers (1996) illuminates the issues dealt with here.

academic literature is that unintegrated firms behave as if they cannot affect the vertically integrated firm's prices (such firms are called a competitive fringe). However, even the assumption of one NGAN provider and price-taking unintegrated firms is likely to be inappropriate (due to NGAN competition and bypass - see discussion below). Rather some form of oligopolistic competition, both upstream and downstream is likely, and this implies most firms are not price takers.

In an oligopoly setting, a price squeeze cannot be assessed without specifying the nature of the strategic interaction between firms. However, (1) the analytics of allowing for such interactions are complex, and consequently such analysis is not commonly undertaken (ARMSTRONG, DOYLE & VICKERS, 1996, p. 136), and (2) basic empirical questions about how firms actually compete are difficult to answer even when considering past behavior, but are all the more so for prospective questions. As a result, it may be practically impossible to develop a robust description of firm behavior, but such a model is required if the competitive implications of wholesale/retail price relativities are to be assessed.

Retail product homogeneity

When retail product differentiation occurs, replicability can no longer be determined by a focus on the vertically integrated firm. With retail product homogeneity, the imputation test is passed so long as $P=W+C$ (the equality is necessary if the vertically integrated firm is active). If the vertically integrated firm lowers P, even by a little, unintegrated firms would incur losses and so such prices could force their exit. With product differentiation, the vertically integrated firm's retail price, P_v, and its transformation costs, C_v, have to be distinguished from those of unintegrated firms, and it no longer follows that if $P_v<W+C_v$, then unintegrated firms necessarily make a loss.

To see this, consider first the case where $P_v=W+C_v$. With product differentiation, each unintegrated firm faces its own downward sloping demand. As a consequence, if the vertically integrated firm marginally lowers its price, then some or even all of those firms may still earn nonnegative profits, though competitive pressure may force them to lower prices and/or output volumes. In contrast, in the homogenous product case, any active unintegrated firms necessarily earn zero profits if $P=W+C$, and at lower

prices must exit or face losses. (Table 1 below summarizes this and the following results.) Thus, $P_v<W+C_v$ does not necessarily violate replicability.

Similarly, $P_v \geq W+C_v$ does not demonstrate that any or all efficient unintegrated firms can profitably supply retail services. Thus, for example, because retail differentiation may involve fixed costs, it is possible for all firms to earn zero profits when the vertically integrated firm sets Pv so as to maximize its profits. Moreover, this may result in optimal product differentiation. However, if the vertically integrated firm were to lower Pv to slightly below the profit-maximizing price, so that Pv still exceeded $W+C_v$, then this would (by definition) not be the profit-maximizing price, yet by assumption, this could render efficient unintegrated supply unprofitable. Thus, replicability (in the sense of prices that allow efficient unintegrated supply) is not guaranteed even if $P_v \geq W+C_v$ [8]. Without an accurate and necessarily complex model of how firms interact, it may be impossible to distinguish a situation with anticompetitive impacts from one with none at all (and such a model may be impossible to produce).

The test, $P_v \geq W+C_v$, may also no longer be a good indicator of opportunity cost recovery. This is because, as before, for every retail sale, the vertically integrated firm makes unit profits, $P-C_v-c$, but product differentiation means that, in claiming a retail sale, the vertically integrated firm only loses some fraction, call it $\sigma<1$, of a unit in wholesale volumes ($-\sigma$ is sometimes called the diversion ratio). If there is a difference between W and c, contrary to the simple case, this leads to a wedge being driven between retailing and wholesaling contributions. The opportunity cost of a retail sale is $\sigma(W-c)$, which implies the opportunity cost test requires that $P_v \geq c(1-\sigma) + \sigma W+C_v$ [9]. If W is set equal to c, then the opportunity cost test is essentially the same as before: $P_v \geq W+C_v$. However, if W exceeds c, as is likely [10], then P_v may be less than $W+C_v$, but the vertically integrated firm may still be recovering its opportunity cost.

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[8] At the margin of the price change, the wholesale revenue foregone may be greater than the net revenue gained. This goes to the profit-maximization interpretation of the test.

[9] WEISMAN (2002) considers this case and also bypass under some simplified assumptions.

[10] Given the assumption of constant returns-to-scale, the regulator would need to ensure its estimate of costs did not accidentally fall below c, otherwise wholesaling would bankrupt the vertically integrated firm. This would also be so if the regulator allowed a contribution to shared costs (as is common, but not consistent with the simple case considered here of constant returns-to-scale).

Passage of the test, $P_v \geq W+C_v$, is also no longer a sufficient, though it remains a necessary, condition for profit-maximization. With product differentiation, the profit-maximizing price would be marked-up above marginal opportunity cost (because firms face downward sloping retail demand curves), so P would be strictly greater than $W+C_v$.

These results are summarized in Table 1, which illustrates what a particular test can demonstrate. Thus, the first column indicates that if $P_v<W+C_v$, then one cannot say whether the vertically integrated firm is covering its wholesaling opportunity cost, or if an efficient unintegrated firm can profitably supply the service. However, one can conclude that the vertically integrated firm is not maximizing profits.

Table 1 - What a given test can demonstrate

If:	$P_v<W+C_v$	$P_v=W+C_v$	$P_v>W+C_v$
Wholesale opportunity cost is covered	Not shown	Yes	Yes
Efficient unintegrated firm is profitable	Not shown	Not shown (Yes) (*)	Not shown
Behavior is profit-maximizing	No	No (Yes) (*)	Not shown

(*) In the special case of contestability (which assumes no product differentiation), the elements in the column under $P_v = W + C_v$ can be replaced with "Yes". This is so even with product differentiation, so long as there are no fixed costs. Then, if entry and exit are free (standard conditions of contestability), it is profit maximizing for the vertically integrated firm to set $P_v = W + C_v$ (the firm effectively faces a horizontal demand curve because customers could switch to an arbitrarily close differentiated service). At such prices, efficient unintegrated firms would cover costs, and outcomes would be efficient.

As noted in section above, the assumption of product homogeneity is particularly inappropriate in the case of NGANs.

Bypass and input substitution

Similar results follow if there is wholesale product differentiation, or if bypass is possible, at the wholesale layer. In particular, focusing on bypass, if $P_v<W+C_v$, then an unintegrated firm may still profitably operate depending on its access to bypass. The outcome, however, may be inefficient, and could also harm competition. Equally, if $P_v<W+C_v$, then the vertically integrated firm's prices may still be covering its wholesaling opportunity costs, because an increase in its retail volumes may be accompanied by a smaller loss of wholesale volumes (due to bypass). However, it is unlikely that such a price could be profit maximizing, so the interpretations of the test (and the results that can be drawn from it) may go in opposite directions.

One-*versus* two-sided markets

In an ordinary, or one-sided market, firms are best thought of as retailing to an end-user. However, in some markets, firms provide a platform that brings different groups of customers together to bring value to each "side" of the market. Such markets are called two-sided. NGAN providers, in supplying broadband, can be thought of as a platform that brings together content seekers (downloaders), who typically pay a monthly charge, and in some locations a per bit rate of some form, and content (including application) providers, some of whom pay for services, for example, that improve the speed that their content reaches the end-user [11]. Content providers, in turn, typically deliver content seekers to advertisers. NGAN providers also link content providers to content seekers via subscription television, and here directly deal with advertisers as well. Moreover, they may also provide web content, again dealing directly with advertisers.

Constructing imputation tests in such two-sided environments is challenging. Further, two-sided market issues are likely to be much more prevalent on NGANs than on copper networks (because broadband and subscription television services are likely to be of substantially more importance than traditional telephony).

Two-sidedness also increases the possibilities for product differentiation by unintegrated carriers, by providing applications for content providers that ensure fast content delivery, or applications for end-users that are embedded with fast content delivery. For the reasons discussed above, this further complicates imputation test interpretation.

■ Summary

In summary, imputation tests are difficult to implement, and without due care their results are misleading. This is especially so in an environment as complex as that of NGANs. Moreover, the cost of 'false positives' is likely to be high, supporting inefficiently high prices, and discouraging vertically integrated firms from vigorously competing. Consequently, imputation testing should not be applied prospectively to new tariffs. Rather, if price squeezes

[11] Akamai is perhaps the preeminent third party provider of this kind of service, but carriers may also be well placed to compete in this market, especially on an NGAN.

are to be prosecuted, this should occur through the rigorous practice of competition law. That is, the situation with, as compared to without, the alleged anticompetitive behavior, should be shown to harm competition, and ultimately consumers, while raising the squeezing firm's profits.

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