Symmetry and the Sixth Force: The Essential Role of Complements*

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July 10, 2024

Abstract

Over forty years later, the five-forces model (Porter, 1980) remains one of the most influential frameworks for formulating strategy. Yet there is a hole in the model, namely, the force of complements. Porter (2008) has advocated against including complements as a force. He argues that the effect of complements fails a test of monotonicity and must be understood via the existing five forces. However, this monotonicity test conflates the positive direct impact of complements with the ambiguous effect complements have on the other forces. Also, the structure of the complements industry can have a direct effect on industry profits, with no impact on the five forces. Because complements have traditionally been neglected, strategy towards them is under-developed relative to strategy built on the other five forces. We provide strategic insights that come from giving equal billing to complements. Starting from Porter's checklist for substitutes and its associated strategies, we create an analogous checklist for complements. Since complements are a symmetric counterpart to substitutes, up to a sign change, the associated strategies are symmetric in the same fashion. Including complements as a sixth force makes the five-forces framework more logically complete and more valuable.

"What immortal hand or eye, Could frame thy fearful symmetry?"
– The Tyger by William Blake

1 Introduction

The five-forces model of Porter (1980) is designed to describe the sources of power that influence the profitability of an industry. The model has been expanded to include factors such as government and demographics (Saloner, Shepard, and Podolny, 2001), consumer preferences (Besanko, Dranove, Shanley, and Schaefer, 2017), and more. One does not want to include too many additional factors. Parsimony of a model is desirable. But, at the same time, a model should not have important holes.

There is an important hole in the five-forces framework, namely, the absence of complements. Porter (2008) and many others (e.g., Saloner, Shepard, and Podolny, 2001; Besanko, Dranove, Shanley, and Schaefer, 2017; Ghemawat, 2017) clearly recognize the relevance of complements to industry profits. A hardware industry needs a software industry in order to flourish, and vice versa. However, Porter (2008) argues that complements cannot be a distinct force and must be understood through their impact on the existing five forces. The framework does not need expanding.

As we explain below, complements are on a logical par with substitutes. Complements and substitutes are symmetric, up to a sign change. Given this symmetry, it would seem that opportunities from complements should be treated as a force in exactly the same way as are threats from substitutes; this is what we did in our value net model (Brandenburger and Nalebuff, 1996). Porter (2008, p.22) claims that complements are unlike substitutes because their effect on industry profits is non-monotonic and, therefore, they cannot be a force:

> [C]omplements are not a sixth force determining industry profitability since the presence of strong complements is not necessarily bad (or good) for industry profitability.

*Important input from Chloe Chen, Judy Chevalier, Jessy Hsieh, and Natalya Vinokurova is grateful acknowledged. We thank the NYU Stern School of Business, NYU Shanghai, and J.P. Valles for financial support.

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As buyer power, supplier power, rivalry, threat of entry, and threat of substitutes go up, industry profits go down. Each of Porter's five forces has a monotonic effect on industry profits. If the effect of strong complements is ambiguous, they cannot be a force.

Adner and Lieberman (2021) provide a comprehensive examination of how complementors disrupt established firms. In one of their examples, the presence of complements directly raises industry profits, but this is more than offset via an indirect effect of reducing product differentiation. They accept Porter's conclusion that since the effect of complements, though important, is non-monotonic, they do not constitute a sixth force. The Adner-Lieberman example is very insightful and we will return to it later. But, again, we hold to the opposite conclusion about complements as a sixth force.

Indeed, the effect of complements is monotonic in the very same way as substitutes. The key point is not to conflate the direct effect of complements – which is always positive – and the indirect effect on the other five forces. The indirect effect can go in either direction and can possibly overturn the direct effect. The very same ambiguity applies to substitutes: The direct effect is always monotonic (negative this time) and the indirect effect can go in either direction.

The contribution of this paper is to make the argument that complements must be a sixth force. We recognize that some readers will be "pre-sold" on our conclusion. Grove (1996) supplements the five-forces analysis with the force of complements to arrive at what he calls the six-forces analysis. Textbooks by Saloner, Shepard, and Podolny (2001, Ch.6) and Besanko, Dranove, Shanley, and Schaefer (2017, Ch.8) explicitly put complements on a par with substitutes. Prior research has emphasized the role of complements, outside of the five-forces model. Teece (1986, 2014) replaces industry analysis with ecosystem analysis. Profits in one part of the ecosystem – the base industry – cannot be analyzed separately from the ecosystem as a whole, complements included. Adner and Kapoor (2010), Adner (2017), Jacobides, Cennamo, and Gawer (2018), Cusumano, Gawer, and Yoffie (2019), and Adner and Lieberman (2021) all consider the active role of complementors in ecosystems. But, to the best of our knowledge, no one, ourselves included, has ever formally made the argument that complements are a force or carefully addressed possible counter-arguments.

The paper proceeds as follows. Section 2 introduces the formal definition of complements. This definition highlights the essential symmetry between complements and substitutes. The mathematial definitions establish that complements must be on an equal footing with substitutes. Section 3 presents the two arguments that have been offered for why complements are not an independent force: (1) their effect is not monotonic; and (2) their effect must be understood through the impact on the other five forces. We identify the flaws in each argument. Section 4 provides strategic insights that come from giving equal billing to complements and connects this paper to the literature on complements. We start from Porter's (1980, 2008) checklist for substitutes and its associated strategies and create an analogous checklist for complements. Naturally, this exercise makes use of the symmetry, up to a sign change, between complements and substitutes. Section 5 offers a brief conclusion. The Appendix provides a mathematical model to support an example we present in the text where increased competition from substitutes raises (rather than lowers) industry profits.

2 Symmetry

There is a prima facie argument for why complements should be a force given that substitutes are a force. Substitutes and complements are on the same logical footing, as we will verify. The concepts are symmetric counterparts, up to a sign change. If a "less than" relationship is deemed a force, then a "greater than" relationship should be, too. The natural prior belief is that the two concepts should be classified in the same way. (For the concept of symmetry up to a sign change, and physical applications, see Padmanabhan et al., 2020.)

We are not the first to recognize symmetry as a desideratum in creating better theories of strategy; see Foss and Hallberg (2014). Indeed, in the five-forces framework, there is an important symmetry between buyers and suppliers – they are simply opposite sides in a buy-sell relationship. Brandenburger and Stuart (1996) extended buyer-supplier symmetry in proposing a definition of value creation in terms of willingness-to-pay minus willingness-to-sell that treats the upstream and downstream symmetrically. (The term "willingness-to-sell" is due to Oberholzer-Gee, 2021.)

There is a basic symmetry between substitutes and complements, as the definitions bring out. Two firms identified by their products A and B are selling substitutes for a customer if:

$$\text{WTP}(A\&B) \leq \text{WTP}(A) + \text{WTP}(B), \tag{1}$$

where $\text{WTP}(A\&B)$ is the willingness-to-pay for products A and B together, $\text{WTP}(A)$ is the willingness-to-pay for A alone when there is no B, and $\text{WTP}(B)$ is the willingness-to-pay for B alone when there is no A. Another way of saying this – by subtracting $\text{WTP}(A)$ from both sides in Inequality 1 – is that a customer

who owns A is less willing to pay for B than a customer who does not already own A (and vice versa with A and B interchanged).

There is a sign-flip definition. In place of $\leq$, write $\geq$. That is, consider the case:

$$\text{WTP}(A\&B) \geq \text{WTP}(A) + \text{WTP}(B). \tag{2}$$

This is the formal definition of what it means to say two products A and B are complements. We see that complementarity is the symmetric counterpart to substitution. Complementarity means that the willingness-to-pay for B when A is owned is greater than or equal to the willingness-to-pay for A alone (and, again, vice versa with A and B interchanged).

The definition of complements goes back to Fisher (1892), Edgeworth (1897), and Pareto (1909). Just as substitutes exist on both the customer and the supplier side, so do complements. Here, the definition is that the willingness-to-sell to firms A and B together is less than the sum of the willingness-to-sell to A alone plus the willingness-to-sell to B alone. In this paper, we emphasize the role of complements on the customer side, but our findings apply equally to the supply side.

Given the symmetry in the definitions of complements and substitutes, one would expect there to be a fundamental sign-flip symmetry in the effects of these two forces. As we next show, this is indeed the case. While the direct effect of the force from substitutes is negative, the direct effect of the force from complements is positive. For both substitutes and complements, the indirect effect they have on the other five forces can go in either direction.

3 Non-Monotonicity and Complementor Industry Structure

Substitutes reduce willingness-to-pay. The total pie shrinks. If the levels of the other forces are held constant, industry profits are thereby expected to fall. For example, Netflix reduces customer willingness-to-pay for going to a movie theater and thereby reduces the profits for the movie theater industry (assuming the presence of Netflix does not also change any of buyer power, supplier power, rivalry, or entry).

The direct effect of strong complements must necessarily be good for industry profitability in the same way that the direct effect of strong substitutes must necessarily be bad for industry profitability. The direction of the effect on profitability is reversed, but this is simply the sign-change effect. This is not the issue. At issue is whether the effect on industry profits is monotonic. Porter (2008, pp.22-23) claims that complements are unlike substitutes because their effect on industry profits is non-monotonic and, therefore, they cannot be a force.

The unfounded concern over the ambiguous impact of complements comes from conflating two distinct effects: (1) a direct effect, and (2) an indirect effect on the other forces. The presence of complements improves profits by raising willingness-to-pay. The second feature of complements is they can reshape the other five forces – for example, by changing barriers to entry or rivalry – and this effect can go in either direction. The indirect effect can dominate and so the net effect of these two factors can also go in either direction.

Porter (2008) presents an example where Microsoft as a complementor provided toolsets that made it easier for firms to write application software and thereby reduced entry barriers into the base industry. Adner and Lieberman (2021) describe how DoorDash, a complementor to restaurants, reduces the importance of a restaurant's physical location, thereby lowering product differentiation, which leads to increased rivalry among restaurants. In these examples, whether the reduced entry barriers or increased rivalry was enough to offset the gain from the increased willingness-to-pay created by the presence of the complement is left unresolved as an empirical matter. That said, we fully agree that it is possible that the indirect effects could dominate, leading to lower industry profits.

If there is perfect symmetry, then it should equally be possible that the presence of strong substitutes can have a negative direct effect on industry profits, but can change the other five forces in a way that raises profits, and that this positive indirect effect can dominate. Just as complements can lower industry profits via their indirect effect, substitutes can raise industry profits via their indirect effect. In Example 1 to follow, the presence of a substitute increases product differentiation and thereby reduces rivalry. Note that, in presenting this example, we do not mean to suggest that this is a common scenario, just that it is a possible one.

Example 1. *Consider the effect of the threat from a generic drug substitute to the branded drug industry. The direct effect is clearly negative since generics reduce willingness-to-pay for the branded drugs. The stronger the substitute, the more it reduces willingness-to-pay (and thereby leaves the branded products with a smaller market). The effect on rivalry among the branded drug makers goes in the opposite direction. The existence of a generic drug entrant takes price-sensitive customers out of the market, leaving behind those most loyal to the branded drugs. We develop this example more formally in the Appendix, where we*

show how an increase in differentiation of the branded products can lead to reduced rivalry and a large price increase, one more than sufficient to offset the loss in customers to the generic substitutes.

Even though the net effect of substitutes in Example 1 is positive, this is not an argument against substitutes being a force. The example depends on an indirect effect overriding the direct effect. We do not say that substitutes are not a force because their net effect is ambiguous. That substitutes are a force follows from their unambiguous direct effect. That complements are a force equally follows from their unambiguous direct effect.

The example is another application of the basic symmetry between substitutes and complements: Every argument regarding a substitute yields a flipped version when it comes to a complement (and vice versa). If complements can lead to more rivalry, then substitutes can lead to less rivalry. Every argument can be flipped.

In general, we subscribe to the view that the net effect of threats from substitutes is likely to be to lower industry profits in the base industry. The branded drugs example we gave is a less usual case. Similarly, we think the net effect of complements is likely to be higher profits. The DoorDash example is the less usual case. We subscribe to the intuition that better complements generally lead to higher industry profits, just as stronger substitutes generally lead to lower industry profits. But monotonicity of the net effect is not something that must logically hold for either substitutes or complements. The fact that the net effect can go either way does not affect the standing of substitutes or complements as a force.

Porter (2008, pp.22-23) makes a second argument for why complements should not be considered a distinct force: The effect of complements on industry profitability can be fully accounted for by tracing their effect through the existing five forces. Including complements as a force would be redundant.

> Complements affect profitability through the way they influence the five forces .... The strategist must trace the positive or negative influence of complements on all five forces to ascertain their impact on profitability.

While Porter does not explicitly say that the the effect of complements on industry profitability must be assessed only via their influence on the five forces, this is the implied message. If complements are not a force, their impact is only via their indirect effect. Such a claim makes sense when one considers the effect of government or demographics or other traditional non-market factors on the profitability of an industry. But it is not correct when it comes to the effect of complements. We demonstrate this via a counterexample.

Example 2. *Consider a monopolized base industry where there are no substitutes, buyer power is near zero, supplier power is near zero, there are no threats from entry, and there is no rivalry since the firm is a monopoly. It would seem that the monopoly firm would be the only player with a claim on industry profits. But this misses the "competition" with complementors. The industry structure of the complementary product determines the extent of this competition and is thus fundamentally important to the base industry profits. This effect is wholly independent of the existing five forces since it has no impact on any of them.*

This example establishes that complements must be a distinct force because their impact would otherwise be missed or unexplained. To illustrate the example, take the monopolist to be Microsoft in the mid-1980s to mid-1990s. Its customers were small relative to the size of the market and had little to no power. Most of the firm's inputs were commodities and there were many suppliers, with little to no power (granting that some star programmers may have been exceptions). The firm was protected from rivalry or entry by its head start and IP. Also, there were no good substitutes.

According to the five forces, Microsoft should have captured nearly all of the value created. Yet, while Microsoft was very profitable, there was another player which had a claim to this value. That player was Intel, the microprocessor manufacturer and major complementor to Microsoft (see Ghemawat, 2017, p.29). In fact, during the mid-1980s to mid-1990s, Intel's profits per PC sold were roughly equal to Microsoft's profits per PC (Casadesus-Masanell, Nalebuff, and Yoffie, 2008, Table 1).

If Intel had been one of many commodity chip makers, it would have priced at close to cost and Microsoft would not have to "compete" with Intel for profits. Microsoft would have been able to double its profits. (Its profits might have more than doubled since it would have been able not only to capture all of Intel's profits, it could also have raised combined profits across the two industries by avoiding double marginalization; see Section 4.) Complementor firms are similar to customers and suppliers in that they, too, along with the base industry firm(s), have a claim on value. The strength of that claim depends on the structure of the complements industry. Microsoft's profits are likely higher when the complements industry is more competitive and lower when the complements industry is also monopolized.

Bringing this example back to Porter (2008), we see that this complementor effect cannot be understood via its influence on the five forces. Whether microprocessors are supplied by an Intel monopoly or by many competing chip makers, the five forces for the operating-system industry are the same. They are all near

zero, as we already noted. Yet, the profitability of the operating system industry fundamentally depends on the industry structure of the complements industry.

Here, we make an important distinction between the existence of the complementary product (the microprocessor) and the structure of the complements (microprocessor) industry. The existence of the complementary product expands the pie. The structure of the complements industry determines the power of complementors to claim value in the operating-system industry. Just as concentration of buyers and suppliers influences buyer and supplier power, so does concentration in the complements industry influence complementor power.

In summary, the potential non-monotonicity of the net effect of complements cannot rule them out as a force. We would have to rule out substitutes as a force as well. Moreover, the effect of complements cannot be understood via the existing five forces, as seen in our Example 2.

4 Complementor Strategies

We ask what changes once one recognizes that complements are a sixth force. In one way, nothing is changed. Researchers have already done significant work analyzing the strategic role of complements without calling them a force; see the discussion below. But there is no simple checklist or set of heuristics underneath the heading "Opportunities from complements" to parallel the heuristics commonly found under each of the existing five forces. We believe the symmetry in potential strategies is under-appreciated. In this section, we make repeated use of symmetry – with a sign change – to develop set of heuristics for strategies towards complements.

Under "Threats from substitutes," Porter's (1980, 2008) checklist includes relative price performance for substitutes and switching costs. The strategist is meant to consider these factors in coming up with an overall assessment of the strength of the substitutes force and developing appropriate strategies. Here, we develop an analogous set of heuristics for complements. A firm's stance toward complements is the flip of its stance toward substitutes, as follows:

1. A firm prefers that its complementors' products represent an attractive price-performance combination. Ideally, complements are high quality, low cost, and proprietary.
2. A firm prefers that its complementors have low market power. For example, it is desirable if customers can easily switch among different complement options.

We expand on each observation in turn. Following McIntyre and Srinivasan (2017), our answers integrate reasoning in the style of strategic management and arguments from industrial-organization economics.

4.1 Quality, Quantity, and Cost of Complements

Under Observation (1), we ask: How can a firm encourage its complementors to make high-quality products? One answer is to commit not to compete with them in the complements space and thereby help ensure that they will earn a return on upfront investments in quality; see Farrell and Katz (2000) and Gawer and Cusumano (2002). Gawer and Henderson (2007) give the example of just such a commitment device when Intel created the Intel Architecture Lab and structured it as a standalone not-for-profit unit. Absent a commitment, a firm can instead develop a reputation for treating its complementors fairly; see Gans and Stern (2003) and Zhu and Liu (2018).

Another strategy is to help customers identify high-quality complements and thereby aid higher-quality complementors vis-à-vis lower-quality complementors. Apple polices the quality of the programs available on iOS to try to ensure that iPhone customers are not disappointed by low-quality apps. It is also possible to ally with high-quality proprietary complementors in order to raise profits by increasing differentiation. Taeuscher and Rothe (2021) note this strategy in investigating the online learning space (MOOCs), where high-quality complements signal overall quality and thereby increase the effectiveness of horizontal product differentiation.

Thinking systematically about complements strategy goes against a view that firms should "stick to their knitting" or (narrowly) focus. In nascent ecosystems, complements may be low-quality or even missing. For example, in the residential solar power industry, bottlenecks have been caused by an underdeveloped complement – namely, financing. To solve this problem, one firm developed its own financing product; see Hannah and Eisenhardt (2018).

Even when complements exist, a firm cannot count on other players to supply the desired quality and quantity of complements. It may need to be actively involved in the complements industry. In the case of car companies and electric charging stations, providers of high-speed electric charging stations are likely constrained in their ability to charge high prices. (This is in part due to the fact that customers have some

ability to substitute by slow charging at home or at work.) This has slowed the entry of independent charging companies. To the extent such firms have entered, they have focused on the most profitable geographies. In the U.S., this has led to "charging deserts" which impact the overall sales of electric vehicles (EV's). (In Europe, carmakers have formed a consortium called Ionity in order to build out a comprehensive high-speed charging network.)

Building a national high-speed charging network also requires coordination. The charging stations are complements to one another, not just to EV's, since a bigger network encourages EV owners to make longer trips if they can rely on a spread-out network of chargers. This points to the likely need for a large player who can solve the coordination problem. But a large player will have some market power. To avoid this issue, an EV maker may want to enter the charging market itself. For example, Tesla has an incentive to ensure that an extensive network exists and is not controlled by a complementor with market power – because that complementor would then have a significant claim on the total pie. To this end, Tesla built a proprietary charging network when launching its EV; see Van den Steen (2020).

Also under Observation (1) about complementor strategy is the strategy of helping complementors lower their costs. For example, a firm may share demand forecasts or provide access to forthcoming technologies. Nintendo, Sony, and Microsoft provide developer interfaces and stage conferences to make it easier to write games. The incentives are most pronounced when the complements are proprietary, so that the benefits are not shared across the entire industry. Miller and Toh (2020) discuss the use of standards setting across complements.

One might conjecture that complementors, in their competition with one another, have sufficient incentive to lower costs. This is not the case. The reason is that a complementor only captures a fraction of the resulting gain. When a complementor lowers its cost, this allows it to lower its price and thereby gain share and profits. But, the lower price of the complement also expands demand in the base industry, so that firms there could raise price. Some fraction of the gain from lowering cost escapes the complementor industry and leaks into the base industry. It is entirely possible that the complementor will have an insufficient incentive to invest in cost-reducing activity.

The extreme version of this phenomenon is seen in the case of perfect complements. Here, two products create no value on their own, but together they create positive value. In this case, when each complementor is a monopoly, their profits are equal regardless of any difference in their costs; see Cournot (1838, p.102) and Casadesus-Masanell, Nalebuff, and Yoffie (2008). An implication is that half the gains from lower costs leak into the complement. One strategy to address this issue is horizontal integration with a complementor.

There is a caveat to the previous discussion. A firm may not want its complementor's price-performance profile to be too favorable. For example, Amazon welcomes third-party sellers to participate on its platform, but it may then decide to compete with them. (Zhu and Liu, 2018 find that Amazon is most likely to enter the product spaces of complementors if they have high sales and do not use Amazon's fulfillment services.) The reason for this inconsistency is that the two firms are both complementors and competitors. A third-party seller is a complementor when it comes to making the Amazon platform more attractive and bringing more people to the platform. But once the customers are on the platform, the seller becomes a competitor. Amazon has an incentive to intervene if it makes higher profits when a purchase is made directly through it rather than via the third party. We call this relationship between the two firms one of ex-ante complementarity and ex-post competition.

4.2 Power of Complementors

Returning to our checklist for strategy towards complements, we ask under Observation (2): How can a firm affect the power of its complementors? One strategy is to enter the complements market with the intent to lower prices. Unlike a typical entry strategy, a firm may not seek to earn profits in the complements market. It may be sufficient to lower prices and thereby ensure that more of the total pie is captured in the base industry.

Separate from direct entry, a firm may support the existing smaller firms or challenger firms in the complements industry. In this regard, Intel has supported Linux to provide competition to Microsoft, and Microsoft has supported AMD in order to provide greater competition to Intel; see Casadesus-Masanell and Yoffie (2007).

A firm might want to enter the complementor market without actually selling any product. In particular, if firm A is more efficient in the complements market, its goal may be not to sell the complementary product but to induce firm B (or several such firms) to lower their price. This can be done via a price squeeze (Ordover, Sykes, and Willig, 1985) or an access squeeze (in which firm A gives a complementor exclusive or preferential treatment conditional on a low price). Here, and unlike traditional predation, the firm may forego recouping losses from low-price entry in the complements market; it might recoup the losses right away via a higher price in the base market (Nalebuff, 2005).

In a similar vein, a firm might withhold support in order to keep a check on a complementor's power. Wang and Miller (2020) show how travel-book publishers strategically withheld some of their best revenue-generating books from the Kindle platform and supported alternative distribution channels, with the goal of maintaining their bargaining power with Amazon. These publishers were concerned about limiting the strength of an important complement. (Eventually, publishers gained more control over pricing and the great majority of books became available on the Kindle platform.)

There is a second issue that arises when each complementor has market power in its own industry. Each firm's attempt to capture profits leads to double marginalization and thus inefficiently high prices – an observation that goes back to Cournot (1838, pp.100-103). (This issue is a horizontal analog to the classic issue of double marginalization along a vertical supply chain; see Spengler, 1950.) The obvious answer is for the firms to coordinate. If competitors coordinate, the result is often lower output and higher prices. This increases profits, but it reduces the value captured by customers. But when complementors coordinate, they raise output and lower prices. Again, profits rise, but, this time, customers actually capture more value.

In Heeb (2003), a monopolist integrates with its complementor and then provides the complementary product at cost. Even though profits are zero in the complements market, integration solves the double-marginalization problem and expands the incentive to innovate. Likewise, two complementors that merge solve the double-marginalization problem and thereby achieve an advantage in both markets over rivals whose pricing is independent and therefore too high; see Nalebuff (2000).

At the policy level, we see how mergers between complementors need to be treated differently from mergers between competitors. They may be pro-consumer exactly when an analogous merger between competitors would be anti-consumer. It is the sign-change symmetry effect again.

By contrast, if the merged firm sells the complements only as a package, this may make it harder for potential rivals to enter, if they need to develop both complementary products, not just one; see Choi and Stefanadis (2001), Choi (2008), and Nalebuff (2004). Even if the merged firm engages in mixed bundling, Masson, Dalkir, and Eisenstadt (2014) demonstrate potential downsides for customers, who may be driven away from their ideal mix-and-match combination of complements. Also, the merged firm may be able to engage in more effective price discrimination.

5 Conclusion

Complements do more than expand industry profits and shape the existing five forces. They constitute a force in their own right and one that has been less understood. Evidence of this is that, to the best of our knowledge, the counter to objections that complements do not constitute a force has not previously been presented. In this paper, we make the counter-arguments and estalbish the logical case that complements sit on an equal footing with the other forces.

The mathematical definition of a complement is the same as that of a substitute – with a reversal of the defining inequality. Given this symmetric relationship, there is no reason to treat complements any differently from substitutes. The argument that complements cannot be a force because their effect is not always positive conflates the positive direct impact of complements with the ambiguous effect complements can have on the other five forces. The same ambiguity arises in the net effect of substitutes. Example 1 in Section 3 made this point concrete.

In addition, the effect of complements cannot be fully understood through their impact on the existing five forces, as we saw in our Example 2 in Section 3. The structure of the complements industry has a direct effect on base industry profits.

Having established the independent importance of complements, we went on to explore and, we hope, expand somewhat, the understanding of strategy towards complements. The broad picture was that existing strategies toward substitutes should be flipped in order to apply to complements.

We see complements as a complement to the five-forces model of Porter (1980). Including complements as a sixth force makes the framework more valuable, not less. The result is a more complete map of the strategic landscape and a more complete set of options for strategists.

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Appendix

This section presents a formal model to support our Example 1 in Section 3. Customers are uniformly located on the line segment $[0, 1]$. There are two incumbent firms. Firm 0 is located at 0 and firm 1 is located at 1. Initially, there are only branded products available in the market. The customer located at x has a willingness-to-pay $v(x) - x$ for the branded product from firm 0 and a willingness-to-pay $v(x) - |1 - x|$ from firm 1. We assume that, for all customers $x \in [0, 0.3)$ and $x \in (0.7, 1]$, the gross willingness-to-pay is 3. For all customers $x \in [0.3, 0.7]$, the gross willingness-to-pay is 2.

When an unbranded substitute arrives in the market, two firms, both located at 0.5, offer identical versions of this product. The customer located at x has a willingness-to-pay $w(x) - |x - 0.5|$, where $w = 0.92$ for all customers.

The idea of the model is that when the unbranded substitute enters the market, it captures all the price-sensitive customers in the "middle" of the market. The remaining customers at the "ends" of the market have a strong preference for one or other branded product. We will see that the outcome is that the (equal) prices of the branded product rise and this increase in price more than offsets the loss of customers to the entrants.

A.1 Pre-Entry Equilibrium

Proposition 1. *There is a Nash equilibrium where firms* 0 *and* 1 *both set a price of* 1*. Each firm sells to the half of the market nearest to its position. Each firm makes a profit of* 0.5*, so that the combined profit is* 1*.*

Proof. If firm 1 sets a price of 1, then firm 0's profit when it sets a price $0 \leq p \leq 1$ is given by:

$$\pi_0 = p \times [0.5 + 0.5(1 - p)] = p(1 - 0.5p).$$

If firm 0 sets $p = 0$, it will sell to the whole market. If it sets $p = 2$, it sells to no customers. Its profit function π_0 is maximized by setting $p = 1$. A parallel argument shows that, if firm 0 sets a price of 1, firm 1 maximizes profit by setting $p = 1$.

Turning to the customers, note that, since all customers have a gross willingness-to-pay of at least 2 and "transportation costs" are equal to or lower that 0.5, all customers prefer to buy the branded product at a price $p = 1$, to not buying it. Indeed, this is true for the customer located at $x = 0.5$ and therefore it is true for all customers. □

A.2 Post-Entry Equilibrium

Proposition 2. *There is a Nash equilibrium in which the two firms offering the unbranded product each set a price of* 0*, and the two firms offering the branded product each set a price of* 1.98*. Each of the latter two firms makes a profit of* 0.594*, so that their combined profit is* 1.188*.*

Proof. The two firms offering the unbranded product are engaged in Bertrand competition and therefore each sets a price of 0. Turning to the firms offering branded products, if firm 1 charges a price of 1.98, then firm 0's profit function is given by:

$$\pi_0 = \begin{cases} p \times [0.3 - 0.5(p - 1.98)] & \text{if } 1.98 \leq p \leq 2.58; \\ p \times 0.3 & \text{if } 1.58 \leq p < 1.98; \\ p \times [0.3 + 0.5(1.58 - p)] & \text{if } 0.98 \leq p < 1.58; \\ p \times [0.6 + 0.5(0.98 - p)] & \text{if } 0.58 \leq p < 0.98; \\ p \times 1 & \text{if } 0 \leq p < 0.58. \end{cases}$$

If firm 0 raise its price above 1.98, it loses customers to the unbranded product. To see this, note that the customer located just below $x = 0.3$ nets $0.92 - 0.2 = 0.72$ if buying from an unbranded firm and nets $3 - 0.3 - 1.98 = 0.72$ if buying from firm 0. The first-order condition for firm 0 is:

$$\frac{d\pi_0}{dp} = (0.3 + 0.5 \times 1.98) - p,$$

which is negative for $p \geq 1.98$. Therefore, in this range, firm 0 maximizes profit by setting $p = 1.98$. Its profit is $0.3 \times 1.98 = 0.594$.

In the next interval, firm 0 does not gain any customers of the unbranded product. For this to happen, it would need to lower price to 0.98, in order to attract the customer of the unbranded product located at $x = 0.3$. To attract customers from firm 1, firm 0 needs to undercut by 0.4 and thereby attract the customer located at $x = 0.7$. So, firm 0 does not do better by lowering its price to a level within the second interval.

If firm 0 does choose to attract customers from firm 1, it maximizes profit by setting $p = 0.3 + 0.5 \times 1.58 = 1.09$. Its profit is 0.594. It will be part of an equilibrium strategy for firm 0 to choose the higher price $p = 1.98$.

The remaining cases are when firm 0 sets a sufficiently low price to attract some customers of the unbranded product. Then, firm 0 will have attracted all of firm 1's customers. If firm 0 sets a price above 0.58, it will only attract customers at locations $x \leq 0.5$. In this range, the first-order condition for firm 0 is:

$$\frac{d\pi_0}{dp} = (0.6 + 0.5 \times 1.98) - p,$$

which is positive. If firm 0 sets a price below 0.58, it will attract all the customers located at $x \in [0.5, 0.7]$. Its profit is 0.58.

We have established that if firm 1 sets a price of 1.98, then it is a best response for firm 0 to set a price 1.98. Individual firm profits – and therefore combined profit – are higher than in the pre-entry game. □

The idea of this game is that the entry of the unbranded substitute shifts more price-sensitive customers to the firms that offer this product. The unbranded firms take 40 percent of the market, but the incumbents undertake a nearly 2x increase in price, and the net effect is to raise their profits.