Information and disclosure in strategic trade policy

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Abstract: We examine the standard assumption in the strategic trade policy literature that governments possess complete information. Assuming instead that firms have better information, we explore the long-term incentives for firms to consistently disclose information to their governments in the standard setting. We find that with quantity competition firms disclose both demand and cost information to the governments, thereby giving some justification to the literature’s omniscient-government assumption. Further, the equilibrium exhibits an informational prisoner’s dilemma with demand uncertainty, but not with cost uncertainty. With price competition, however, firms have no incentives to disclose information.

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1. Introduction

In their seminal publication Brander and Spencer (1985) explored how in the presence of international oligopolies, strategic government interventions can improve domestic welfare at the expense of other countries. While their work has stimulated innumerable applications and extensions, subsequent writers have discovered that their main result is sensitive to the model’s key assumptions. For example, when price competition is substituted for quantity competition in the Brander-Spencer model, the optimal policy switches from export subsidies to export taxes (Eaton and Grossman, 1986).

Subtler but equally controversial in the Brander-Spencer model and much of the work that has since followed is the assumption that governments have complete information about the underlying economy. Even if this assumption is a simplification of what governments actually know about the targeted firms and markets, it still begs the question of how or from where governments obtain such information. A natural candidate for the source of this information must be firms, but one may wonder if firms could ever have an incentive to disclose its information to the government.

Several authors, including Qiu (1994), Brainard and Martimort (1996) and Maggi (1999), have done pioneering work in addressing this issue by having the governments use non-linear subsidies to get the firms to reveal their types (i.e., the information they have). Though these papers provide great insight into the real effects in designing trade policies that obtain revelation, as we will discuss shortly, there are several conflicting effects that sum to the real effect. Our main purpose is to isolate on the primary effects of these policies: the government’s value of the information and the firms’ loss from disclosing this information. To do so, we explore an alternative and simpler approach to government learning.

Our basic insight is that government policies are rarely a one-time event, but rather there is a long-term relationship between the government and the firm. The firm possessing private information about a key parameter understands that over time market conditions are likely to vary and affect the parameter in unpredictable ways. As a result, though at a given point in time it may not want to disclose the information
because of its effect on the government’s policy, the firm may benefit from a long-term agreement to disclose information to the government. The objective of this paper is to examine, within the standard Brander-Spencer framework, when firms have such a long-run incentive to disclose information to the government.

But would firms really disclose information to its government? And how do they commit to an agreement to disclose information over a long haul? Surprisingly, given the concern regarding the information policymakers have, firms typically disclose a good deal of information with their governments in exchange for the subsidies. As a well-known example, the US Export-Import bank requires a good deal of information – both demand and cost related – from US companies. Specifically, for its large aircraft subsidy the Export-Import’s requirements include, *inter alia*, operating statistics for the airline for at least the past three years including load factors, yield (passenger and cargo), aircraft utilization rates, passenger revenue, tonnage revenue, operating expenses “for each geographic region or route type and each business segment.” ¹ More generally, for any applicant the Ex-Im Bank requires, e.g., financial statements, Federal tax returns and that inventory be valued in accordance with *Generally Accepted Accounting Principles*. Thus, the Ex-Im Bank, a classic illustration of how governments subsidize trade, collects both demand and cost information.

In other areas, governments require information from firms before financial bailouts (Chrysler, US airlines) are given or anti-dumping fines are levied.² Likewise, in other countries companies and their governments often share information (e.g., in Japan METI). Finally, agreements of this type are common among businesses through trade associations (see Vives 1990), firm specific agreements (see Lee and

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¹ www.exim.gov. Other requirements include “Audited balance sheet, income, and cash flow statements and annual reports for the three most recent fiscal years, and interim statements for the most recent period… Annual statements must be prepared in accordance with internationally accepted accounting principles and audited in accordance with international standards… Projected balance sheet, income, and cash flow statements for 5 year period, accompanied by supporting assumptions.”

²There is also ancillary evidence that the disclosed is truthful, as firms are usually adamant that the information they disclose with their government remains secret. For example, the National Customs Brokers and Forwarders Association of America is strongly opposed to a plan by the Department of Commerce and U.S. Census Bureau to disclose export data as part of the war on terrorism. “warning that more widespread, detailed, export data sharing could damage U.S. trade” (Edmonson, 2004). Researchers also know of the difficulty in obtaining and of the restrictions placed on firm specific government data.
Huang 2000) or through third parties. For instance, in the auto industry The Harbour Report discloses, e.g., labor productivity at each plant, which is obtained from each car manufacturer.

To examine the firms’ long-run incentive to disclose information to its government, we adopt the Brander-Spencer setting, in which two firms from different countries compete in a third market. We assume that demand and/or cost parameters fluctuate over time and that the actual parameter values are revealed to the firms but not to the governments. If firms have entered into an institutionalized arrangement to disclose information to their governments, then governments are constantly updated with new information and are able to affect the export policy under complete information as envisioned in Brander and Spencer (1985). On the other hand, if firms and governments have no such agreements, then governments must operate without precise information. The question we address then is: would firms commit to disclosing future information to their governments? In answering this question, a surprising second question arises: would the government want the information?

We address this issue in four separate cases, depending on the type of competition – prices or quantities – and the type of information – common (demand) or individual (cost). The first distinction is motivated by the fact that predictions of the Brander-Spencer model are sensitive to the choice of strategic variables. The second is motivated by results in the information literature, in which the type of uncertainty – common (demand) or individual (cost) – is known to affect outcomes.

We find that with quantity competition a firm always wants to disclose information to its government, regardless of the type of information or what the rival does. Government wants to receive information regardless of the type of information or what the other government does. Thus, provided that the costs of information disclosure and verification are negligible, the model has the unique equilibrium in dominant strategies, in which governments end up having complete information, as typically assumed in the strategic trade policy literature. However, though governments prefer to be informed so as to more precisely carry out trade policy, with unknown demand domestic welfare would be greater should they jointly commit
to not receiving information from their firms. That is, there is an informational prisoner’s dilemma. However, this is unlike the prisoner’s dilemma found in Brander and Spencer because with cost uncertainty domestic welfare is greater with both governments informed than with neither government informed.

With price competition, we find that, while the governments still want to receive the information, the dominant strategy for the firms is not to disclose information to the governments, regardless of the type of uncertainty or what the rival does. Thus, in equilibrium the governments remain uninformed. To induce the firms to disclose the information the governments could provide home firms with upfront fixed subsidies sufficient to entice them to disclose information. However, with unknown costs, domestic welfare would be lower if they jointly received information. An interesting interpretation of these results is that firms do not want to disclose information when they will be taxed, but do want to disclose information when they will be subsidized. This may initially seem obvious since firms generally prefer subsidies over taxes. However, future information can lead to a reduction in taxes and so one might expect the same incentive regardless of whether the subsidy is positive or negative.

The results here also provide some insight to the previous noteworthy research in this area by Qiu (1994) and Maggi (1999). ³ Qiu (1994) examined the environment in which one firm’s cost is unknown to both its government and the rival firm, and compared separating/screening (or complete information) to pooling (or incomplete) contracts by the government. He found that separating contracts welfare-dominates pooling contracts for quantity competition but the effects of price competition and common parameter uncertainty, which we examine, are unresolved.⁴ In addition, since there is only one active government in Qiu, the prisoner’s dilemma aspect that we find with two active governments is not revealed. One important insight in Qiu is that the separating contract informs both the home government and the rival firm. However, the welfare implications of these two informational effects are not separated. By focusing on

³ Brainard and Martimort (1996) also present a model in which they discuss the role of contracts to extract information from firms. However, Maggi (1998) proves that their equilibrium does not exist.
⁴ It has recently been pointed out (Okajima 2003, Qiu 2003) that in price competition there is no separating equilibrium so the price competition case cannot be analyzed.
government learning and relying on results in the literature for the latter, we are able to separate the two effects.\footnote{For example, it is known in the information sharing literature that in quantity competition, the rival’s learning of a firm’s cost raises expected welfare.}

In contrast with Qiu, Maggi (1999) examined the effect an unknown common demand parameter has on strategic trade policy. The key result is that when only one government is using revealing contracts to learn the demand, the uncertainty has no effect on the Brander-Spencer result, but with two active governments the demand uncertainty undermines the value of strategic commitment by reducing the set of subsidy schedules that reveal information, thereby exacerbating the prisoners’ dilemma in the Brander-Spencer model. In contrast, we find that it is the government’s learning that creates the prisoner’s dilemma.

One difficulty Maggi encounters is that the case of a common unknown cost cannot be considered because the single-crossing condition does not hold with price competition and so there exist no subsidy schedules that reveal information. In addition, the case of firm specific cost is not considered, while we consider these cases. More importantly, since only revelation mechanisms are considered in Maggi (1999), the results are composed of two effects; one from the government learning and one from the set of available revelation mechanisms. To disentangle these two effects, in this paper we hold constant the government’s instrument across incomplete and complete information, reverting to single-rate export subsidies used in the Brander-Spencer model.

The remainder of the paper is organized in four sections. The next section gives a more detailed overview of the model. In section 3, we examine the case of quantity competition with unknown demand (Section 3.A) and unknown costs (section 3.B). In Section 4 we turn to price competition, examining both unknown demand (section 4.A) and unknown costs (section 4.B). Subsection 4.C considers extensions on the basic model structure. Section 5 discusses the implications of having non-trivial information verification costs. Section 6 summarizes the findings and discusses related issues. The appendix contains most of the proofs of the lemmas and propositions presented in the text of the paper.
2. An overview of the model

We adopt the standard three-country setting due to Brander and Spencer (1985), in which two firms, labeled firm one and firm two, domiciled in countries one and two, compete in a third country with both governments intervening. They operate in an environment in which demand or firm-specific cost parameters vary over time and new parameter values are revealed to the firms but not to the governments.

We model the interaction in four stages. In stage one, the firm and the government in each country simultaneously decide whether to enter into a long-term information-disclosure agreement: the firm to disclose future information and the government to receive this information. If both agree, they create the institutional structure to have verifiable information disclosure with setup costs $v_F$ to the firm and $v_G$ to the government with $v_F, v_G \geq 0$. To focus on the primary issues, the verification costs are assumed to be identical and arbitrarily small in both countries until section 5, where the case of non-trivial verification costs is analyzed. In stage two, nature selects new values for the parameter and reveals the values to the firms but not to the governments. If in the first stage the firm and the government agreed to share information, then the firm discloses the verifiable information to its government; otherwise the government remains uninformed. In stage three, governments simultaneously choose export subsidy rates. Here, there are three cases to consider, depending on the governments’ information: two symmetric cases – both governments are informed, or neither is informed – and one asymmetric case, in which only one government is informed. In stage four, firms observe the subsidy rates and simultaneously choose quantities or prices. We solve the model for the subgame-perfect Nash equilibrium.

3. Quantity competition

For quantity competition we assume that firms produce homogeneous goods at constant marginal costs $c_i (i = 1, 2)$ and face linear demand. Letting $q_i$ denote firm $i$’s export sales, and choosing the units appropriately, we write the inverse demand
\[ p = A - q_i - q_j; \, i, j = 1, 2, \]

where it is understood throughout that \( i \neq j \).\(^6\) As a benchmark, consider the Brander-Spencer model with no uncertainty. Government \( i \) sets subsidy \( s_i \) to maximize the country’s welfare, \( w_i \), knowing that the firms will observe the subsidy rates and then choose quantities to maximize profits \( \pi_i \). Computation shows that in equilibrium government \( i \) subsidizes the home firm at the rate

\[ s_i^{bs} = (A - 3c_i + 2c_j)/5, \]

and firm \( i \) earns the profit

\[ \pi_i^{bs} = (4/25)(A - 3c_i + 2c_j)^2 = (q_i^{bs})^2 \]

with domestic welfare that equals

\[ w_i^{bs} = (2/25)(A - 3c_i + 2c_j)^2 \]

where the superscript obviously stands for “Brander-Spencer.”

3.4. Demand uncertainty and quantity competition

In this subsection we focus on demand uncertainty. Assume that the demand intercept \( A \) is distributed with mean \( \bar{A} \) and variance \( \sigma^2(A) \) and the distribution is such that the outputs are positive in equilibrium at all times. Looking for the subgame-perfect Nash equilibrium, we begin with the fourth stage of the game.

3.4.1. The fourth-stage game

In the fourth stage, the firms play a one-shot game of complete information, since they know the value of the demand intercept and the export subsidy rates committed to by the governments. Thus, firm \( i \) chooses quantity \( q_i \) to maximize profit:

\[ \pi_i = (A - q_i - q_j)q_i - (c_i - s_i)q_i. \]

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\( ^6 \) For the environments considered here making the goods differentiated has no effect on the results.
where \( s_i \) is the subsidy rate given to firm \( i \). In equilibrium firm \( i \) exports the quantity

\[
(1) \quad q_i^*(A) = \frac{(A - 2c_i + 2s_i + c_j - s_j)}{3},
\]

and earns the profit

\[
(2) \quad \pi_i^*(A) = \left( A - 2c_i + 2s_i + c_j - s_j \right)^2/9.
\]

These quantities and profits vary with realizations of demand intercept \( A \).

### 3.A.2. The third-stage game

Moving backward to the third stage of the game, we determine governments’ optimal subsidy rates. There are three types of subgames to consider, depending on whether and which governments are informed.

Consider first the environment in which neither government is informed. Then the game between the governments is one of two-sided incomplete information, so we look for the Bayesian-Nash equilibrium. In this case, each government, taking the other’s subsidy rate as given, maximizes ex ante national welfare, defined as the difference between expected profit and expected subsidy payment:

\[
E[w_i(A)] = E[\pi_i^*(A) - s_i q_i^*(A)],
\]

where expectations operator \( E(.) \) is over \( A \). Substituting for \( \pi_i^*(A) \) and \( q_i^*(A) \) from (2) and (1), \( E[w_i(A)] \) can be expressed as

\[
E[w_i(A)] = \left( \bar{A} - 2c_i + 2s_i + c_j - s_j \right)^2/9 + \sigma^2(A)/9 - s_i \left( \bar{A} - 2c_i + 2s_i + c_j - s_j \right)/3.
\]

The first-order condition gives the best-response subsidy rate

\[
(3) \quad b_i(s_j) = \left( \bar{A} - 2c_i + c_j - s_j \right)/4.
\]

The equilibrium subsidy rates satisfy both governments’ best responses, and are given in

\[
(4) \quad s_i^{nm} = \left( \bar{A} - 3c_i + 2c_j \right)/5
\]

where superscripts \( (nm) \) indicates that neither government is informed. These subsidy rates depend on the mean of the demand intercept, \( \bar{A} \), but not on its actual realization.

Observe that \( s_i^{nm} \) are identical to the equilibrium subsidy rates \( s_i^{bs}(\bar{A}) \) from the Brander-Spencer
model, where $\overline{A}$ in parentheses indicates that $s_i^{bs}$ is evaluated at $A = \overline{A}$. This is not surprising because, when the distribution of the demand intercept becomes degenerate at $\overline{A}$, the present model converges to the Brander-Spencer model.

Substituting the equilibrium subsidy rates $s_i^{m}$ into the profit function (2) gives firm i’s profit in stage four

$$\pi_i^{m}(A) = (5A + \overline{A} - 18c_i + 12c_j)^2/225.$$  

Taking expectations over $A$ yields the ex-ante profits

$$E[\pi_i^{m}(A)] = 4(\overline{A} - 3c_i + 2c_j)^2/25 + \sigma^2(A)/9.$$  

Observe that the first term on the right-hand side is identical to $\pi_i^{bs}(\overline{A})$ so the above can be written

(5)  

$$E[\pi_i^{m}(A)] = \pi_i^{bs}(\overline{A}) + \sigma^2(A)/9.$$  

As $\sigma^2(A) > 0$, (5) implies that ex ante equilibrium profits exceed those from the Brander-Spencer model. These gains arising from the mean-preserving spread of the distribution of the demand intercept are familiar from elementary analysis and stem from the convexity of the profit function with respect to the demand intercept.

Using (1), (2) and (4) we can also find the expected welfare:

(6)  

$$E[w_i^{m}(A)] = 2(\overline{A} - 3c_i + 2c_j)^2/25 + \sigma^2(A)/9$$

$$= w_i^{bs}(\overline{A}) + \sigma^2(A)/9,$$

where $w_i^{bs}(\overline{A})$ is the equilibrium welfare from the Brander-Spencer model evaluated at $A = \overline{A}$. Again, the convexity of the welfare function is responsible for the welfare gains relative to the Brander-Spencer model. Intuitively, the variance terms in both (5) and (6) are equal as the government cannot respond to the realization of $A$.

We now turn to the second case, in which only one government is informed. Assume, for concreteness, that government 1 is informed. Then, the third-stage game is one of one-sided incomplete
information. Since government 1 knows the value of the demand parameter, it chooses $s_1$ to maximize the level of national welfare, given the realized value $A$:

\[(7) \quad w_1(A) = \pi_1^*(A) - s_1q_1^*(A),\]

where $q_1^*(A)$ and $\pi_1^*(A)$ are given in (1) and (2). The optimal (best-response) subsidy rate is

\[(8) \quad b_1(A) = (A - c_1 + c_2 - s_2)/4,\]

which depends on the realized demand parameter $A$. By contrast, since government 2 maximizes ex ante welfare, its best-response subsidy rate is the same as (3):

\[b_2 = (A - 2c_2 + c_1 - s_1)/4.\]

Using these two best-response functions as well as each government’s expectation of the other’s best-response function based on (3) and (8), and the other’s expectation of its own best-response function, we obtain these equilibrium subsidy rates:\(^7\)

\[s_1^{cn}(A) = (5A - \overline{A} - 12c_1 + 8c_2)/20\]

\[s_2^{nc} = (\overline{A} - 3c_2 + 2c_1)/5,\]

where superscript $cn$ indicates that the government in question has complete (c) information while the other government is not informed (n); superscript $nc$ denotes the other way around. These expressions show clearly that government 1 can, but government 2 cannot, fine-tune its optimal policy according as the realization of $A$. Interestingly, $s_2^{cn} = E[s_1^{cn}(A)] = s_1^{nm}$; the expected subsidy rates equal $s_1^{nm}$ in (4).

Substituting these subsidy rates into the profit function, we obtain these equilibrium profits:

\[\pi_1^{cn}(A) = (5A - \overline{A} - 12c_1 + 8c_2)^2/100\]

\[\pi_2^{nc}(A) = (5A + 3\overline{A} - 24c_2 + 16c_1)^2/400.\]

Straightforward calculation yields the equilibrium welfare levels

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\(^7\) A simple way to derive this is to note, starting from the incomplete information equilibrium, that a change in $A$ affects government 1’s subsidy linearly and so government 1’s expected subsidy does not change.
$$w_1^{cn}(A) = (5A - \overline{A} - 12c_1 + 8c_2)^2/200$$

$$w_2^{nc}(A) = (5A - 29 \overline{A} + 72c_2 - 48c_1)(5A - 17 \overline{A} + 36c_2 - 24c_1)/3600 + \sigma^2(A)/9.$$ 

Taking expectations, we obtain these ex ante equilibrium profits and welfare:

(9) $$E[\pi_1^{cn}(A)] = \pi_1^{bs} (\overline{A}) + \sigma^2(A)/4$$

(10) $$E[\pi_2^{nc}(A)] = \pi_2^{bs} (\overline{A}) + \sigma^2(A)/16.$$ 

(11) $$E[w_1^{cn}(A)] = w_1^{bs} (\overline{A}) + \sigma^2(A)/8$$

(12) $$E[w_2^{nc}(A)] = w_2^{bs} (\overline{A}) + \sigma^2(A)/16.$$ 

Note that in this case, when the government can condition its policy on A, the variance term is half of the firms ((9) and (11)), while if it cannot, their variances are equal ((10) and (11)).

Using equations (5-6) and (9-12), we are now in a position to state the effect government learning has on profit and welfare when the other government does not learn. (We drop country subscripts in stating all our lemmas and propositions.)

**Lemma 1. When demand is uncertain and firms compete in quantities,**

(i) $$E[\pi^{en}(A)] > E[\pi^{nn}(A)]$$ and $$E[w^{en}(A)] > E[w^{nn}(A)].$$

(ii) $$E[\pi^{nc}(A)] < E[\pi^{nn}(A)]$$ and $$E[w^{nc}(A)] < E[w^{nn}(A)].$$

In words, part (i) of the lemma says that a firm has an ex ante incentive to disclose information to the government, and the government prefers receiving the information, if the rival pair does not share information.

The intuition is as follows. When it acquires demand information, a welfare-maximizing government would subsidize exports at higher rates when demand is higher and at lower rates when demand is lower. Thus, for firm 1, which discloses information, good news (high demand) results in even greater profits while bad news (low demand) results in even smaller profits. Next, this increases ex ante profit.
because of convexity. More precisely, since the firm’s equilibrium profits are increasing and convex in its government’s subsidy and intercept, and since the subsidy is linear and increasing in the realized intercept, disclosing information makes profits more convex in $A$ and so increases ex ante profit. As for welfare, since firm 1 becomes more aggressive when demands are higher, there is more profit shifting from firm 2 to firm 1 at higher demands. Although there is less profit shifting at low demands, since profits are lower then it is never enough to make up for the losses suffered at higher demands. This profit shifting is also what drives part (ii), which says that information disclosure in country 1 is bad for firm 2 and its country’s welfare.

This reasoning does not depend specifically on the information that the rival government has, and hence is valid even with the rival government informed. To show this, we now turn to the third case, in which both governments are informed. In this case, the third-stage game is one of complete information, so both governments behave like government 1 in the previous case, maximizing national welfare

$$w_i(A) = \pi_i^*(A) - s_q^*(A),$$

given $A$, where $q^*(A)$ and $\pi_i^*(A)$ are given in (1) and (2). Calculations show that equilibrium subsidy rates are

$$s_i^{cc}(A) = (A - 3c_i + 2c_j)/5,$$

where superscripts (cc) indicates that both governments have complete information.

Substituting $s_i^{cc}(A)$ into (2) yields the equilibrium profit

$$\pi_i^{cc}(A) = 4(A - 3c_i + 2c_j)^2/25,$$

with the equilibrium national welfare:

$$w_i^{cc}(A) = \pi_i^{cc}(A) - s_i^{cc}(A)q_i^{cc}(A)$$

$$= 2(A - 3c_i + 2c_j)^2/25.$$  

These equilibrium profits and welfare depend on the actual value of $A$, and their ex ante values are

$$E[\pi_i^{cc}(A)] = \pi_i^{bs}(\bar{A}) + 4\sigma^2(A)/25$$

(13)
(14) \[ E[w_{i}^{cc}(A)] = w_{i}^{bs}(\bar{A}) + 2\sigma^{2}(A)/25. \]

Using (9-14), we obtain this next lemma.

**Lemma 2:** When demand is uncertain and firms compete in quantities,

(i) \[ E[\pi^{cc}(A)] > E[\pi^{cc}(A)] \text{ and } E[w^{cc}(A)] > E[w^{cc}(A)]= \]

(ii) \[ E[\pi^{cc}(A)] > E[\pi^{cc}(A)] \text{ and } E[w^{cc}(A)] > E[w^{cc}(A)]= \]

For part (i), both a firm and its government have an ex ante incentive to disclose information if the rival pair disclose information, thereby confirming our conjecture. It follows from the two lemmas that, regardless of what the rival does, a firm is better off informing its own government. Notice also that the gain to the firm is always greater than the gain to the government because the former includes the subsidies from the government. On the other hand, it is inferred from part (ii) of Lemma 1 and Lemma 2 that the firm and its country are always made worse off when the rival firm decides to disclose information to its government.

**3.A.3. The first stage**

We now move back to the first stage of the game, in which the firm and the government in each country simultaneously and independently decide whether to enter into a long-term agreement to disclose information. Lemmas 1 and 2 together indicate that assuming negligible verification costs disclosing information to the government is the dominant strategy for both firms and that receiving information is the dominant strategy for both governments. Hence,

**Proposition 1:** With unknown common demand and quantity competition, the game has the unique equilibrium in which both firms commit to disclosing information to their governments.

There are several additional interesting aspects. First, the firm’s gain from disclosing is always greater than the country’s gain. Second, both the firm and the country are harmed when the rival discloses. In particular, the country’s benefit from its firm disclosing information is less than its harm from the rival
firm disclosing to its government. This second point leads to the following surprising result: although governments end up having complete information as assumed in the Brander-Spencer model, comparison of (6) and (14) indicates that each country’s welfare would be greater if the governments jointly committed to not receiving information from the firms. This prisoner’s dilemma situation is stated formally in

**Proposition 2: With unknown demand and quantity competition,**

\[ E[w^*(A)] < E[w^m(A)]. \]

Although firms welcome aggressive interventions from informed governments when demands are high, the proposition indicates that too much subsidy competition at high demands is welfare worsening. This is in the spirit of the Brander-Spencer model. Notice, however, that the prisoners’ dilemma here is fundamentally different from that of the Brander-Spencer (1985) case. There, the prisoner’s dilemma arises owning to the governments’ inability to commit to not subsidizing exports. Here, governments intervene whether they are informed or not, and the prisoners’ dilemma is due to the governments’ inability to commit to not learning.

Our result that the learning leads to a prisoner’s dilemma is also in contrast to a conclusion that could be drawn from Maggi (1999): that the demand uncertainty exacerbates the prisoner’s dilemma inherent in the Brander-Spencer model. However, Maggi examines policy instruments that also reveal the state of the world. Thus, the policy instrument has two purposes: to acquire information for the government and to give the country’s firm a strategic advantage. Maggi does not consider policy instruments whose sole role is to give the country’s firm a strategic advantage. Thus, one cannot infer from Maggi whether the government would prefer the latter, i.e. to set a strategic policy while remaining uninformed.\(^8\)

Finally, the prisoner’s dilemma arises in the present case because there is too much subsidy competition at high demands, suggesting that subsidy competition may be mitigated when policy

\(^8\) In this case, we hypothesize that the differences will depend on the degree of uncertainty. Specifically, Maggi finds that as the demand uncertainty increases, the prisoner’s dilemma aspect is stronger.
interventions are not perfectly correlated between governments. To investigate this conjecture, we turn in the next subsection to the case in which uncertainty is over the firm (or country) specific variable (cost), whose results will reinforce the difference between the prisoner’s dilemma here versus that in Brander and Spencer (1985).

3.B. Cost uncertainty and quantity competition

We assume in this section that unit cost $c_i$ is distributed independently of each other, with mean $\bar{c}_i$ and variance $\sigma^2(c_i)$ ($i = 1,2$) while the demand parameter $A$ is fixed. For ease, it is initially assumed that $\sigma^2(c_1) = \sigma^2(c_2) \equiv \sigma^2$. The minor effects asymmetry has will be noted in subsection 4.C below. Let $c \equiv (c_1, c_2)$. Because firm-specific cost information is likely to be private, the analysis of unknown costs allows for many variations, depending on what the rival learns in stage two, whether a firm can disclose information to its rival (which occurs in practice), and whether the government can disclose information to the rival government. Cataloging all the reasonable variations would be extensive and yet yield only small differences in the main qualitative results and then only if the products are strategic complements as in the next section. Therefore, for expositional purposes we choose the structure that allows the easiest comparison with the unknown demand case and the one that also emphasizes the focus of this paper, i.e., a firm’s incentive to disclose information to its government. Thus, we assume that in stage two each firm learns its rival’s cost as well as its own. Since it is more plausible, for example, that Toyota is better informed about GM’s production costs than the U.S. government, this assumption is a simplification of the idea that firms are better informed about the rivals’ costs than the governments. Where other variations have an effect on our results will be discussed in subsection 4.C.

As the analysis follows the same steps in the previous section, we present only the results here with the derivations in Appendix A.

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9 This structure is also assumed in the contracting literature with uncertainty. For example, in the principle-agent problem examined by Fershtman and Judd (1997), p. 929, each firm manager knows the other firm’s manager’s costs.
Lemma 3: When costs are unknown and firms compete in quantities, for $i = 1, 2$

(i) $E[\pi^m(c)] > E[\pi^n(c)]$ and $E[w^m(c)] > E[w^n(c)]$.

(ii) $E[\pi^c(c)] > E[\pi^n(c)]$ and $E[w^c(c)] > E[w^n(c)]$.

In words, when the rival firm does not disclose information, a firm has an incentive to inform its government (part i). This result is similar to part (i) of lemma 1, and has a similar intuitive explanation. The informed government tends to subsidize exports at higher rates when costs are lower and at lower rates when costs are higher, so good news (low costs) translates into even better news while bad news (high costs) elicits bad responses from the informed government. Given convexity, an increase in variance improves the firm’s ex ante profit, and the country ex ante welfare.

Unlike with unknown demand, however, firm 2, which does not disclose information to its government, also benefits from firm 1’s decision to disclose information to its own. Here, bad news for firm 1 (higher than expected costs) is good news for firm 2. Further, since government 1 reduces its subsidy to firm 1 when firm 1’s costs are high, good news for firm 2 (high firm 1 costs) translates into even better news (lower subsidy for firm 1); similarly, bad news for firm 2 elicits a bad response from government 1. In contrast, with unknown demand, good news for firm 2 (higher than expected demand) elicits a bad response from government 1 in the form of a higher subsidy for firm 1. Hence, with unknown demand, firm 2 and its government are made worse off from firm 1 disclosing information to its government, while with unknown firm specific costs, firm 2 and its country are better off from firm 1 disclosing information to its government.

Lemma 4: When costs are unknown and firms compete in quantities,

(i) $E[\pi^c(c)] > E[\pi^n(c)]$ and $E[w^c(c)] > E[w^n(c)]$.

(ii) $E[\pi^c(c)] > E[\pi^n(c)]$ and $E[w^c(c)] > E[w^n(A)]$.

That is, with unknown costs and quantity competition, a firm and a government have an ex ante incentive to
commit to the firm disclosing information, provided that the rival pair does the same. Further, if they do disclose, they are made better off if the rival firm and its government also disclose.

Lemmas 3 and 4 combined show that assuming negligible verification costs, it is the dominant strategy for the firm to disclose information to its government, while the dominant strategy for the government is to receive cost information. We have established:

**Proposition 3:** *When costs are unknown and firms compete in quantities, the game has the unique equilibrium in dominant strategies, in which firms and governments commit to disclosing information to both countries.*

Though the characteristics of unknown cost and that of unknown demand seem identical, comparing (A4) and (A10) in Appendix A yields one major difference: with unknown costs there is no informational prisoner’s dilemma.

**Proposition 4:** *When costs are unknown and firms compete in quantities, \( E[w^e(c)] > E[w^m(c)] \).*

For the reason already explicated for unknown demand, the firm’s expected profits increase by disclosing what it learns with its government independently of the rival’s choice (lemmas 3 and 4). One difference to the firm, though, is that with unknown costs, the firm is made better off from its rival disclosing to its government while with unknown intercept it is made worse off from its rival disclosing.

We emphasize that this result does not depend on the assumption that the firm’s government does not learn the rival’s cost. In the other permutations we consider (e.g., the rival learns and/or its government learns a firm’s cost if a firm discloses), the propositions do not change.\(^\text{10}\)

The analysis so far has found that if the verification costs are small, then firms prefer to disclose

\(^{10}\) The calculations are available on request from the authors. However, it is not surprising in light of a standard result in the information sharing literature (see, e.g., Vives 1990) which reinforces the effect here: a firm would enter an ex ante agreement to disclose cost information with its rival. This in part drives the results found in Qiu (1994).
information to their governments and so governments end up having complete information (or as well informed as firms) as assumed in the standard strategic trade policy literature. However, given the sensitivity of duopoly models to the type of competition, we examine in the next section whether the above propositions hold when firms compete in prices.

4. Price competition

We thus consider price competition. Following the literature [e.g., Eaton and Grossman (1986)], we assume that price-setting firms produce differentiated goods and, by the appropriate choice of units, write demand for good i as

\[ q_i = \alpha - p_i + \delta p_j, \]

where \( \delta (0 < \delta < 1) \) measures the degree of product differentiation between the two goods. As the derivations follow analogously to the previous sections and provide no new insights, they are relegated to the appendix.

4.4. Price competition and demand uncertainty

We first examine the case of unknown demand. Assume that the common demand intercept \( \alpha \) varies with mean \( \bar{\alpha} \) and variance \( \sigma^2(\alpha) \). To simplify the exposition and focus on demand uncertainty, in this subsection we assume that firms have identical constant marginal costs \( c \).

As before, the game has four stages. Before we proceed, however, we first discuss the benchmark two-stage model without uncertainty (Eaton and Grossman 1986).11 In this model, each government first chooses subsidy rate \( s_i \) to maximizes welfare \( w_i = \pi_i - s_i q_i \), and firms then choose prices to maximize the profit

\[ \pi_i = (\alpha - p_i + \delta p_j)(p_i - c + s_i) \]

---

given subsidy rate $s$. The equilibrium price is

$$p_i^{eq}(\alpha) = [(2 + \delta)(\alpha + c) - (2s_i + \delta s_i)]/\Delta.$$ 

where $\Delta = 4 - \delta^2$ and the superscripts eg stand for “Eaton-Grossman”. Substitution of $p_i^{eq}(\alpha)$ into $\pi_i$ and $w_i$ and straightforward calculation of the government’s problem yields the equilibrium subsidy rate, output, profit and welfare as follows:

$$s_i^{eq}(\alpha) = -\delta^2(\alpha - (1 - \delta)c]/(\Delta - 2\delta) < 0.$$ 

$$\pi_i^{eq}(\alpha) = (\Delta - 2)^2\{[\alpha - (1 - \delta)c]/(\Delta - 2\delta)\}^2 = [q_i^{eq}(\alpha)]^2$$

$$w_i^{eq}(\alpha) = 2(\Delta - 2)\{[\alpha - (1 - \delta)c]/(\Delta - 2\delta)\}^2.$$ 

As is well known, when firms compete in prices, the optimal policy intervention is an export tax: $s_i^{eq}(\alpha) < 0$.

With this benchmark in mind, we now consider the fourth stage of our model.

4.A.1. The fourth-stage game

In the fourth stage, firms play a one-shot game of complete information. For given $\alpha$, $s_i$ and $s_j$, the equilibrium price is the same as those from the Eaton-Grossman model, and so output and profits are

(35a) \[ q_i^{eq}(\alpha) = [(2 + \delta)\alpha - (2 - \delta^2)(c - s_i) + \delta (c - s_j)]/\Delta \]

(35b) \[ \pi_i^{eq}(\alpha) = q_i^{eq}(\alpha)^2. \]

4.A.2. The third-stage game

As the analysis is similar to the one in the previous sections, we present only the results, with the derivations in Appendix B.

Lemma 5. With unknown demand and price competition,

(i) \[ E[\pi^u(\alpha)] < E[\pi^m(\alpha)] \] and \[ E[w^c(\alpha)] > E[w^m(\alpha)]. \]

(ii) \[ E[\pi^m(\alpha)] > E[w^m(\alpha)] \] and \[ E[w^m(\alpha)] > E[w^m(\alpha)]. \]
Part (i) of the lemma implies that, if the rivals do not disclose information with their government, then the firm does not disclose information to its government either, although its government still wants to be informed. Part (ii) of the lemma indicates that the firm that does not disclose information to its government benefits from the rival disclosing information. The effect on the firms’ profits and the rival government from disclosing demand information here contrasts sharply with the results with quantity competition. The reason is because with price competition, the informed government (government 1) raises export tax at high demands and lowers tax at low demands. Thus, informing the government dampens profit variability for firm 1, thereby reducing the ex ante profit. On the other hand, higher export taxes on firm 1 at high demands means even higher prices and profits for firm 2. Similarly, low demands lead to even lower profits, and this increase in profit variability is welcome by firm 2 and its government.

The above intuition does not depend on whether or not government 2 is informed, and hence also holds when firm 2 discloses information with its government.

**Lemma 6: When demand is uncertain and firms compete in prices,**

(i) \( E[\pi^c(\omega)] < E[\pi^n(\omega)] \) and \( E[w^c(\omega)] > E[w^n(\omega)] \).

(ii) \( E[\pi^c(\omega)] > E[\pi^n(\omega)] \) and \( E[w^c(\omega)] > E[w^n(\omega)] \).

Thus, even if the rival firm discloses information, a firm still does not want to disclose information to its government, while the government still prefers information as shown in part (i). On the other hand, part (ii) shows that if a firm discloses information it wants the rival to do the same.

Part (i) of lemma 5 and that of lemma 6 together imply that not disclosing information to its government is the dominant strategy for a firm, although the governments always prefer to be informed. Thus, in this case, verification costs are irrelevant for the primary results.

**Proposition 5: With unknown demand and price competition, the model has the unique equilibrium in**
dominant strategies, in which neither firm commits to disclosing information with its government.

Finally, despite the fact that the firm’s profit increases when its rival discloses information, each firm’s profit is higher with neither firm disclosing than both disclosing information to the governments.

**Proposition 6: With unknown demand and price competition**

\[ E[\pi^g(\omega)] < E[\pi^m(\omega)] \text{ and } E[w^g(\omega)] > E[w^m(\omega)]. \]

Thus, firms are better off not disclosing information to governments and so the governments are uninformed in equilibrium. However, governments would be better off being informed. Therefore, as with unknown costs and quantity competition, the governments by providing the firms with upfront lump-sum subsidies sufficient to compensate the losses they suffer from disclosing information, can increase welfare.

**4.B. Cost uncertainty and strategic complements**

This subsection examines the case of unknown costs when firms compete in prices. Assume that costs \(c_i\) are distributed independently, with mean \(\bar{c}_i\) and variance \(\sigma^2(c)\). The asymmetry on variance has one minor effect, which is described in the next subsection. As before, assume that in the second stage each firm learns the rival’s cost as well as its own, and that governments never learn the foreign firm’s cost.

In this case we find that most results are the same as with unknown demand and price competition (see Appendix C for the explicit derivations). In particular, the counterpart to proposition 5 holds. As with strategic complements and unknown demand, the firm’s profits decrease when it discloses information. Thus, verification costs are irrelevant to the primary results.

**Proposition 7: With unknown costs and price competition, the model has the unique equilibrium in dominant strategies, in which neither firm commits to disclosing information to its government.**

The main difference from the case of unknown demand is that, although each government wants to
be informed regardless of what the rival government does, governments are better off jointly uninformed than jointly informed.

**Proposition 8:** With unknown costs and price competition,

\[ E[\pi_i^{ec}(c)] < E[\pi_i^{nm}(c)] \text{ and } E[w_i^{ec}(c)] < E[w_i^{nm}(c)]. \]

Further, unlike in the demand case, the government does not like the rival firm disclosing information to its government. Thus, the case of strategic complements with unknown costs is nearly identical to the case of strategic substitutes with unknown demand. The only difference is that with unknown costs the firm does not want to disclose information. In other words, although each government wants information unilaterally, if both governments succeed in extracting cost data from the firms by providing upfront subsidies, both countries would be worse off than they are in the equilibrium. Thus, ignorance is bliss.

**4.C. Extensions to the cost case**

As noted earlier, the case of unknown, firm-specific costs allows for several possible variations to the basic structure over the questions of what the rival and its government learn, as well as the effect of asymmetric variances. For the most part, these variations have little effect, and in particular with quantity competition they do not affect the main results that for negligible verification costs both the government and the firm benefit from information disclosure and that both are better off when both firms disclose than when neither firm discloses – there is no prisoner’s dilemma. Essentially, this is true with price competition, but there are some interesting, if minor, differences in the government’s incentives.

First, consider relaxing the symmetry assumption on variance so that \( \sigma^2(c_1) \neq \sigma^2(c_2) \). Now, suppose that firm 1 has a smaller cost variance than firm 2. To get the intuition of what this asymmetry effects, suppose that firm 1’s cost has zero variance – it is constant at the mean. Then there is no learning for government 1. Then if government 2 learns firm 2’s cost, it is better off from both disclosing while government 1 is worse off. More generally, if \( \sigma^2(c_1) < 2\sigma^2(c_2) \) for country 2 there is no prisoner’s dilemma.
from both disclosing, although there is for country 1. Differences in variance have no effect on the firms’ incentives.

Another possibility, though perhaps less plausible, is that there are information leakages: once a firm discloses information to its government, the rival government also obtains the information (see the example in the introduction of the US Commerce Department wanting to disclose information). In this case, the government is made worse off when its firm discloses information to both governments: the gain from it learning is less than the loss from the rival government learning.\(^{12}\) Hence the government has an incentive to keep the information secret.\(^{13}\) As a result, the government prefers neither disclosing to both disclose for all \(\sigma^2 > 0\). The firm’s incentives are the same whether the rival government learns or not; they do not want to disclose information. In addition, they do not want the rival government to disclose its firm’s cost information with the firm’s government. The firm prefers neither disclosing to both disclosing. To summarize, a government likes learning either firms’ costs and dislikes the rival government learning either firms’ costs. A firm never likes any government learning any firm’s costs.

Finally, consider the case in which the firms initially do not know each other’s cost. If by disclosing cost information the firm’s government and its rival learn the firm’s cost, then it is still a dominant strategy for the firm not to disclose its information to its government. Further, firms prefer neither firm disclosing to both disclosing information with their governments, unless the variances differ substantially. For example, if firm 1’s cost variance is significantly smaller than firm 2’s (i.e., \(\hat{\sigma}^2(c_1) < \hat{\sigma}^2(c_2)\)), then firm 1 prefers both firms disclosing to neither disclosing, because the benefit from learning the rival’s cost outweighs the loss from its cost being learnt. However, by this logic firm 2 prefers neither disclosing.

When firms initially do not know each other’s cost, there is a more significant change in the government’s choice: it no longer wants the firm to disclose information. However, if \(\hat{\sigma}^2(c_1) < \hat{\sigma}^2(c_2)\), then

\(^{12}\) Likewise, when the rival firm reveals, the home government benefits from its learning but is made even worse off from the rival government’s learning from the rival firm.

\(^{13}\) This contrasts with quantity competition, in which the government benefits from the rival government learning.
like firm 1, government 1 could also prefer both firms disclosing to neither firm disclosing. However, the
critical variance for the firm and its government differs: the government may prefer both firms disclosing
while the firm does not, but not vice versa. Lastly, the possibility of disclosed information leaking to the
rival government does not change any of these results. In addition, neither the firm nor the government
wants the information disclosed with the rival government. Although these variations may be intuitively
implausible, their results reinforce the main results.

5. Non-trivial verification costs

   It has so far been assumed that verification costs were negligible. In this section, the effect of
relaxing this assumption is explored. In price competition, since firms do not want to disclose information
at arbitrarily small verification costs, they never do so when verification costs are higher. Thus, the primary
effects of non-trivial verification costs are in quantity competition; that is, when both the firm and the
government benefit from information disclosure. The reason there is an effect of any interest is because the
benefit the firm obtains differs from what the government obtains.

5.A Quantity competition with unknown demand intercept

   Using equations (5-6) and (9-14), define $\Delta \pi^n(A)$ as the change in profits when it discloses but its
rival does not, i.e., $\Delta \pi^n(A) = E[\pi^c(A)] - E[\pi^m(A)] = 5\sigma^2(A)/36$. Likewise define $\Delta w^n(A)$ as the change in
welfare from a firm disclosing when the rival does not disclose and $\{\Delta \pi^c(A), \Delta w^c(A)\}$ when the rival
discloses. A critical point to note is that the welfare gain from information disclosure is always less than
firm’s gain, while the welfare costs include both the firm and the government’s verification costs.
Calculation shows that $\Delta \pi^n(A) > \Delta \pi^c(A) > \Delta w^c(A) > \Delta w^n(A)$. As a result, in generalizing proposition 1, all
that matters is the welfare change and total verifications costs ($v_F + v_G$) since if $\Delta w > v_F + v_G$, then $\Delta \pi > v_F$. 

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Proposition 1': *With unknown common demand and quantity competition,*

A. if $v_F + v_G < \Delta w^*(A)$, then the game has the unique equilibrium in which both firms disclose information with their governments.

B. if $\Delta w^d(A) < v_F + v_G < \Delta w^c(A)$, then the game has two equilibria: one in which both disclose and one in which neither disclose.

C. if $v_F + v_G > \Delta w^c(A)$, then the game has the unique equilibrium in which neither firm discloses information with its government.

Part A. of proposition 1', is a restatement of proposition 1 in section 3. Part B. is driven by the fact that the government gains more from disclosure when the other government has disclosed. Thus, there are two equilibria: if the other country discloses the best response is to disclose and if the other country does not disclose, the best response is to not disclose. Finally part C. is simply the possibility that verification costs – ability to set up a system in which information is verifiably disclosed – can be sufficiently large relative to the gain from disclosure such that disclosure does not occur.

It has already been noted that even if verification costs are zero, there is a prisoner’s dilemma: both countries are better off if they both did not disclose than if they both disclosed (proposition 2). Intriguingly, in this case, an *increase in the verification costs increases welfare*. That is, if the governments’ verification costs increased enough so that $v_G > \Delta w^c(A)$, then no disclosure would result which would raise welfare.

5.B *Quantity competition with unknown costs*

Following the analysis of section 5.A, equations (A3-A4), (A5-A8) and (A9-A10) in Appendix A can be used to calculate the gain from disclosing information. Define $\Delta \pi^i(c)$ as the change in the firm’s profits when it discloses but its rival does not, i.e., $\Delta \pi^i(c) = E[\pi^i(c)] - E[\pi^m(c)]$. Likewise, define $\Delta w^i(c)$ as the change in welfare from a firm disclosing when the rival does not disclose and $\{\Delta \pi^c(c), \Delta w^c(c)\}$ when
the rival discloses. Calculation shows that the rival’s decision no longer affects the firm or the government’s benefit from disclosing: $\Delta \pi^y(c) = \Delta \pi^x(c)$ and $\Delta w^x(c) = \Delta w^y(c)$. Moreover, as with unknown demand intercept the firm benefits more from disclosing than the government, so total verification costs and welfare changes drive the results. With no restrictions on the size of verification costs we can now state proposition 3 more generally:

**Proposition 3': When costs are unknown and firms compete in quantities,**

A. if $v_F + v_G < \Delta w^x(c)$, then the game has the unique equilibrium in which both firms disclose information with their governments.

B. if $v_F + v_G > \Delta w^x(c)$, then the game has the unique equilibrium in which neither discloses with their government.

   Although, there is no prisoner’s dilemma with the disclosing of cost information (proposition 4), a different coordination problem may arise. Specifically, even if $v_F + v_G > \Delta w^x(c)$, this does not imply that welfare would be lower for all if both countries disclosed information. This is because $E[w^{\alpha(x)}] - E[w^{\alpha(y)}] = 7\sigma^2/c(36) > \Delta w(c) = E[w^{\alpha(x)}] - E[w^{\alpha(y)}] = 2\sigma^2/c(36)$; the gain for a country of going from an outcome in which neither country disclose to an outcome in which both countries disclose is greater than its unilateral decision to disclose information. Thus, the two countries may benefit by agreeing to simultaneously establishing within each country the institution needed to have information disclosure.

5.C Price competition

From section 4, in price competition, the firm’s profits decrease when it discloses information regardless of the type of information. Thus, verification costs are irrelevant to the propositions (equilibrium results). The only modification in the results is to note that with unknown demand intercept, then if $v_F + v_G < E[w^{\alpha(x)}] - E[w^{\alpha(y)}]$, then the governments by providing the firms with upfront lump-sum subsidies
sufficient to compensate the losses they suffer from disclosing information, can increase welfare.

6. Summary of results

As variations in both the type of competition and the type of information seems to introduce many cases, it is useful to step back and see that in fact there are consistent informational effects (i.e., ignoring verification costs) in the model: First, whatever the foreign country’s decision, the government always has the unilateral incentive to acquire information from its firm. Second, a government’s acquiring of information has the same effect on the rival firm and its government. Third, a firm’s incentive does not depend on type of uncertainty. Finally, a firm does not want to disclose when the subsidy is negative (i.e., with strategic complements). The consistency can probably be most easily seen in the following table that indicates the effect of a decision to disclose information:

<table>
<thead>
<tr>
<th>Type of information → Type of competition ↓</th>
<th>Demand</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Substitutes</strong></td>
<td>Profits increase</td>
<td>Profits increase</td>
</tr>
<tr>
<td></td>
<td>Welfare increases</td>
<td>Welfare increases</td>
</tr>
<tr>
<td></td>
<td>Prisoner’s dilemma (W)</td>
<td>No prisoner’s dilemma</td>
</tr>
<tr>
<td><strong>Complements</strong></td>
<td>Profits decrease</td>
<td>Profits decrease</td>
</tr>
<tr>
<td></td>
<td>Welfare increases</td>
<td>Welfare increases</td>
</tr>
<tr>
<td></td>
<td>No prisoner’s dilemma</td>
<td>Prisoner’s dilemma (W)</td>
</tr>
</tbody>
</table>

This table also helps us to connect the present work to the related works mentioned earlier. Qiu, studying the case of firm-specific cost uncertainty in quantity competition and price competition (the two right-hand boxes of the table), showed that in quantity competition the separating equilibrium dominates pooling equilibrium. In his analysis only one government is active and separating contracts disclose the home firm’s cost to the rival as well as to the home government. Our model isolates on the second effect finding it holds with bilateral intervention in quantity competition. Moreover, price competition can be analyzed and we find that the firm is harmed by revealing information to its government, which ties in with
the non-existence of the pooling equilibrium in Qiu.\textsuperscript{14} Moreover, we find a prisoner’s dilemma in this case when bilateral intervention is considered. While a government would prefer learning (and hence separating contracts if they existed), this only holds in unilateral intervention. The governments would make themselves worse off if both induced their firms to reveal to them.

Maggi, on the other hand, compared the equilibrium with and without demand uncertainty under nonlinear contracts both in quantity and price competition (the two left-hand boxes). Comparing our results and those with zero variances shows that, when the governments’ policy is limited to linear subsidies, the profits and welfare are always higher with uncertainty regardless of the type of competition and the type of uncertainty.

\textsuperscript{14} See Okajima (2003) and Qiu (2003).
Appendix A: Derivations for strategic substitutes and unknown costs (section 3.B)

As with unknown intercept, in the fourth stage firms play a one-shot game of complete information.

The expressions for the stage four equilibrium quantity $q_i^*(c)$ and profit $\pi_i^*(c)$ are the same as in (1) and (2),

(A1) $q_i^*(c) = (A - 2c_i + 2s_i + c_j + s_j)/3.$

(A2) $\pi_i^*(c) = (A - 2c_i + 2s_i + c_j + s_j)^2/9$,

except that here unit costs instead of demand intercept are random.

In the third-stage game, with neither government informed, each government chooses a subsidy rate to maximize ex ante national welfare

$$E[w_i(c)] = E[\pi_i(c)] + s_iE[q_i(c)],$$

$$= (A - 2\tilde{c}_i + 2s_i + \tilde{c}_j - s_j)^2/9 - s_i(A - 2\tilde{c}_i + 2s_i + \tilde{c}_j - s_j)/3 + 5\sigma^2(c)/9.$$

Straightforward computation yields the equilibrium subsidy rate:

$$s_i^{tn} = (A - 3\tilde{c}_i + 2\tilde{c}_j)/5.$$

This is identical to the subsidy rate from the Brander-Spencer model when unit costs are evaluated at means; $\tilde{c} \equiv (\tilde{c}_i, \tilde{c}_j)$. Substituting $s_i^{tn}$ into the profit function yields the ex post equilibrium profit:

$$\pi_i^{tn}(c) = (6A - 10c_i - 8\tilde{c}_i + 5c_j + 7\tilde{c}_j)^2/225.$$

Taking expectations over $c$, we have the ex ante profit

(A3) $E[\pi_i^{tn}] = \pi_i^{bs}(\tilde{c}) + 5\sigma^2(c)/9,$

where

$$\pi_i^{bs}(\tilde{c}) = 4(A - 3\tilde{c}_i + 2\tilde{c}_j)^2/25$$

is the Brander-Spencer equilibrium profit evaluated at $c = \tilde{c}$. The ex ante welfare then is

(A4) $E[w_i^{tn}] = w_i^{bs}(\tilde{c}) + 5\sigma^2(c)/9$

where $w_i^{bs}(\tilde{c}) = 2(A - 3\tilde{c}_i + 2\tilde{c}_j)^2/25$ is the equilibrium welfare from the Brander-Spencer model at $c = \tilde{c}$.  

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When only government 1 is informed, it knows the domestic firm’s unit cost, but does not know the foreign firm’s unit cost, so it maximizes the expected national welfare:

\[ E_2[w_1] = E_2[\pi_1^*(c_2)] + s_i E_2[q_1^*(c_2)], \]

where operator \( E_2[.] \) indicates that expectations are taken over \( c_2 \). Using (A1) and (A2) we can write \( E_2[w_1] \) as

\[
(A5) \quad E_2[w_1] = (A - 2c_1 + 2s_1 + \tilde{c}_2 - s_2)^2/9 - s_i(A - 2c_1 + 2s_1 + \tilde{c}_2 - s_2)/3 + \sigma^2/9.
\]

The first-order condition gives the best response function

\[ b_1(s_2) = (A - 2c_1 + \tilde{c}_2 - s_2)/4. \]

Government 2 is uninformed, and is confronted with the problem similar to the one when both are uninformed. Its best-response function is written

\[ b_2(s_1) = (A - 2\tilde{c}_2 + \tilde{c}_1 - s_1)/4. \]

The equilibrium subsidy rates are

\[ s_1^{eq}(c_1) = (2A - 5c_1 - \tilde{c}_1 + 4\tilde{c}_2)/10 \]

\[ s_2^{ne} = (A - 3\tilde{c}_2 + 2\tilde{c}_1)/5, \]

which satisfy the two best-response functions and each government’s expectation of the rival’s best-response function and the rival’s expectation of their own. Substituting these subsidy rates into the profit functions yields the ex post equilibrium profits:

\[ \pi_1^{eq}(c) = (6A - 15c_1 - 3\tilde{c}_1 + 5c_2 + 7\tilde{c}_2)^2/225 \]

\[ \pi_2^{ne}(c) = (12A - 20c_2 - 16\tilde{c}_2 + 15c_1 + 9\tilde{c}_1)^2/900. \]

Taking expectations, we obtain the ex ante equilibrium profits:

\[
(A5) \quad E[\pi_1^{eq}] = \pi_1^{bs}(\tilde{c}) + 10\sigma^2(c)/9
\]

\[
(A6) \quad E[\pi_2^{ne}] = \pi_2^{bs}(\tilde{c}) + 25\sigma^2(c)/36.
\]
Straightforward calculation shows the ex ante equilibrium welfare levels:

\[(A7) \quad E[w_i^{\text{ca}}] = w_i^{\text{bs}}(\tilde{c}) + 11\sigma^2(c)/18\]

\[(A8) \quad E[w_2^{\text{nc}}] = w_2^{\text{bs}}(\tilde{c}) + 25\sigma^2(c)/36.\]

Lemma 3 follows from Using (A4 - A4) and (A5 – A8).

When both governments are informed of the own firm’s costs each government solves the problem similar to the one confronting government 1 in the previous case.

Simple computation yields the equilibrium subsidy rates:

\[s_i^{\text{sc}} = (2A - 5c_i - \tilde{c}_i + 4\tilde{c}_j)/10; \quad i, j = 1, 2.\]

Since the governments do not know the rival firm’s costs, this is the same as the equilibrium subsidy rate for government 1 when it is the only one that is informed. On substituting \(s_i^{\text{sc}}\) into the profit function (A2), we obtain the equilibrium ex post profit:

\[\pi_i^{\text{sc}}(c) = (4A - 10c_i - 2\tilde{c}_i + 5c_j + 3\tilde{c}_j)^2/100\]

Taking expectations over \(c\) yields the ex ante profit:

\[(A9) \quad E[\pi_i^{\text{sc}}] = \pi_i^{\text{bs}}(\tilde{c}) + 5\sigma^2(c)/4\]

The expected welfare level obtains straightforwardly:

\[(A10) \quad E[w_i^{\text{sc}}] = w_i^{\text{bs}}(\tilde{c}) + 3\sigma^2(c)/4.\]

Lemma 4 follows from (A5–A8) and (A9–A10). Propositions 3 follows from lemmas 3 and 4. Proposition 4 follows from (A3) and (A10).

Appendix B: Derivations for strategic complements and unknown intercept (section 4.A)

In the third stage, we consider three types of subgames as before, depending on whether and which governments are informed. With neither government informed, each maximizes ex ante welfare:

\[(B1) \quad E[w_i(\alpha)] = E[\pi_i^{\text{eq}}(\alpha) - s_i^{\text{eq}}(\alpha)] = \pi_i^{\text{eq}}(\tilde{\alpha}) + s_i^{\text{eq}}(\tilde{\alpha}) + \sigma^2(\hat{\Delta} - 2)^2 + \tilde{\delta}\Lambda^2/\Lambda^2\]
where \( \pi_i^{eq}(\alpha) + s_i q_i^{eq}(\alpha) \) are defined in the main body. The first order condition gives the best response subsidy rate

\[
b_i(s_j, \bar{\alpha}) = [2(\bar{\alpha} - c) - \delta(\bar{\alpha} + c - s_j) - \delta^2 c] \delta^2 / 4(\Delta - 2)
\]

The equilibrium subsidy rates are:

\[
s_i^{nn} = s_i^{eq}(\bar{\alpha}) < 0,
\]

Substituting the subsidy in two the profit and welfare function and taking the expectation yields

(B2) \[ E[\pi_i^{mn}(\alpha)] = \pi_i^{eq}(\bar{\alpha}) + \sigma^2(\alpha)/(2 - \delta)^2, \]

(B3) \[ E[w_i^{mn}(\alpha)] = w_i^{eq}(\bar{\alpha}) + \sigma^2(\alpha)/(2 - \delta)^2 \]

where \( \pi_i^{eq}(\bar{\alpha}) \) and \( w_i^{eq}(\bar{\alpha}) \) are the Eaton-Grossman equilibrium profits and welfare, evaluated at \( \alpha = \bar{\alpha} \).

When only government 1 is informed it then maximizes ex post welfare

\[ w_1(\alpha) = \pi_1(\alpha) - s_1 q_1(\alpha), \]

given \( \alpha \). Maximization yields the best response function

\[
b_1(s_j, \alpha) = [2(\alpha - c) - \delta(\alpha + c - s_j) - \delta^2 c] \delta^2 / 4(\Delta - 2)
\]

Government 2 is not informed and maximizes (A1) which yields the same best response function, which government 1 knows. Government 2 only has an expectation of government 1’s best response function, which equals \( b_1(s_2, \bar{\alpha}) \) which government 1 knows. From this can be derived the equilibrium subsidy rates:

(B4) \[ s_1^{eq}(\alpha) = s_i^{eq}(\bar{\alpha}) - \delta^2 (\alpha - \bar{\alpha})(2 + \delta)/(\Delta - 2) < 0 \]

\[ s_2^{nc} = s_i^{eq}(\bar{\alpha}) < 0, \]

Substituting these equilibrium subsidies into output (35a), we can compute the profits and the welfare. Taking expectations yields the following ex ante values:

(B5) \[ E[\pi_1^{eq}(\alpha)] = \pi_1^{eq}(\bar{\alpha}) + \sigma^2(\alpha)(2 + \delta)^2/16 \]
(B6) \[ E[\pi_2^{nc}(\alpha)] = \pi_i^{eq}(\tilde{\alpha}) + \sigma^2(\alpha)(\Delta + 2\delta)^2 / 16(\Delta - 2)^2. \]

(B7) \[ E[w_1^{ca}(\alpha)] = w_i^{eq}(\tilde{\alpha}) + \sigma^2(\alpha)(2 + \delta)^2 / 8(\Delta - 2). \]

(B8) \[ E[w_2^{cc}(\alpha)] = w_i^{eq}(\tilde{\alpha}) + \sigma^2(\alpha)(\Delta + 2\delta)^2 / 16(\Delta - 2)^2. \]

Lemma 5 follows from (B3 – B8).

With both governments informed, in the final stage this is essentially the Eaton and Grossman case, the equilibrium subsidy, profit and welfare are

\[ s_i^{cc}(\alpha) = s_i^{eq}(\alpha) \]

\[ \pi_i^{cc}(\alpha) = \pi_i^{eq}(\alpha) \]

\[ w_i^{cc}(\alpha) = w_i^{eq}(\alpha). \]

Taking expectations over \( \alpha \) and simplifying, we find the equilibrium ex ante profit and welfare:

(B9) \[ E[\pi_i^{cc}(\alpha)] = \pi_i^{eq}(\tilde{\alpha}) + \sigma^2(\alpha)((\Delta - 2)/(\Delta - 2\delta))^2. \]

(B10) \[ E[w_i^{cc}(\alpha)] = w_i^{eq}(\tilde{\alpha}) + 2\sigma^2(\alpha)(\Delta - 2)/(\Delta - 2\delta)^2. \]

Lemma 6 follows from (B5 – B10). **Proposition 5** follows from lemmas 5 and 6 and **Proposition 6** follows from comparison of B2-B3 with (B9-B10).

**Appendix C: Derivations for strategic complements and unknown costs (section 4.B)**

Assume now that costs \( c_i \) are distributed independently of each other, with mean \( \tilde{c}_i \) and variance \( \sigma^2(c) \). As before, first the benchmark two-stage model without uncertainty (Eaton and Grossman 1986) is derived. In this model, each government first chooses subsidy rate \( s_i \) to maximize welfare \( w_i = \pi_i - s_iq_i \), and firms then choose prices to maximize the profit

\[ \pi_i = (\alpha - p_i + \delta p_i)(p_i - c_i + s_i) \]

given subsidy rate \( s_i \). The best response price is \( p_i = (\alpha + c_i - s_i + \delta p_i)/2 \) and the equilibrium price is
\[ p_{1q}(c) = \frac{[(2 + \delta)\alpha + 2(c_i - s_i) + \delta(c_j - s_j)]}{\Delta}. \]

Substitution of \( p_{1q}(\alpha) \) into \( \pi_i \) and \( w_i \) and straightforward calculation of the government’s problem yields the equilibrium subsidy rate, output, profit and welfare as follows:

\[ s_{1q}(\alpha) = -\delta^2[\alpha(\Delta + 2\delta) - (\Delta - 2\delta^2) c_i + \delta(\Delta - 2)c_i]/(\Delta^2 - 4\delta^2) < 0. \]

\[ \pi_{1q}(c) = (\Delta - 2)^2 \{[(\Delta + 2\delta)\alpha - (\Delta - 2\delta^2)c_i + \delta(\Delta - 2)c_i]/(\Delta^2 - 4\delta^2)\}^2 = [q_{1q}(c)]^2 \]

\[ w_{1q}(c) = 2(\Delta - 2)^2 \{[(\Delta + 2\delta)\alpha - (\Delta - 2\delta^2)c_i + \delta(\Delta - 2)c_i]/(\Delta^2 - 4\delta^2)\}^2. \]

Now, with cost uncertainty, firms play a one-shot game of complete information in the fourth stage.

For given \( \alpha, s_i \) and \( s_j \), therefore, the equilibrium is the same as in the Eaton-Grossman model, and so the equilibrium output and profits are denoted by

\[ q_{1q}(c) = \frac{[(2 + \delta)\alpha - (2 - \delta^2)(c_i - s_i) + \delta(c_j - s_j)]}{\Delta} \]

\[ \pi_{1q}(c) = q_{1q}(c)^2. \]

In the third stage, a procedure similar to the one used in the previous cases establishes the following results.

For the case with neither government informed, we have

\[ E[\pi_{1m}(c)] = \pi_{1q}(c) + (2 - \delta^2)^2 \sigma^2/\Delta^2 + \delta^2 \sigma^2/\Delta^2 \]

(C1) \[ E[w_{1m}(c)] = w_{1q}(c) + (2 - \delta^2)^2 \sigma^2/\Delta^2 + \delta^2 \sigma^2/\Delta^2, \]

while with both governments informed

\[ E[\pi_{1c}(c)] = \pi_{1q}(c) + (2 - \delta^2)^2 \sigma^2/16 + \delta^2 \sigma^2/16 \]

(C2) \[ E[w_{1c}(c)] = w_{1q}(c) + 2(2 - \delta^2)\sigma^2/16 + \delta^2 \sigma^2/16. \]

For the asymmetric case, with only firm 1 disclosing information to its government, we have the following equilibrium profits

\[ E[\pi_{1a}(c)] = \pi_{1q}(c) + (2 - \delta^2)^2 \sigma^2/16 + \delta^2 \sigma^2/\Delta^2 \]

\[ E[\pi_{2a}(c)] = \pi_{2q}(c) + (2 - \delta^2)^2 \sigma^2/\Delta^2 + \delta^2 \sigma^2/16, \]

and the equilibrium welfare
E[w_1^{eq}(c)] = w_1^{eq}(c) + (2 - \delta^3)\sigma^2/8 + \delta^2\sigma^2/\Delta^2

E[w_2^{eq}(c)] = w_2^{eq}(c) + (2 - \delta^2)\sigma^2/\Delta^2 + \delta^2\sigma^2/16.

Proposition 7 follows straightforwardly from these equilibrium profits and welfare levels. Proposition 8 follows from comparing (C1) and (C2) and noting that $\Delta^2 < 16$.

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