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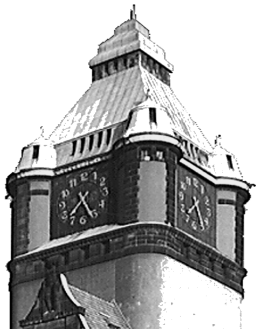

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Ambiguity and the Incentive to Export

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Abstract:

This paper examines the optimal production and export decisions of an international firm facing exchange rate uncertainty when the firm's preferences exhibit smooth ambiguity aversion. Ambiguity is modeled by a second-order probability distribution that captures the firm's uncertainty about which of the subjective beliefs govern the exchange rate risk. Ambiguity preferences are modeled by the (second-order) expectation of a concave transformation of the (first-order) expected utility of profit conditional on each plausible subjective distribution of the exchange rate risk. Within this framework, we show that ambiguity has no impact on the firm's propensity to export to a foreign country. Ambiguity and ambiguity aversion, however, are shown to have adverse effect on the firm's incentive to export to the foreign country.

JEL-Classification: D21; D81; F31

Keywords: Ambiguity; Ambiguity aversion; Exports; Production

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1. Introduction

The study of an international firm under exchange rate uncertainty has been the subject of considerable research in decision making under uncertainty (Katz and Paroush, 1979; Kawai and Zilcha, 1986; Broll and Zilcha, 1992; Viaene and Zilcha, 1998; Wong, 2007; to name just a few). The extant literature examines the production and export decisions of the international firm using the standard von Neumann-Morgenstern expected utility representation. Such a modeling approach rules out the possibility that the firm is unable to unambiguously assign a probability distribution that uniquely describes the exchange rate risk, which gives rise to ambiguity, or uncertainty in the sense of Knight (1921).

Since the seminal work of Ellsberg, ambiguity has been alluded to the violation of the independence axiom, which is responsible for the decision criterion being linear in the outcome probabilities. There are ample experiments (Einhorn and Hogarth, 1986; Sarin and Weber, 1993; Chow and Sarin, 2001) and surveys (; Viscusi and Chesson, 1999; Chesson and Viscusi, 2003; Eichberger et al., 2008) that document convincing evidence that individuals prefer gambles with known rather than unknown probabilities, implying that ambiguity aversion prevails.

The purpose of this paper is to incorporate ambiguity into the model of an international firm under exchange rate uncertainty. Klibanoff et al. (2005) have recently developed a powerful decision criterion known as "smooth ambiguity aversion" that is compatible with ambiguity averse preferences under uncertainty (hereafter referred to as the KMM model). The KMM model features the recursive structure that is far more tractable in comparison to other models of ambiguity such as the pioneering maxmin expected utility (or multiple-prior) model of Gilboa and Schmeidler (1989). Specifically, the KMM model represents ambiguity by a second-order probability distribution that captures the firm's uncertainty about which of the subjective beliefs govern the price risk. The KMM model then measures the firm's expected utility under ambiguity by taking the (second-order) expectation of a concave

transformation of the (first-order) expected utility of profit conditional on each plausible subjective distribution of the price risk. This recursive structure creates a crisp separation between ambiguity and ambiguity aversion, i.e., between beliefs and tastes, which allows us to study these two attributes independently. Another nice feature of the KMM model is that we can apply the conventional techniques in the decision making under uncertainty in the context of ambiguity (Taboga, 2005; Gollier, 2011; Snow, 2010, 2011; Alary et al., 2013).

Within the KMM model, we derive the necessary and sufficient condition under which the ambiguity-averse firm optimally refrains from exporting to a foreign country. This condition applies irrespective of whether ambiguity is present or not. Ambiguity as such has no impact on the firm's propensity to export. Since exporting to the foreign country exposes the firm to the exchange rate risk, the prevalence of ambiguity creates additional risk to the ambiguity-averse firm. Hence, the firm finds it less attractive to export to the foreign country in the presence than in the absence of ambiguity. This result extends to the case of greater ambiguity aversion. Ambiguity and ambiguity aversion as such have adverse effect on the firm's incentive to export.

The rest of this paper is organized as follows. Section 2 delineates the KMM model of an international firm under exchange rate uncertainty. Section 3 examine how ambiguity and ambiguity aversion affect the firm's optimal production and export decisions. The final section concludes.

2. The model

Consider an international firm that faces exchange rate uncertainty. There is one period with two dates, 0 and 1. To begin, the firm produces a single homogeneous good in the home country according to a known cost function, $C(Q)$, where $Q \geq 0$ is the level of output,

$C(0) = C'(0) = 0$, and $C'(Q) > 0$ and $C''(Q) > 0$ for all $Q > 0$.[1] The firm also has to decide how to allocate its entire output, Q, between domestic sales and foreign exports. Specifically, the firm commits to selling Q_d units of the good in the home market and exporting the rest, $Q_f = Q - Q_d$, to a foreign country at $t = 1$, where $0 \leq Q_d \leq Q$.

We model the exchange rate uncertainty by a random variable, $\tilde{S}$, that denotes the spot exchange rate at $t = 1$ and is expressed in units of the home currency per unit of the foreign currency.[2] The spot exchange rate, $\tilde{S}$, is distributed according to an objective cumulative distribution function, $H(S)$, over support $[\underline{S}, \overline{S}]$, where $0 < \underline{S} < \overline{S}$. The firm, however, is uncertain about $H(S)$ and thus faces ambiguity. Let $F(S|\theta)$ be the firm's subjective cumulative distribution function of $\tilde{S}$ over support $[\underline{S}, \overline{S}]$, where θ is the realization of an unknown parameter, $\tilde{\theta}$. The KMM model represents ambiguity by a second-order subjective cumulative distribution function of $\tilde{\theta}$, $G(\theta)$, over support $[\underline{\theta}, \overline{\theta}]$ with $\underline{\theta} < \overline{\theta}$, which captures the firm's uncertainty about which of the subjective cumulative distribution function, $F(S|\theta)$, governs the random spot exchange rate, $\tilde{S}$. Following Snow (2010, 2011), we assume that the firm's ambiguous beliefs are unbiased in the sense that the expected exchange rate risk is equal to the objective exchange rate risk:

$$\int_{\underline{\theta}}^{\overline{\theta}} F(S|\theta) \mathrm{d}G(\theta) = H(S), \tag{1}$$

for all $S \in [\underline{S}, \overline{S}]$.[3]

The firm is competitive in both the home and foreign markets. The selling price in the home market is P_d per unit, where $P_d > 0$ is denominated in the home currency. On the other hand, the selling price in the foreign market is P_f per unit, where $P_f > 0$ is denominated in the foreign currency.[4] The firm's profit at date 1, denominated in the home

[1] The strict convexity of the cost function reflects the fact that the firm's production technology exhibits decreasing returns to scale.

[2] Throughout the paper, random variables have a tilde ($\tilde{}$) while their realizations do not.

[3] The assumption that the expected exchange rate risk is equal to the objective exchange rate risk is motivated by the premise that the behavior of an ambiguity-neutral decision maker should be unaffected by the introduction of, or changes in, ambiguity.

[4] Due to the segmentation of the home and foreign markets, arbitrage transactions are either impossible or unprofitable, thereby invalidating the law of one price. See Engel and Rogers (1996, 2001) and Parsley and Wei (1996) for supportive evidence that arbitrage transactions among national markets are indeed imperfect.

currency, is given by $\tilde{\Pi} = P_d Q_d + \tilde{S} P_f Q_f - C(Q)$, where $Q = Q_d + Q_f$. To have a non-trivial problem, we assume that $\underline{S} P_f < P_d < \overline{S} P_f$ so that neither domestic sales dominate nor are dominated by foreign exports for sure. The firm possesses a von Neumann-Morgenstern utility function, $U(\Pi)$, defined over its home currency profit at date 1, Π, with $U'(\Pi) > 0$ and $U''(\Pi) < 0$, indicating the presence of risk aversion.

The recursive structure of the KMM model implies that we can compute the firm's expected utility under ambiguity in three steps. First, we calculate the firm's expected utility for each subjective cumulative distribution function of $\tilde{S}$. Second, we transform each (first-order) expected utility obtained in the first step via an increasing function, $\varphi(\cdot)$. Finally, we take the (second-order) expectation of the transformed expected utility obtained in the second step with respect to the second-order subjective cumulative distribution function of $\tilde{\theta}$. The firm's ex-ante decision problem as such is given by

$$\max_{Q_d \geq 0, Q_f \geq 0} \int_{\underline{\theta}}^{\overline{\theta}} \varphi \Big\{ \int_{\underline{P}}^{\overline{P}} U[P_d Q_d + S P_f Q_f - C(Q)] \mathrm{d}F(S|\theta) \Big\} \mathrm{d}G(\theta). \tag{2}$$

Inspection of the objective function of program (2) reveals that the effect of ambiguity, represented by the cumulative distribution function, $G(\theta)$, and the effect of ambiguity preferences, represented by the shape of the ambiguity function, $\varphi(\cdot)$, can be separated and thus studied independently.

We say that the firm is ambiguity averse if, for any given pair of domestic sales and foreign exports, (Q_d, Q_f), the objective function of program (2) decreases when the firm's ambiguous beliefs, specified by $G(\theta)$, change in a way that induces a mean-preserving spread in the distribution of the firm's expected utility. According to this definition, Klibanoff et al. (2005) show that ambiguity aversion implies concavity for $\varphi(\cdot)$, and that a concave transformation of $\varphi(\cdot)$ results in greater ambiguity aversion. Throughout the paper, we assume that $\varphi(\cdot)$ satisfies that $\varphi'(\cdot) > 0$ and $\varphi''(\cdot) < 0$, implying that the firm is ambiguity averse.

The Kuhn-Tucker conditions for program (2) are given by

$$\int_{\underline{\theta}}^{\overline{\theta}} \int_{\underline{S}}^{\overline{S}} \varphi' \Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)] \mathrm{d}F(S|\theta) \Big\}$$

$$\times U'[P_d Q_d^* + SP_f Q_f^* - C(Q)][P_d - C'(Q^*)] \mathrm{d}F(S|\theta) \mathrm{d}G(\theta) \leq 0, \tag{3}$$

and

$$\int_{\underline{\theta}}^{\overline{\theta}} \int_{\underline{S}}^{\overline{S}} \varphi' \Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)] \mathrm{d}F(S|\theta) \Big\}$$

$$\times U'[P_d Q_d^* + SP_f Q_f^* - C(Q)][SP_f - C'(Q^*)] \mathrm{d}F(S|\theta) \mathrm{d}G(\theta) \leq 0, \tag{4}$$

where Q_d^* and Q_f^* are the firm's optimal domestic sales and foreign exports, respectively, and $Q^* = Q_d^* + Q_f^*$. The second-order conditions for program (2) are satisfied given the assumed properties of $\varphi(\cdot)$, $U(\Pi)$, and $C(Q)$.

3. The impact of ambiguity on exports

We first derive conditions under which domestic sales dominate foreign exports, i.e., $Q_d^* > 0$ and $Q_f^* = 0$. Denote Q° as the solution to $C'(Q^\circ) = P_d$. Since $Q_d^* > 0$ and $Q_f^* = 0$, condition (3) holds with equality and becomes

$$\varphi'\{U[P_d Q_d^* - C(Q_d^*)]\} U'[P_d Q_d^* - C(Q_d^*)][P_d - C'(Q_d^*)] = 0. \tag{5}$$

It then follows from Eq. (5) that $Q_d^* = Q^\circ$. Condition (4) holds as an inequality at $Q_d^* = Q^\circ$ and $Q_f^* = 0$, which becomes

$$C'(Q^\circ) \geq \int_{\underline{\theta}}^{\overline{\theta}} \int_{\underline{S}}^{\overline{S}} SP_f \mathrm{d}F(S|\theta) \mathrm{d}G(\theta) = \int_{\underline{S}}^{\overline{S}} SP_f \mathrm{d}H(S), \tag{6}$$

where the equality follows from Eq. (1). Hence, we establish our first proposition.

Proposition 1. *The ambiguity-averse international firm optimally refrains from exporting to the foreign country, i.e., $Q_f^* = 0$, if, and only if, the following condition holds:*

$$P_d \geq \int_{\underline{\theta}}^{\overline{\theta}} \int_{\underline{S}}^{\overline{S}} SP_f \mathrm{d}F(S|\theta)\mathrm{d}G(\theta) = \int_{\underline{S}}^{\overline{S}} SP_f \mathrm{d}H(S). \tag{7}$$

The intuition for Proposition 1 is as follows. The marginal revenue from domestic sales is certain and equal to P_d. Exporting to the foreign country, however, exposes the firm to the exchange rate risk. The firm, being risk averse and ambiguity averse, has to be compensated for bearing the exchange rate risk. Domestic sales as such dominate foreign exports if, and only if, the expected marginal revenue from the latter does not exceed the marginal revenue from the former. This condition applies irrespective of whether ambiguity is present or not. Hence, ambiguity has no impact on the firm's propensity to export to the foreign country.

Given that condition (7) does not hold, the firm optimally chooses $Q_f^* > 0$. The firm must attain a higher value of its objective function of program (2) than in the case that exporting to the foreign country is prohibited:

$$\int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta) > \varphi\{U[P_d Q^\circ - C(Q^\circ)]\}. \tag{8}$$

Let W^* be the solution to

$$\int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta)$$

$$= \varphi\{U[P_d Q^\circ - C(Q^\circ) + W^*]\}. \tag{9}$$

Eqs. (8) and (9) imply that $W^* > 0$, which captures the compensation demanded by the firm to give up the privilege of exporting to the foreign country.

Let $Q_d^\dagger$ and $Q_f^\dagger$ be the firm's optimal domestic sales and foreign exports, respectively, when the firm faces no ambiguity, i.e., $F(S|\theta) = H(S)$ for all $\theta \in [\underline{\theta}, \overline{\theta}]$ and $S \in [\underline{S}, \overline{S}]$. Given

that condition (7) does not hold, we have $Q_f^\dagger > 0$. Hence, the firm needs to be compensated if it has to give up the privilege of exporting to the foreign country. The compensation in the absence of ambiguity, $W^\dagger > 0$, must be the solution to

$$\varphi\Big\{\int_{\underline{S}}^{\overline{S}} U[P_d Q_d^\dagger + SP_f Q_f^\dagger - C(Q^\dagger)]\mathrm{d}H(S)\Big\} = \varphi\{U[P_d Q^\circ - C(Q^\circ) + W^\dagger]\}. \tag{10}$$

Comparing W^* and $W^\dagger$ yields the following proposition.

Proposition 2. *Given that condition (7) does not hold, introducing ambiguity to the ambiguity-averse international firm reduces the compensation demanded by the firm to give up the privilege of exporting to the foreign country.*

Proof. Since $\varphi''(\cdot) < 0$, Jensen's inequality implies that

$$\begin{aligned}
&\int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{\int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta) \\
&< \varphi\Big\{\int_{\underline{\theta}}^{\overline{\theta}}\int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)]\mathrm{d}F(S|\theta)\mathrm{d}G(\theta)\Big\} \\
&= \varphi\Big\{\int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)]\mathrm{d}H(S)\Big\},
\end{aligned} \tag{11}$$

where the equality follows from Eq. (1). Since $Q_d^\dagger$ and $Q_f^\dagger$ are the firm's optimal domestic sales and foreign exports, respectively, in the absence of ambiguity, it must be true that

$$\begin{aligned}
&\varphi\Big\{\int_{\underline{S}}^{\overline{S}} U[P_d Q_d^\dagger + SP_f Q_f^\dagger - C(Q^\dagger)]\mathrm{d}H(S)\Big\} \\
&> \varphi\Big\{\int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)]\mathrm{d}H(S)\Big\}.
\end{aligned} \tag{12}$$

Eqs. (11) and (12) imply that

$$\int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{\int_{\underline{S}}^{\overline{S}} U[P_d Q_d^* + SP_f Q_f^* - C(Q^*)]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta)$$

$$< \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^\dagger + S P_f Q_f^\dagger - C(Q^\dagger)] \mathrm{d}H(S) \Big\}. \tag{13}$$

It then follows from Eqs. (9), (10), and (13) that $W^* < W^\dagger$. $\square$

The intuition for Proposition 2 is as follows. Exporting to the foreign country exposes the firm to the exchange rate risk. The presence of ambiguity creates additional risk to the ambiguity-averse firm. Hence, the firm finds it less attractive to export to the foreign country in the presence than in the absence of ambiguity, rendering that $W^* < W^\dagger$. Ambiguity as such reduces the value to export.

Klibanoff et al. (2005) show that the firm becomes more ambiguity averse when $\varphi(\cdot)$ is replaced by $K[\varphi(\cdot)]$ in the objective function of program (2), where $K(\cdot)$ satisfies that $K'(\cdot) > 0$ and $K''(\cdot) < 0$. Let $Q_d^\diamond$ and $Q_f^\diamond$ be the optimal domestic sales and foreign sales, respectively, when the firm's smooth ambiguity preferences are represented by $K[\varphi(\cdot)]$. Given that condition (7) does not hold, we have $Q_f^\diamond > 0$. The compensation demanded by the more ambiguity-averse firm to give up the privilege of exporting to the foreign country, $W^\dagger > 0$, must be the solution to

$$\int_{\underline{\theta}}^{\overline{\theta}} K\Big\{ \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^\diamond + S P_f Q_f^\diamond - C(Q^\diamond)] \mathrm{d}F(S|\theta) \Big\} \Big\} \mathrm{d}G(\theta)$$

$$= K\Big\{ \varphi\{U[P_d Q^\circ - C(Q^\circ) + W^\diamond]\} \Big\}. \tag{14}$$

Comparing W^* and $W^\diamond$ yields the following proposition.

Proposition 3. *Given that condition (7) does not hold, making the ambiguity-averse international firm more ambiguity averse reduces the compensation demanded by the firm to give up the privilege of exporting to the foreign country.*

Proof. Since $K''(\cdot) < 0$, Jensen's inequality implies that

$$\int_{\underline{\theta}}^{\overline{\theta}} K\Big\{\varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^{\diamond} + SP_f Q_f^{\diamond} - C(Q^{\diamond})]\mathrm{d}F(S|\theta)\Big\}\Big\}\mathrm{d}G(\theta)$$

$$< K\Big\{ \int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^{\diamond} + SP_f Q_f^{\diamond} - C(Q^{\diamond})]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta)\Big\}. \tag{15}$$

Since Q_d^* and Q_f^* are the optimal domestic sales and foreign sales, respectively, when the firm's smooth ambiguity preferences are represented by $\varphi(\cdot)$, it must be true that

$$\int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^{*} + SP_f Q_f^{*} - C(Q^{*})]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta)$$

$$> \int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^{\diamond} + SP_f Q_f^{\diamond} - C(Q^{\diamond})]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta). \tag{16}$$

Eqs. (15) and (16) imply that

$$\int_{\underline{\theta}}^{\overline{\theta}} K\Big\{\varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^{\diamond} + SP_f Q_f^{\diamond} - C(Q^{\diamond})]\mathrm{d}F(S|\theta)\Big\}\Big\}\mathrm{d}G(\theta)$$

$$< K\Big\{ \int_{\underline{\theta}}^{\overline{\theta}} \varphi\Big\{ \int_{\underline{S}}^{\overline{S}} U[P_d Q_d^{*} + SP_f Q_f^{*} - C(Q^{*})]\mathrm{d}F(S|\theta)\Big\}\mathrm{d}G(\theta)\Big\}. \tag{17}$$

It then follows from Eqs. (9), (14), and (17) that $W^{\diamond} < W^*$. □

The intuition for Proposition 3 is as follows. When the firm is more ambiguity averse, exporting to the foreign country becomes less attractive as the firm has to be exposed to the exchange rate risk. Hence, the compensation demanded by the firm to give up the privilege of exporting to the foreign country decreases in a systematic manner with greater ambiguity aversion.

4. Conclusion

In this paper, we have examined the production and export decisions of an international firm under exchange rate uncertainty when the firm's preferences exhibit smooth ambiguity aversion developed by Klibanoff et al. (2005). The KMM model represents ambiguity by a second-order probability distribution that captures the firm's uncertainty about which of the subjective beliefs govern the exchange rate risk. On the other hand, the KMM model specifies ambiguity preferences by the (second-order) expectation of a concave transformation of the (first-order) expected utility of profit conditional on each plausible subjective distribution of the exchange rate risk. Within this framework, we have shown that the ambiguity-averse firm optimally refrains from exporting to a foreign country if, and only if, the expected marginal revenue from foreign exports does not exceed the marginal revenue from domestic sales. This condition applies irrespective of whether ambiguity is present or not. Hence, ambiguity has no impact on the firm's propensity to export. We have further shown that the firm finds it less attractive to export to the foreign country in the presence than in the absence of ambiguity, and with greater ambiguity aversion. The value of export as such decreases when ambiguity and ambiguity aversion prevail.

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