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Injunctions and Hold-up under Weak Patent Protection†

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This paper analyzes how injunctions relate to patent hold-up problems. To this end, we present a simple model of licensing negotiations between a patent holder and a downstream firm in the shadow of litigation. More specifically, we consider the situation in which an injunction is granted as a matter of course if a patent is found valid and infringed upon in litigation, but the patent holder may be under-compensated due to aspects of the patent remedy system other than injunctions. We show that if the downstream user is unaware of the patent before any investment in initially designing its product, the patent hold-up problems created by injunction threats are worrisome when (i) the redesign process is costly, (ii) the degree of patent protection (by aspects of the patent remedy system other than injunctions) is sufficiently strong and (iii) the injunction is requested not to practice the patented technology exclusively but to collect excessive patent royalties. Even if the downstream user is aware of the patent before the initial investment, the patent hold-up problems do not disappear. The findings here imply that a discretionary approach is required towards denying injunctions against patent infringement. If the degree of patent protection is not sufficiently strong, denying injunctions can exacerbate the under-compensation problem. However, once patent protection improves enough (not necessarily perfectly), we may see a surge of patent hold-up problems, and it would be better to apply alternative patent remedies in place of injunctions when necessary. Lastly, we discuss several possible alternatives to injunctions and their pros and cons.

I. Introduction

The two fundamental pillars of patent remedies are awarding patent damages and issuing an injunction. In the U.S., it was a general rule that the court awarded patent damages to compensate the patent holder for prior infringement and granted a permanent injunction to prevent continuing infringement if the court found the patent valid and infringed upon. However, since around the early 2000s, there has been vigorous debate regarding the prospect of hold-up problems associated with injunctions in patent cases. Subsequently, the U.S. Supreme Court made a substantial change to the prospective remedy. In *eBay v. MercExchange*, the Supreme Court instructed the district courts to exercise discretion as to whether to grant or deny injunctive relief depending on results of a four-factor test.[1]

Concerns over patent hold-up associated with injunctions grew rapidly after the well-known patent dispute between NTP and Research in Motion (RIM). After RIM had successfully launched Blackberry, a device offering wireless email service, NTP asserted that RIM infringed on NTP's patents. In the patent lawsuit, the jury found that NTP's patents were valid and RIM had infringed upon those patents. Subsequently, NTP sought an injunction, which would have been resulted in the closure of the Blackberry service if the injunction had been enforced. Because RIM was desperate to avoid the effects of the injunction, RIM settled the dispute by agreeing to pay $612.5 million to NTP, much more than the damages established by the jury.[2]

As illustrated by the NTP case, concerns about injunctions are more common in the information technology sector, including, for example, telecommunication parts and devices, computer software and hardware, and semiconductors. (Shapiro, 2010) There could be many reasons for this, but to name a few,[3] first, firms in this sector are more easily exposed to the risk of infringing on a patent inadvertently, not only because many patents are of dubious quality and have vague and broad claims but also because products tend to be complex and include many features. Second, a redesign process in response to an allegation of patent infringement can be quite costly and time-consuming.

In many countries, including Korea, however, an injunction is still issued as a matter of course by law if a patent is held valid and infringed upon during patent litigation.[4] Considering that firms in other countries, at least in the information technology sector, may also face a similar situation, a natural question comes to mind, i.e., whether or not Korea should also follow such patent reforms as in US? It is not straightforward to answer this question. Because there has also been criticism

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[1] *eBay Inc. v. MercExchange, LLC.*, 547 U.S. 388 (2006), "According to well-established principles of equity, a plaintiff seeking a permanent injunction must satisfy a four-factor test before a court may grant such relief. A plaintiff must demonstrate: (1) that it has suffered an irreparable injury; (2) that remedies available by law, such as monetary damages, are inadequate to compensate for that injury; (3) that, considering the balance of hardships between the plaintiff and defendant, a remedy in equity is warranted; and (4) that the public interest would not be disserved by a permanent injunction."

[2] For more details of the dispute between NTP and RIM, see, for example, *CNN Money*, *IEEE Spectrum* (2006. 3. 1), or the *Wall Street Journal* (2006. 3. 4).

[3] For the complete list, see Shapiro (2010), p.283.

[4] For a comparison across countries on issuing an injunction in patent cases, for example, see Cotter and Golden (2019).

that patent remedies in Korea do not provide strong protection for patent holders in terms of the level of patent damage and win rates,[5] any such reforms may worsen the under-compensation problem for the patent holders in Korea.

This paper analyzes how injunctions relate to a patent holder's payoff when the patent remedy system may not provide enough protection for the patent holder due to aspects other than injunctions. By comparing that payoff to a benchmark level, we identify conditions under which the patent holder is over-compensated by obtaining or threatening to seek an injunction, that is, patent hold-up associated with an injunction arises. Next, according to the analysis, we attempt to draw policy implications for the patent remedy system in Korea. We also briefly discuss several alternatives to injunctions as remedies.

To this end, we present a simple model of licensing negotiations between a patent holder and a downstream firm in the shadow of litigation. More specifically, we consider a model in which the two parties have two different opportunities to negotiate a patent license: one before a patent lawsuit and the other after.

We assume the following litigation process. First, as is often assumed in the recent literature, patents are probabilistic property rights, meaning that patents are held and infringed upon only with some probability of patent lawsuits.[6] We call this type of probability patent "strength" following the literature. Second, both patent strength and patent damage may be discounted to some degree.

To reflect the reality and to take into account key elements which may cause patent hold-up in patent infringement lawsuits, we also assume that the redesigning process is costly once the product of the downstream firm is designed to incorporate the patented feature, as in such cases, the initial investments are specific to the patented technology and thus sunk. In a similar vein, we consider the scenario associated with the "inadvertent infringement" model, in which the downstream firm is unaware of the patent when initially designing its product. We also analyze the "early negotiation" model in which the downstream firm can contemplate whether to incorporate the patented feature into its product while remaining aware of the patent and then compare the results from the two models.

In the inadvertent infringement model, we show that patent hold-up problems are worrisome when (i) the redesign process is costly, (ii) patent strength discounting and patent damage discounting are not too large, and (iii) the patent holder obtains or threatens to seek an injunction not to exclude the downstream firm from practicing the patent but to collect excessive patent royalties. If the injunction is granted but the patent holder still wants to license the patent to the downstream firm, the patent holder captures part of the redesign cost regardless of the value of the patented technology, which potentially causes the patent holder's payoff to exceed the benchmark level. However, if patent strength discounting and patent damage discounting are too large, capturing part of redesign cost would not be sufficient to compensate for the loss caused by the weak patent protection. Our results also indicate that a perfect degree of patent protection is not a prerequisite for a patent reform such as the recent one in the US.

The patent hold-up problem can arise even in the early negotiation model. Two

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[5]For example, see Kim (2015).
[6]For example, see Gallini (2002) and Lemley and Shapiro (2005), among others.

different patent hold-up types can emerge. In case the downstream firm decides to use the patented feature after the initial negotiations break down, we see the same type of hold-up problems directly associated with the threat of an injunction. In contrast, if the downstream firm decides not to incorporate the patented feature into its product, we see a different type of hold-up problem. In these cases, the patent holder is over-compensated mainly because the downstream firm withdraws a chance to fight for the invalidation of the patent or defend the infringement allegation. This type of hold-up is especially serious for weak patents.

This paper contributes to the literature on the patent hold-up issue. Many studies have shed light on hold-up problems in a standard setting context. Among others, Farrell *et al.* (2007) offers an excellent overview of related issues. The key issue here is that the bargaining power of a patent holder during license negotiations increases dramatically once a technical standard, including technology protected by a patent holder's patent, is established as an industry standard. The patent holder can then collect much higher royalties than would have been determined before the standard was adopted or before the downstream firm decided to incorporate the standard into its product. Papers in this strand of the literature mainly focus on finding a good way to discipline opportunistic behavior by patent holders through the use of antitrust or patent laws or on studying whether FRAND commitments[7] made by patent holders can effectively mitigate hold-up problems. For example, Ganglmair *et al.* (2012) develops a model in which a patent holder, who abides by a FRAND commitment, and a downstream firm engage in royalty negotiations. They show that FRAND can indeed mitigate a hold-up problem but that it also retards innovation by reducing the patent holder's payoff. They also suggest that an option-to-license contract under which the patent holder and the downstream firm negotiate before any standard-specific investment by the downstream firm is made can outperform the FRAND commitment. In comparison to these works, we attempt to examine hold-up problems associated with injunctions in more general patent license negotiations. Studies by Shapiro (2010; 2017) are more closely related to this paper in that those studies focus on licensing negotiations between a single patent holder and a single downstream user. Shapiro (2010) analyzes conditions under which hold-up problems arise, confining his attention to cases in which the patent holder is a non-practicing entity (NPE).[8] Shapiro (2017) investigates conditions under which ongoing royalties outperform injunctions, also confining his attention to cases in which the court already has discretion as to whether to grant an injunction or to order ongoing royalties, and where the patent has already been found valid and infringed upon. Because we must consider the possibility that the patent remedy system may not provide enough protection for the patent holder due to aspects other than injunctions, our model integrates and extends the above two models. More specifically, we analyze how both remedies for past and future infringements affect the patent holder's payoff considering license negotiations before and after litigation and general competitive relationships between patent holders and downstream users.

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[7]FRAND is an abbreviation for "Fair, Reasonable, and Non-Discriminatory." Most well-known standard-setting organizations require participants to commit to license their patents on FRAND terms once technology protected by those patents is included in an industry standard later.

[8]Non-practicing entity refer to a patent-owning company that does not practice any of their own patents for themselves but that simply attempt to collect patent royalties by asserting their patents.

Lemley and Shapiro (2007) briefly discuss patent hold-up caused by injunctions but focus more on royalty stacking, which refers to situations in which a single downstream user takes a risk of infringing on many different patents owned by different patent holders. They demonstrate how royalty stacking can amplify hold-up problems in a relationship between a single-downstream user and a multiple-patent holder.

This paper is also related to a number of studies exploring more sophisticated litigation strategies of NPEs. Choi and Gerlach (2018) and Hovenkamp (2013) study how a NPE can more effectively assert their patents while facing multiple potential infringers. Choi and Gerlach (2018) examine the effects of an information externality produced by a prior litigation outcome on subsequent litigations. Assuming asymmetric information between the NPE and downstream users with regard to the type of NPE, Hovenkamp (2013) studies the incentives of NPEs to initiate litigation in the early stage to build a litigious reputation for subsequent litigation. Lemus and Temnyalov (2017) analyze the roles of NPEs when practicing entities can outsource the filing of lawsuits against one another to a NPE and show that the existence of NPEs may increase both the innovation incentives of practicing entities and social welfare.

A number of works in Korea study patent hold-up problems as well. Many of them, such as Cha (2015), Oh (2014) and Song (2014), examine whether the court needs to deny an injunction in a patent infringement case if a plaintiff owns standard essential patents under a FRAND commitment. Several other studies, including those by Cho (2015), Sim (2013) and Son (2011), examine hold-up problems created by injunctions in more general cases of patent licensing. However, while all of the studies discussed above offer insights from a legal perspective, they do not provide a sufficient theoretical background. Moreover, despite the fact that there has been criticism that patent remedies in Korea do not provide strong protection for patent holders, as in Kim (2015), previous works do not seriously take into account such criticism.

The remainder of the paper is organized as follows. Section 2 presents the model. In section 3, we discuss the benchmark royalty rate and payoffs. In sections 4 and 5, we study the inadvertent infringement model and the early negotiation model respectively, in turn. Section 6 discusses policy implications and a few alternative remedies to an injunction. Finally, section 7 concludes the paper.

II. Model

This section introduces the model, which is a modified and integrated version of the two models from Shapiro (2010; 2017). Consider the following three agents in the model: a patent holder P (plaintiff in patent litigation), a downstream firm D (defendant in patent litigation) and the Court C. P owns a single patent, and D produces a good that can potentially employ a technology protected by the patent.

A. *Patented Feature and Competitive Relationship*

Unit time profits for P and D vary depending on whether D includes the patented feature in its product. We denote unit time profits for P and D by π^P

TABLE 1— UNIT TIME PROFITS

	P's unit time profit	D's unit time profit
Patented feature in D's product	π^P	π^D
No patented feature in D's product	$\pi^P + \Delta^P$	$\pi^D - \Delta^D$

and π^D, respectively, when the patented feature is incorporated into D's product. Compared to this situation, if D's product is produced without the patented feature, D's product becomes less attractive or more costly to produce. As a result, D's unit time profit should decrease. We denote this type of loss faced by D as Δ^D. In contrast, P's unit time profit will increase if D's product does not incorporate the patented feature. We denote this gain by P as Δ^P. The unit time profits for each case can then be summarized, as presented in Table 1. All four variables (π^P, π^D, Δ^P and Δ^D) are non-negative, and $\pi^D \geq \Delta^D$.

This profit specification is fairly general in that it can reflect many competitive or licensing relationships between the two firms. For example, we can consider a case in which P is a NPE (by setting $\pi^P = \Delta^P = 0$) as well as a case in which P and D are competitors ($\Delta^P, \Delta^D > 0$).

B. *Patent Litigation Process*

Once P initiates a patent lawsuit, it takes time, $T > 0$, until the litigation ends. We normalize the patent length to 1 such that T denotes the litigation duration as a fraction of the patent length.

When the litigation ends, C decides who wins the litigation. If P's patent is upheld as valid and deemed to have been infringed upon by D, P is the winner of the litigation. In this case, C orders D to pay unit time damages r for the past infringement. In addition, a permanent injunction is granted to prevent future infringements, which requires D to obtain a license from P to continue to sell its product as it is or to redesign the product to stop using the patented feature. In contrast, if P's patent is upheld as invalid or is deemed not to have been infringed upon by D, D is the winner of the litigation. If this is the case, D can continue to sell its product without any further action.

Furthermore, to consider the possibility of under-compensation for patentees, we make the following key assumptions. First, we assume that the "actual" probability λ that P wins the litigation can be less than or equal to the "fair" probability θ that P deserves to win the litigation given the intrinsic characteristics of the patent. As is usual in the literature, θ is referred to as the "patent strength." D wins the litigation with the complementary probability $1 - \lambda$. Second, we also assume that unit time patent damages r n be calculated as less than or equal to the benchmark patent damages r^{BM}. We will discuss how this benchmark level is set in the paragraphs below.[9] Patent strength discounting and patent damage discounting

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[9]See subsection E for a more detailed discussion of the benchmark royalties.

would reflect reality well, for example, if evidence gathering is difficult due to a lack of legislation and/or policies governing the patent litigation process. Below we state these assumptions more formally.

Assumption 1. $\lambda = \rho\theta$, where $\rho \in [0,1]$ is the degree of patent strength discounting.

Assumption 2. $r = \tau r^{BM}$, where $\tau \in [0,1]$ is the degree of patent strength discounting.

Lastly, each party has to incur costs denoted by L^P and L^D, respectively, for litigation. We only analyze cases in which these costs are not so large that P has sufficient incentive to initiate litigation, at least without any patent strength discounting and/or patent damage discounting. All of the above information about the litigation process is common knowledge.

C. *Product Redesign*

Regardless of whether D incorporates the patented feature into its product or not, we assume that the same fixed costs are required for the initial product design. However, if the patented feature is included initially but must be excluded later, for example in order to comply with a permanent injunction order, D must bear the redesign costs of $F > 0$. The redesign process is completed instantly.[10]

D. *Timeline*

As in Shapiro (2010), we consider the two different but similar models: "inadvertent infringement[11]" and "early negotiations." Game trees for the two models are depicted in Figures 1 and 2, respectively. For simplicity, we do not consider time discounting.

In the first model, D includes the patented feature into its product without being aware of P's patent protecting that feature. Next, ex-ante (before litigation) royalty negotiations take place. If the ex-ante negotiations fail, P decides whether to file a lawsuit.[12] In case there is litigation, court decisions are made after T amount of time passes. If P wins the litigation, the two parties engage in ex-post (after litigation) royalty negotiations once again. If these ex-post negotiations fail, D

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[10]Even if we assume that the redesign process is time-consuming, as in Shapiro (2010), qualitative results do not change. In fact, the instant redesign process specification underrates hold problems associated with injunctions compared to the specification from Shapiro (2010).

[11]This corresponds to the "surprise" model in Shapiro (2010).

[12]In principle, the analysis would be more complete if we analyze D's optimal response to the accusation of a patent infringement as well. To reduce the number of cases under consideration, we assume that D proceeds with the trial without redesigning its product right away instead of halting sales of its product or that D proceeds with the trial by redesigning its product immediately. In fact, this assumption underestimates the potential extent of patent hold-up but does not affect our qualitative results.
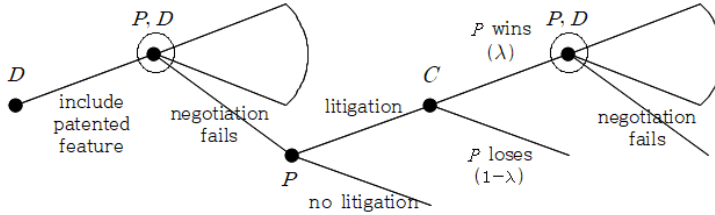
FIGURE 1— INADVERTENT INFRINGEMENT
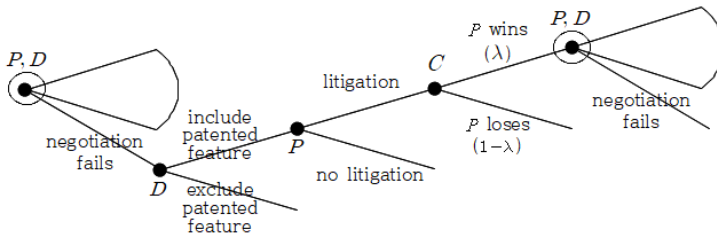
FIGURE 2— EARLY NEGOTIATION

redesigns the product.[13]

In the second model, the game proceeds in the same manner as above except that P and D engage in ex-ante negotiations before D's initial product design.

E. *Royalty Negotiation*

We assume that a Nash bargaining solution determines royalty rates when P and D engage in ex-ante and ex-post negotiations. Parameters $\beta \in [0,1]$ and $1 - \beta$ represent the bargaining power of P and D, respectively. Because we analyze a Nash bargaining problem with symmetric information, P receives a share β of the gains from trade in addition to its own disagreement payoff. Similarly, D receives a share $1 - \beta$ of the gains from trade in addition to its own disagreement payoff.

III. Benchmark Royalty Rate and Payoff

Before analyzing the two models presented in the previous section, we briefly discuss the benchmark royalty rate and benchmark payoff for the patent holder. First, we define the benchmark royalty rate r^{BM} as P's unit time payoff net of

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[13]As discussed in the previous footnote, in principle the analysis would be more complete if we also analyze D's optimal response subsequent to the failed ex-post royalty negotiations. D could stop selling its product or redesign its product. Again, we abstract from this analysis by assuming that D wants to redesign and keep selling the product for the remaining period, i.e., $(1 - T)(\pi - \Delta^D) > F$. In fact, assuming D's optimal response as in footnotes 4 and 5 makes negotiation environments less favorable for P.

π^P that would result via ex-post royalty negotiations if the redesign costs are zero such that there is no concern over a hold-up. In this case, gains from trade exist if and only if

(1) $(1-T)(\pi^P + \pi^D) \geq (1-T)\left[(\pi^P + \Delta^P) + (\pi^D - \Delta^D) \right] \Leftrightarrow \Delta^D \geq \Delta^P.$

Disagreement payoffs to P and D are expressed as $(1-T)(\pi^P + \Delta^P)$ and $(1-T)(\pi^D - \Delta^D)$, respectively. Therefore, the benchmark royalty rate is $r^{BM} = \Delta^P + \beta(\Delta^D - \Delta^P)$ if inequality (1) holds, and $r^{BM} = \Delta^P$ otherwise. In summary,

(2) $$r^{BM} = \Delta^P + \beta \max\{\Delta^D - \Delta^P, 0\},$$

which can be considered as a form of either "lost profits" or "reasonable royalties." We can observe that the benchmark royalty rate is P's marginal benefit of using the patented feature without licensing plus the gains from licensing discounted by its bargaining power.

Similarly, we also set the benchmark payoff for the patent holder as the sum of the profit level it earns when the patented feature is used by both P and D and the benchmark royalties discounted by the patent strength:

(3) $$\Pi^{P|BM} = \pi^P + \theta r^{BM}$$

The benchmark payoff would be equal to the patent holder's equilibrium payoff under the following assumptions. First, litigation costs are zero such that these costs do not affect either party's payoff.[14] Second, C sets damages equal to r^{BM} when necessary. Third, there is no patent strength discounting or patent damage discounting during the litigation process.

In what follows, we will compare P's expected payoffs to this benchmark payoff in each model. If the former is larger (smaller) than the latter, we consider the difference between the two to be the portion of P's payoff attributable to the hold-up (hold-out).

IV. Inadvertent Infringement

In this section, we study the inadvertent infringement model, in which D initially designs its product with the patented feature without being aware of P's patent covering that feature. In order to look for a subgame prefect Nash equilibrium,

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[14]Actually, assuming litigation costs are neutral is sufficient. We will show under which conditions litigation costs are neutral later.

we solve the model by means of backward induction. We shall mainly focus on determining how much the patent holder's equilibrium payoff is and comparing that to the benchmark level to understand the magnitude of the hold-up (or hold-out). All proofs omitted here are in the appendix.

First, we consider the last stage, in which P and D negotiate over patent royalties after P wins the litigation. Given the assumption that D does not stop producing but redesigns its product when licensing negotiations fail, disagreement payoffs to P and D are expressed as $(1-T)(\pi^P + \Delta^P)$ and $(1-T)(\pi^D - \Delta^D) - F$, respectively. If the two parties sign a licensing agreement, prospective payoffs to P and D are expressed as $(1-T)\pi^P$ and $(1-T)\pi^D$, respectively. Therefore, there are gains from trade if and only if

$$(4)\; (1-T)(\pi^P + \pi^D) \geq (1-T)\Big[(\pi^P + \Delta^P) + (\pi^D - \Delta^D) \Big] - F \Leftrightarrow \Delta^D + \frac{F}{1-T} \geq \Delta^P.$$

The equilibrium outcome of ex-post negotiations is as follows. If there are no gains from trade, negotiations break down, and each party simply receives its own disagreement payoff. In contrast, if there are gains from trade, they reach a licensing agreement in which they split the gains from trade according to each party's bargaining power on top of receiving their own disagreement payoffs; i.e., P and D's payoffs are respectively given by

$$(5) \qquad\qquad (1-T)(\pi^P + \Delta^P) + \beta\Big[(1-T)(\Delta^D - \Delta^P) + F \Big]$$

$$(6) \qquad\qquad (1-T)(\pi^D - \Delta^D) - F + (1-\beta)\Big[(1-T)(\Delta^D - \Delta^P) + F \Big].$$

The next lemma summarizes the results of the ex-post negotiations.

Lemma 1.
In ex-post negotiations, the patent holder and the downstream firm sign a licensing agreement if there are gains from trade; i.e., equation (4) holds. Otherwise, negotiations break down. The payoffs for the patent holder and the downstream firm are given by

$$(7) \qquad \Pi^{P|ex-post} = (1-T)(\pi^P + \Delta^P) + \beta \max\{(1-T)(\Delta^D - \Delta^P) + F, 0\},$$

$$(8)\; \Pi^{D|ex-post} = (1-T)(\pi^D - \Delta^D) - F + (1-\beta)\max\{(1-T)(\Delta^D - \Delta^P) + F, 0\},$$

Two aspects related to these equations are important to note here. First, the condition for successful licensing negotiations is relaxed when redesigning is costly. (To see this, compare the inequalities (4) and (1)). Given that redesigning D's product is costly at this point, the two firms can retain those costs as well by signing
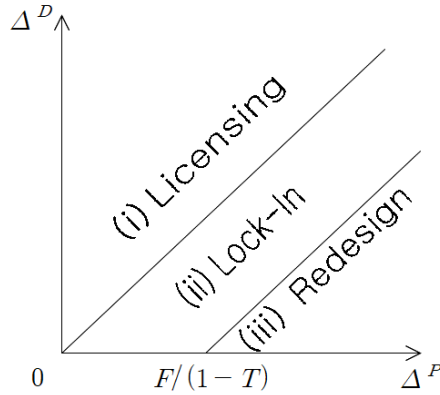
FIGURE 3— LICENSING OUTCOMES BY UNDERLYING NATURE

a licensing agreement. Hence, P's gains from prohibiting D from using the patented feature (Δ^P) now must be smaller than not only D's loss (Δ^D) but also the redesign costs spread over the remaining period the ($\frac{F}{1-T}$).

To simplify the discussion below, we categorize the underlying nature of ex-post licensing negotiations into the following three states depending on whether inequality (1) or (4) holds. "Licensing" states refer to cases in which a licensing agreement is reached regardless of whether the redesign costs are zero or F; i.e., $\Delta^D \geq \Delta^P$. "Lock-in" states refer to cases in which a licensing agreement is reached due to the positive redesign costs, i.e., $\Delta^D + \frac{F}{1-T} \geq \Delta^P \geq \Delta^D$. "Redesign" states refer to cases in which a licensing agreement cannot be reached regardless of whether the redesign costs are zero or F; i.e., $\Delta^P \geq \Delta^D + \frac{F}{1-T}$ (See Figure 3).

Second, P captures a part of the redesign costs (βF) unrelated to the value of the patented innovation in the licensing and lock-in states. As will become clear later, this is a key factor determining the degree to which P can hold-up D.

Next, we determine the expected payoffs for P and D depending on P's decision whether to bring a lawsuit. If P does not file a lawsuit, P ultimately receives $\Pi^{P|no-suit} = \pi^P$. Similarly, D receives $\Pi^{D|no-suit} = \pi^D$ in the end.

Even if P sues D at the cost of L^P, P earns π^P per unit time until the litigation outcomes are known or if it loses the litigation. However, if P wins the litigation, it earns $\Pi^{P|ex-post}$ for the remaining period plus damages $T\tau r^{BM}$ awarded by the court for the past infringement. After some tedious algebra, one can ascertain each party's expected payoffs from the litigation, as in the following lemma.

Lemma 2.
If the patent holder files a lawsuit, the expected payoffs for the patent holder and the downstream firm are given respectively by

(9)

$$\Pi^{P|suit}$$

$$= \pi^P + \rho\theta[T\tau r^{BM} + (1-T)\Delta^P + \beta\max\{(1-T)(\Delta^D - \Delta^P) + F, 0\}] - L^P,$$

(10)

$$\Pi^{D|suit}$$

$$= \pi^D + \rho\theta[-T\tau r^{BM} - (1-T)\Delta^D - F + (1-\beta)\max\{(1-T)(\Delta^D - \Delta^P) + F, 0\}] - L^D.$$

In equation (9), one can see how the size of extra (expected) benefits for P from the litigation is determined. It is simply the product of the probability that P wins the litigation ($\rho\theta$) and the amount of extra payoffs that P can capture if it wins (the term in the squared bracket). These extra payoffs can again be decomposed into two parts: the term associated with patent damage ($T\tau r^{BM}$) and the terms associated with an injunction order (all of the other terms in the squared bracket). The greater the patent strength discounting or patent damage discounting, the smaller the size of the extra benefits for P.

P will optimally choose to litigate if and only if the extra benefits from litigation exceed the litigation costs; i.e.,

(11) $$\rho\theta[T\tau r^{BM} + (1-T)\Delta^P + \beta\max\{(1-T)(\Delta^D - \Delta^P) + F, 0\}] \geq L^P.$$

As stated earlier in section II, we consider only cases in which P's litigation threat is credible, at least without any patent strength discounting and patent damage discounting. More specifically, we assume that the benchmark royalties discounted by the patent strength exceed the corresponding litigation costs, which ensures that P's litigation threat is credible without patent strength discounting or patent damage discounting.[15]

Assumption 3. $\theta[\Delta^P + \beta\max\{\Delta^D - \Delta^P, 0\}] \geq L^P.$

What remains in this section is to study the equilibrium payoffs of the entire game and to compare those to the benchmark payoffs. Depending on whether or not the two firms reach a licensing agreement during ex-post negotiations, the results are qualitatively different. Therefore, we consider the licensing and lock-in states first and then the redesign states later.

A. *Licensing and Lock-In States*

We consider the licensing and lock-in states at this point. In the appendix, we prove the following statement.

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[15]This corresponds to inequality (11) when $\rho = \tau = 1$ and $F = 0$.

Lemma 3.
In the licensing and lock-in states, ex-ante negotiations are always successful. The patent holder has an incentive to file a lawsuit if

$$(12) \qquad \rho\theta[T\tau r^{BM} + (1-\beta)(1-T)\Delta^P + \beta(1-T)\Delta^D + \beta F] \geq L^P.$$

The equilibrium payoffs for the patent holder and the downstream firm determined during ex-ante negotiations are expressed respectively as

$$(13) \quad \Pi^P = \begin{cases} \pi^P + \rho\theta[T\tau r^{BM} + (1-\beta)(1-T)\Delta^P + \beta(1-T)\Delta^D + \beta F] + \beta L^D - (1-\beta)L^P & \text{if (12)}, \\ \pi^P & \text{if} \sim (12), \end{cases}$$

$$(14) \quad \Pi^D = \begin{cases} \pi^D + \rho\theta[T\tau r^{BM} + (1-\beta)(1-T)\Delta^P + \beta(1-T)\Delta^D + \beta F] + (1-\beta)L^P - \beta L^D & \text{if (12)}, \\ \pi^D & \text{if} \sim (12) \end{cases}$$

where r^{BM} is defined as in (2).

Lemma 3 tells us that ex-ante negotiations always result in a licensing agreement in licensing and lock-in states. This does not necessarily mean that the patent holder is always able to collect some positive patent royalties. When P's litigation threat is not credible (i.e., when inequality (12) does not holds), they reach a licensing agreement at a patent royalty rate of zero simply because nothing changes as a result of the ex-ante negotiations.

However, if P's litigation threat is credible, the two firms anticipate that they will have to engage in costly litigation. Because the two firms always reach a licensing agreement during ex-post negotiations in the licensing and lock-in states, they can do better by signing a licensing agreement given these circumstances and avoiding the litigation costs. To see this, it is helpful to compare Π^P with $\Pi^{P|suit}$. The two payoff functions are identical except for the last terms associated with litigation costs (i.e., $\beta L^D - (1-\beta)L^P$ and $-L^P$). The net bargaining surplus discussed above is captured by the last term in Π^P, $\beta L^D - (1-\beta)L^P$. This term can be positive or negative depending on the relative amount of the litigation cost and on the bargaining power capabilities of the two firms in principle. For the remainder of this analysis, we assume that the litigation costs are neutral, which means that $\beta L^D - (1-\beta)L^P$ is zero.[16]

Proposition 1.
In the licensing and lock-in states, the patent holder is over-compensated, i.e.,

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[16]This assumption is true if, for example, $\beta = 1/2$ and $L^P = L^D$.

$\Pi^P > \Pi^{P|BM}$, if patent strength discounting and patent damage discounting are low, and otherwise the patent holder is under-compensated (i.e., $\Pi^P < \Pi^{P|BM}$). In order to state the above result more formally, we define a set E that contains all pairs (τ, ρ) for which the patent holder's payoff is equal to the benchmark level; i.e.,

$$E = \{(\tau, \rho) \in [0,1]^2 \mid \Pi^P = \Pi^{P|BM}\}.$$

E is a convex curve in the $\tau\rho$ -plane depicted by thick solid lines as in panel (a) or (b) in Figure 4. In the region to the upper right of the curve, the patent holder is over-compensated, and in the region to the lower left, the patent holder is under-compensated.

In the licensing and lock-in states, the hold-up problem arises as long as the extent of patent strength discounting or patent damage discounting is not excessive. In other words, the patent holder can obtain excessive patent royalties even when the full degree of patent protection ($\tau = \rho = 1$) is not being offered. Of course, the patent holder is under-compensated if the degree of patent protection becomes too weak

To gain a deeper understanding of the above finding, we express the difference between the patent holder's payoff and the benchmark. For expositional convenience, we consider licensing states, but the same logic applies to lock-in states as well.

(15) $\Pi^P(\tau, \rho) - \Pi^{P|BM} = \rho\theta\beta F - \{1 - \rho\tau T - \rho(1 - T)\}\theta r^{BM}$

The first term on the right side is the value of the expected redesign costs capturable by the patent holder with an injunction threat. This term is the component that causes the patent holder's payoff potentially to exceed the benchmark level. The second term on the right side shows how much less the expected patent royalties are relative to the benchmark level. These discounts can be further decomposed into two parts: one associated with patent damage ($\rho\tau T$) and the other associated with the
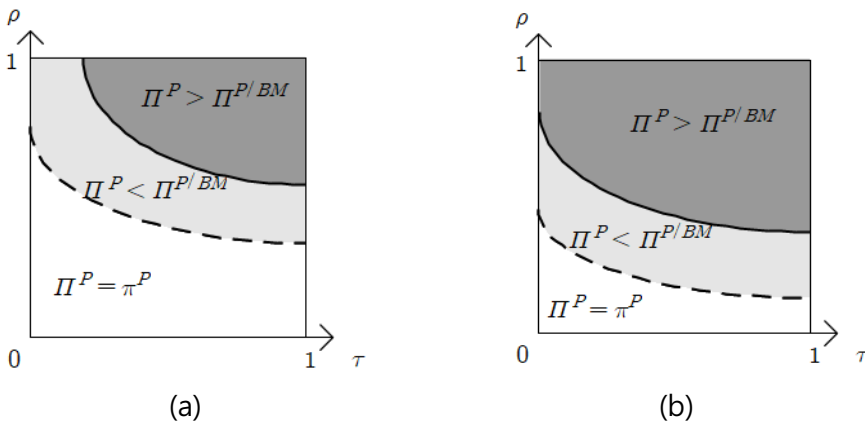
FIGURE 4— COMPARISON BETWEEN THE PATENT HOLDER'S PAYOFF AND THE BENCHMARK LEVEL

injunction threat ($\rho(1-T)$). As the degree of patent protection increases, the first term increases while the second one decreases. All other things being equal, the degree of the hold-up, i.e., the term in equation (15), increases with a decrease of T or with an increase of β or F.

Proposition 1 implies that a discretionary approach is required with regard to denying injunctions against patent infringement. If the degree of patent protection is not sufficiently strong, banning injunctive reliefs can exacerbate the under-compensation problem. Thus, it may be at least temporarily desirable to allow the patent holder to request an injunction as leverage for collecting excessive patent royalties. Nonetheless, it must be considered that such an approach has clear limitations in the sense that it is an attempt to increase the patent holder's payoff not based on the intrinsic value of the patent but based on the hold-up component.

A more fundamental solution would be to strengthen the degree of patent protection in other dimensions. However, once the under-provision of patent protection improves to a certain (not necessarily perfect) degree, the patent hold-up problems can come to the fore. In such a case, it may be desirable to limit the patent holder's right to seek injunctive relief in licensing or lock-in states. We will discuss how to deal with hold-up problems in section VI.

B. *Redesign State*

At this point, we consider redesign states in which ex-post negotiations break down because the patent holder wants to stop the downstream firm from utilizing the patented feature. We follow a similar procedure to construct the patent holder's payoff and then compare that to the benchmark level. The next lemma characterizes the equilibrium outcomes and the patent holder's payoff in redesign states.

Lemma 4.
In redesign states, the patent holder has an incentive to file a lawsuit if

$$(16) \qquad \rho\theta\{1-(1-\tau)T\}\Delta^P \geq L^P.$$

The condition under which there are gains from trade in ex-ante negotiations is given by

$$(17) \qquad \rho\theta\{(1-T)(\Delta^P - \Delta^D) - F\} \leq L^P + L^D.$$

If (16) holds but (17) does not, ex-ante negotiations break down. Otherwise, ex-ante negotiations are successful. The equilibrium payoffs to the patent holder and the downstream firm are expressed respectively by

$$\Pi^P =$$

$$(18) \quad \begin{cases} \pi^P + \rho\theta[1 - (1-\tau)T]\Delta^P - L^P & \text{if } (16) \wedge (\sim(17)), \\ \pi^P + \rho\theta[\{1 - (1-\tau)T\}\Delta^P - \beta\{(1-T)(\Delta^P - \Delta^D) - F\}] & \text{if } (16) \wedge (17), \\ \pi^P & \text{if } \sim(16), \end{cases}$$

$$\Pi^D =$$

$$(19) \quad \begin{cases} \pi^D - \rho\theta[T\tau\Delta^P + (1-T)\Delta^D + F] - L^D & \text{if } (16) \wedge (\sim(17)), \\ \pi^D - \rho\theta[T\tau\Delta^P + (1-T)\Delta^D + F + (1-\beta)\{(1-T)(\Delta^P - \Delta^D) - F\}] & \text{if } (16) \wedge (17), \\ \pi^D & \text{if } \sim(16), \end{cases}$$

In redesign states, the joint surplus of the two firms is maximized when the patent holder excludes the downstream firm from using the patented feature. With this consideration, we consider the following three distinct cases in turn. Case (i): if equation (16) holds but (17) does not, the patent holder captures the full extra surplus that it would expect to obtain from the litigation. Case (ii): if both equation (16) and (17) hold, ex-ante negotiations are successful due to the relatively high litigation costs. The patent holder and the downstream firm agree on avoiding the litigation costs in this case. However, the patent holder loses the opportunity to obtain a permanent injunction, as represented by the second line in the square bracket in equation (18). Case (iii): if equation (16) does not hold, the patent holder cannot expect any extra surplus from litigation.

The patent holder's payoff would be highest without patent strength discounting and patent damage discounting. However, even in such a case, the patent holder's payoff is only equal to or less than the benchmark payoff.

Proposition 2.

In redesign states, the patent holder earns the benchmark payoff, i.e., $\Pi^P = \Pi^{P|BM}$ if there is no patent strength discounting and patent damage discounting, and if either the patent holder's litigation costs are zero or the underlying nature of licensing negotiations is on the boundary of the lock-in and redesign states.

Otherwise, the patent holder is under-compensated; i.e., $\Pi^P < \Pi^{P|BM}$.

In sharp contrast to the findings in licensing and lock-in states, there is no concern over patent hold-up in redesign states. These results can be understood as follows. Here, patent strength or patent damage can still be discounted as before. However, the patent holder seeks the injunction not to demand higher royalties but to practice the patented feature exclusively so that some of the redesign cost is no longer captured by the patent holder. Consequently, there is no chance for the patent holder to be over-compensated in redesign states.

Considering the results from Proposition 1 and 2 together, our model shows that patent hold-up problems are worrisome when (i) the redesign process is costly, (ii) patent strength discounting and patent damage discounting are not excessive, and

(iii) an injunction is requested not to exclude the downstream firm from utilizing the patent but to collect excessive patent royalties (i.e., in licensing and lock-in states).[17]

V. Early Negotiation

In this section, we examine the early negotiation model in which P and D engage in ex-ante negotiations before D initially designs its product. As in the previous section, we mainly focus on comparing the patent holder's equilibrium payoff with the benchmark payoff to understand the magnitude of the hold-up (or hold-out).

Because the game proceeds identically to the inadvertent infringement model does beginning the moment P initiates litigation (see Figures 1 and 2), we can refer to the results for such subgames in the previous section. Then, it remains to analyze D's optimal decision regarding the initial product design and the bargaining outcomes during ex-ante negotiations.

If P's litigation threat is not credible, it is always optimal for D to include the patented feature in its product ("do not design around"). In contrast, if P's litigation threat is credible, D has to compare the benefits and costs of not designing around the patented feature. If D does not design around the feature, D will face litigation and ultimately receive $\Pi^{D|suit}$, as defined in Lemma 2. If D excludes the feature ("design around"), D ultimately receives $\pi^D - \Delta^D$. Therefore, D's optimal decision regarding the initial product design is described below.

Lemma 5.
If the patent holder's litigation threat is not credible (equation (11) does not hold), the downstream firm never designs arounds the feature. Otherwise, the patent holder does not design around if $\pi^D - \Delta^D < \Pi^{D|suit}$ and does design around it otherwise ($\pi^D - \Delta^D \geq \Pi^{D|suit}$).

During ex-ante negotiations, the disagreement payoffs depend on D's decision regarding the initial product design. If D still wants to include the patented feature even after the failure of the negotiations, the equilibrium outcomes coincide with those either in Proposition 1 or Proposition 2. Otherwise, the disagreement payoffs of P and D are respectively expressed as $\pi^P + \Delta^P$ and $\pi^D - \Delta^D$. Then, it becomes immediately necessary to characterize the equilibrium of the early negotiation model as follows. We correspondingly denote the equilibrium payoffs to P and D in the early negotiation model as $\tilde{\Pi}^P$ and $\tilde{\Pi}^D$.

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[17]Even if Propositions 1 and 2 have important implications with regard to enforcement intensity, as represented by unobservable variables in our model, one can think of a testable hypothesis regarding these propositions when there is a policy change that strengthens patent protection. For example, assuming that the downstream firm's investment level is positively correlated with its expected payoff, one can test whether the investment levels of downstream firms change differently depending on other variables related to the magnitude of the hold-up problems (for example, the levels of the redesigning costs) with such a policy change. However, conducting such an empirical analysis may not be an easy task for the following reason. In many circumstances, it is challenging to classify firms exclusively into two categories, i.e., upstream or downstream firms, making it difficult to find a proxy variable that can feasibly measure the degree of the patent hold-up.

Proposition 3.
If the downstream firm does not design around after the ex-ante negotiations break down, the equilibrium is then characterized as in Proposition 1 in licensing and lock-in states or as in Proposition 2 in redesign states. If the downstream firm designs around, (i) ex-ante negotiations are successful when $\Delta^D \geq \Delta^P$, during which the equilibrium payoffs to the two firms are respectively $\tilde{\Pi}^P = \pi^P + \Delta^P + \beta(\Delta^D - \Delta^P)$ and $\tilde{\Pi}^D = \pi^D - \Delta^D + (1-\beta)(\Delta^D - \Delta^P)$ and (ii) break down when $\Delta^P > \Delta^D$, at which point the equilibrium payoffs to the two firms are respectively $\tilde{\Pi}^P = \pi^P + \Delta^P$ and $\tilde{\Pi}^D = \pi^D - \Delta^D$.

The patent hold-up problem can arise even in the early negotiation model. If the two firms expect that D will utilize the patent after the failure of current negotiations, the patent holder can be over-compensated by the threat of an injunction, as demonstrated in the previous model.

However, in the opposite case, the two firms expect that a breakdown in ex-ante negotiations does not lead to D's infringement on P's patent. Therefore, the payoffs to the two firms are irrelevant with regard to the redesign costs, and there is no scope for the patent hold-up problem associated with an injunction. Nonetheless, the patent holder's payoff can still be excessive unless the patent strength is equal to one. To observe this, note that

$$(20) \qquad \tilde{\Pi}^P - \Pi^{P|BM} = (1-\theta)[\Delta^P + \beta \max\{\Delta^D - \Delta^P, 0\}] \geq 0.$$

These excessive payoffs result not from the threat of an injunction but from the probabilistic nature of patents. Here, the downstream firm does not want to incur the risk of going to court and thus relinquishes the chance to fight for the invalidation of the patent or to defend against the infringement allegation. The weaker the patent strength is, the greater the hold-up component of the patent holder's payoff becomes.[18]

The exact condition under which D designs around is given in the appendix, but we illustrate how this condition changes depending on the patent strength and the underlying nature of licensing in Figure 5. In each panel, there is a graph which delivers information similar to that in Figure 4. In the region to the upper right of the thick solid curves, the patent holder is over-compensated. Similarly, in the region to the upper right of the short dashed curves, the patent holder's litigation threat is credible. The newly added long dashed (blue) curve represents the points at which D is unvarying with regard to redesigning or not redesigning. In the region to the upper right of those curves, designing around is optimal for D. As shown in Figure 5, a weaker patent strength means less room for designing around. Going through a similar exercise, we can also find that weaker bargaining power by the patent holder

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[18]Shapiro (2010) also describes the same finding. There can potentially be other social costs associated with probabilistic patents. Many other studies have explored these issues from various angles. For example, Farrell and Shapiro (2008) study the welfare implications of licensing of probabilistic patents to multiple firms when the redesign process is neither time-consuming nor costly.

or a longer duration of litigation will lead to less room for designing around.

We can also check when patent hold-out (or reverse patent hold-up) tends to occur in Figure 5. Patent hold-out refers to a situation in which downstream firms intentionally ignore patents or refuse royalty negotiations to use those patents at lower royalty rates or for free. In our model, the hold-out problem arises when the patent holder's payoff is less than the benchmark level. In Figure 5, this corresponds to the region to the lower left of both of the following two curves: those represented by thick solid lines and those indicated by long dashed lines. This finding implies that patent hold-out problem can prevail when the degree of patent protection is not sufficiently strong.
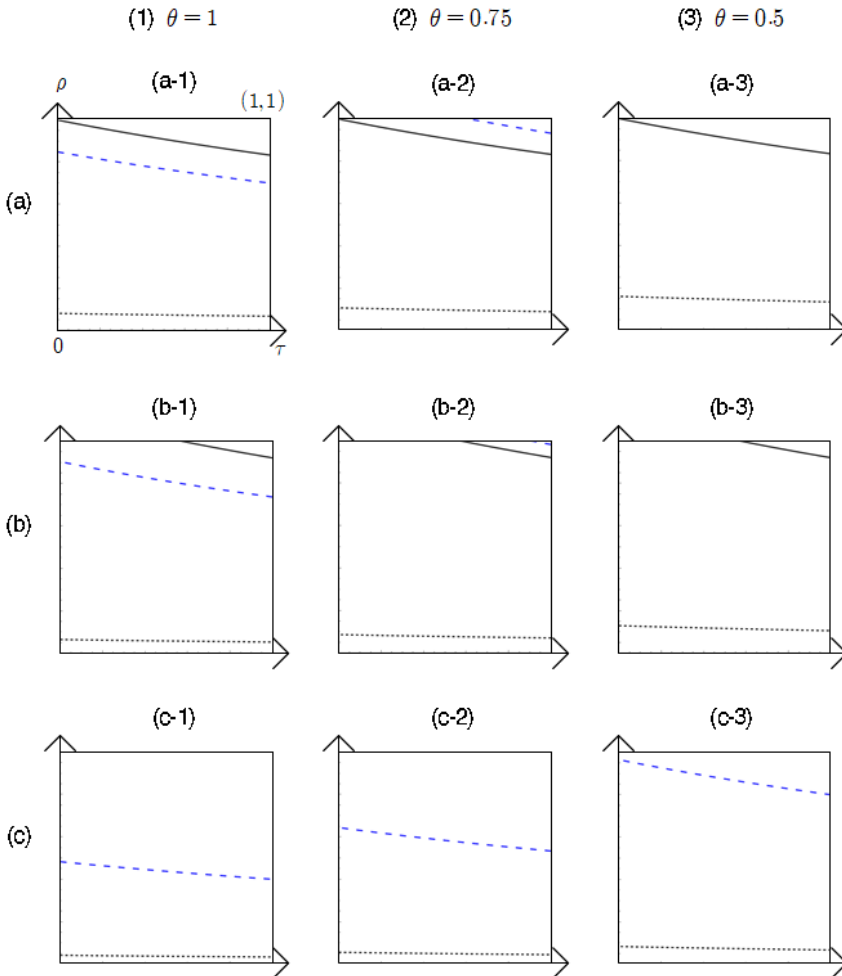
FIGURE 5— EXAMPLE EQUILIBRIUM OUTCOMES IN THE EARLY NEGOTIATION MODEL

Note: In each panel, the horizontal axis represents the degree of patent damage discounting and the vertical axis represents the degree of patent strength discounting. In this example, parameter values were set such that rows (a), (b) and (c) correspond to the licensing, lock-in and redesign states, respectively. More specifically, $\Delta^D = 30$, $F = 10$, $T = 0.2$ and $\Delta^P = 20$ in rows (a), 35 in (b) and 60 in (c). The patent strength is set to 1 in column (1), to 0.75 in (2) and to 0.5 in (3). All other parameter values are set as follows: $\beta = 0.5$, $L^P = L^D = 2$.

We can also compare the results in the previous model (inadvertent infringement model) and those in the current one (early negotiation model) to observe how the patent holder's payoff is affected when D has the opportunity to decide whether or not to design around before the initial negotiation between the two firms. Depending on the parameter values, the results can differ. When the patent strength equals one, the patent holder's payoff is equal to the benchmark level given that designing around is optimal for D. Therefore, there is a possibility that the problem of under-compensation or over-compensation for the patent holder in the previous model can be corrected in the current model (the region to the upper right of the long dashed curve in panels (a-1), (b-1) and (c-1)). However, when the patent strength is less than one, the level of over-compensation can be switched to another level (the region to the upper right of the long dashed curve in panels (a-2) and (b-2)), or the under-compensation problem can be overturned to the over-compensation problem (the region to the upper right of the long dashed curve in panels (c-2) and (c-3)). As stated earlier, patent hold-up associated with D's designing around strategy is not directly related to the threat of an injunction

VI. Policy Implications

Thus far, we have mainly examined how and under which conditions the threat of an injunction results in the patent hold-up problem. From the results in the previous section, we can infer that if policymakers endeavor to improve the degree of patent protection, patent hold-ups may be prevalent in the near future, though this is not the case thus far. Accordingly, it may be beneficial to contemplate in advance applicable alternative patent remedies in place of an injunction when necessary.

In this section, we briefly discuss such alternative remedies. To this end, here we consider only cases in which the degree of patent protection is strong enough such that patent the hold-up issue may be worrisome. In other words, we consider only cases in which τ and ρ are close to 1 in our model.

The most basic alternative remedy conceivable here is the awarding of "ongoing royalties." This remedy allows the downstream firm to continue to infringe on the asserted patent as long as the downstream firm pays ongoing royalties set by the court onwards. In fact, the ongoing royalties remedy is in force in patent litigation in the U.S., specifically after the *eBay v. MercExchange* case.

To observe how the ongoing royalties remedy can address the hold-up problem associated with an injunction, we reconsider our model and suppose this time that $\tau = \rho = 1$, with the court setting the ongoing royalty rate to r^{BM}. The following proposition shows how the outcomes of ex-post negotiations turn out.

Proposition 4.

Suppose that the degree of patent protection is perfect, i.e., $\tau = \rho = 1$, and that the court orders the downstream user to pay ongoing royalties at the royalty rate of r^{BM} instead of granting an injunction when the patent holder wins the litigation. In this case, the downstream firm chooses to pay ongoing royalties if

(21)
$$\Delta^P \le \Delta^D + \frac{F}{1-T}.$$

and to redesign its product otherwise. The payoff to the patent holder during ex-ante negotiations is

(22)
$$\Pi^{P|ex-post} = (1-T)[\pi^P + \Delta^P + \beta \max\{\Delta^D - \Delta^P, 0\}].$$

If we compare this case with one in which the court grants an injunction as a matter of course, we find that the conditions under which the downstream firm does not have to redesign its product (see equations (21) and (4)) remain the same. However, when comparing the patent holder's payoffs, we find a distinct difference. Under the ongoing royalty regime, the patent holder no longer captures a part of the redesign costs (see equations (22) and (7)). Therefore, the patent hold-up problem caused by the threat of an injunction disappears when we switch to the ongoing royalty regime.

One caveat to the above finding is that it was derived assuming that the degree of patent protection is perfect. If the degree of patent protection is strong enough but still not perfect, the patent holder is under-compensated under the ongoing royalty regime.

Practically, the court has to bear slightly more of a burden by setting a fair ongoing royalty rate. Of course, because the court has to award patent damages for the prior infringement even under the (as-a-matter-of-course) injunction regime, one simple approach is to match the ongoing royalty rate to the reasonable royalty rate calculated for awarding patent damages. This approach would work well if underlying market conditions are stable over time, as in our model. If market conditions are expected to change significantly, however, the ongoing royalty rate must be adjusted accordingly.

Nevertheless, it is almost certain that the ongoing royalty remedy should be the backbone of alternative remedies because it is not only relatively easy to implement but also considering that the other remedies discussed below are basically a mixture of the ongoing royalty remedy and some other means. It will be valuable to learn lessons from the US experience[19] and accumulate more research[20] on how properly to set patent royalty rates from a practical perspective.

We also introduce two hybrid types of remedies suggested and briefly discussed by Shapiro (2017) in turn. The first is to grant an "injunction with a ban on licensing." Under this remedy regime, the court allows the patent holder to choose between two remedies: ongoing royalties or an injunction order with an additional court order precluding the patent holder from engaging in licensing negotiations with the downstream firm.

Under the same assumption that the degree of patent protection is perfect, let us see how the ex-post (litigation) payoff to the patent holder is determined under this remedy regime in our model. If the patent holder chooses to obtain the modified injunction, the ex-post payoff to the patent holder is simply $(1-T)(\pi^P + \Delta^P)$. On

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[19]For example, see Lemley (2011) and Sidak (2016).
[20]Some existing studies in Korea on this topic include that by Chang (2017).

the other hand, if the patent holder opts for paying ongoing royalties, the ex-post payoff is expressed as equation (22). The patent holder prefers the ongoing royalty remedy in the licensing states and is indifferent between the two remedies in the lock-in and redesign states. Therefore, the patent holder's payoff remains the same, as before (equation (22)), which implies that this modified injunction remedy can handle patent hold-up problems.

In fact, this remedy is likely to perform better than the ongoing royalty remedy in some circumstances. Even if the degree of patent protection is strong enough but still not perfect, the patent holder can be fairly compensated at least when $\Delta^P > \Delta^D$ such that the patent holder prefers to obtain a modified injunction over ongoing royalties. Furthermore, this remedy causes the patent holder to self-select the more preferred prospective remedy of the two, which can be a substantial merit when the court does not have enough information about the underlying nature of licensing negotiations or market conditions.

Despite the above advantages, there are a few factors that we also need to deliberate on from a practical viewpoint prior to the implement of this remedy. For this remedy to work as intended, the court should be able to ensure that the two firms do not engage in licensing negotiations after the injunction order. If this is not possible, the introduction of certain punishment measures for such negotiations should be considered.

The second hybrid type of remedy is "ongoing royalties followed by an injunction." Under this remedy regime, the court postpones the time at which the injunction goes into effect and allows the downstream firm to pay ongoing royalties until that time.

We determine how the patent ex-post payoff turns out under this remedy regime as well. In addition to the same assumptions used in the two previous cases, we also assume that the injunction order goes into effect at $T + t$ and the redesign costs are reduced to $f < F$ at that time. Because only the timing of the negotiations is delayed slightly, the patent holder's ex-post payoff can be expressed as

$$(23) \quad \Pi^{P|ex-post} = \\ (1-T)\pi^P + t\tau r^{BM} + (1-T-t)\Delta^P \beta \max\{(1-T-t)(\Delta^D - \Delta^P) + f, 0\}.$$

This remedy will fairly compensate the patent holder well when the degree of patent damage discounting is nil, and the redesign costs can be reduced in a short time interval. Another merit of this remedy, though scarcely considered in our model, is that the remedy will allow the downstream firm to escape a considerable loss from not being able to sell its product even if the redesign process is lengthy. However, for this remedy to perform as intended, the court should be able to make a proper decision regarding how long to delay the implementation of the injunction order. At the same time, setting a fair ongoing royalty rate is also a prerequisite for this remedy to perform well.

VII. Concluding Remarks

This paper analyzes how injunctions relate to a patent holder's payoff when the patent remedy system may not provide enough protection for the patent holder due to aspects other than injunctions. By comparing that payoff to the benchmark payoff, we identify conditions under which patent hold-up problems associated with an injunction arise.

We show that if the downstream user is unaware of the patent before any investment when initially designing its product, patent hold-up problems created by injunction threats are worrisome when (i) the redesign process is costly, (ii) patent strength discounting and patent damage discounting are not excessive, and (iii) an injunction is requested not to exclude the downstream firm from utilizing the patent but to collect excessive patent royalties. Even if the downstream user is aware of the patent before the initial investment, patent hold-up problems do not disappear.

Our results imply that a discretionary approach is required with regard to denying injunctions against patent infringement. If the degree of patent protection is not sufficiently strong, denying injunctions can exacerbate the under-compensation problem. Thus, it may be at least temporarily desirable to allow the patent holder to request an injunction as leverage for collecting excessive patent royalties. However, once patent protection improves enough (not necessarily perfectly), we may see a surge of the patent hold-up problems. In such cases, it would be better to apply the alternative patent remedies discussed in section VI when necessary. Because all of the alternative remedies are at least partly based on the ongoing royalty remedy, it is important to accumulate more knowledge on how properly to set the patent royalty rate from a practical perspective in advance.

This paper only considers patent license negotiations between a single patent holder and a single downstream firm. Thus, one avenue for future research is to check whether our results carry over to more complex patent license settings. For example, in a model where one product potentially infringes on many patents owned by multiple patent holders, it would be interesting to investigate if our results change substantially depending on whether the related patents are substitutes or complements or whether license negotiations take place simultaneously or sequentially. Another meaningful future research agenda would be to explore more explicitly how patent hold-ups associated with injunctions change the intensity of innovation activities or the compositions of innovation projects pursued by both patent holders and downstream users.

APPENDIX

Proof of Lemma 2.

Until the final court decision is made, both firms will utilize the patent and earn $T\pi^P$ for that period. If the patent holder loses the litigation, it earns $(1-T)\pi^P$ for the remaining period. If the patent holder wins, it earns $T\tau r^{BM} + \Pi^{P|ex-post}$. Because the probability that P wins the litigation is $\lambda = \rho\theta$, the expected payoff for P from filing a suit is given by

$$(A\text{-}1) \quad \Pi^{P|ex-post} = T\pi^P + \rho\theta(T\tau r^{BM} + \Pi^{P|ex-post}) + (1-\rho\theta)(1-T)\pi^P - L^P.$$

Plugging equation (7) into (A-1) and rearranging the terms yield equation (9). In a similar way, equation (10) can be obtained. *Q.E.D.*

Proof of Lemma 3.

It is obvious that if the patent holder's litigation threat is not credible, P and D's payoffs are π^P and π^D, respectively.

At this point, we consider the case in which the patent holder's litigation threat is credible. In the licensing and lock-in states, equation (11) can be written as equation (12). Because in this case the two firms always sign a licensing agreement during ex-post negotiations, the joint surplus does not change, but the two firms must pay litigation costs. To avoid these costs, they always sign a licensing agreement during ex-ante negotiations. Therefore, the patent holder's payoff in this case equals

$$(A\text{-}2) \qquad\qquad \Pi^P = \Pi^{P|suit} + \beta(L^P + L^D).$$

By substituting equation (9) in licensing and lock-in states for $\Pi^{P|suit}$, we obtain equation (13). The payoff to the downstream firm can be obtained in a similar manner. *Q.E.D.*

Proof of Proposition 1.

Here, we only offer the proof in lock-in states, but the proof in licensing states is similar. Note that $\Delta^D + \dfrac{F}{1-T} \geq \Delta^P \geq \Delta^D$ in lock-in states. Therefore, the patent holder's payoff and the benchmark payoff are given by

$$(A\text{-}3) \qquad \Pi^P(\tau,\rho) = \pi^P + \rho\theta[T\tau\Delta^P + (1-T)\{\Delta^P + \beta(\Delta^D - \Delta^P) + \beta F\}]$$

$$(A\text{-}4) \qquad\qquad \Pi^{BM} = \pi^P + \theta[\Delta^P + \beta(\Delta^D - \Delta^P)]$$

Because the following equations are true,

(A-5)
$$\frac{\partial \Pi^P}{\partial \tau} = \rho \theta T \Delta^P > 0$$

(A-6)
$$\frac{\partial \Pi^P}{\partial \rho} = \theta[T\tau\Delta^P + (1-T)\{\Delta^P + \beta(\Delta^D - \Delta^P)\} + \beta F] > 0$$

(A-7)
$$\frac{\partial^2 \Pi^P}{\partial \tau^2} = 0, \ \frac{\partial^2 \Pi^P}{\partial \rho^2} = 0$$

(A-8)
$$\frac{\partial^2 \Pi^P}{\partial \tau \partial \rho} = \theta T \Delta^P > 0$$

the payoff function to the patent holder is increasing and concave in its arguments.

Using the properties of $\Pi^P(\tau, \rho)$, we now investigate the properties of E. E is a level set on the $\tau\rho$-plane such that $\Pi^P(\tau, \rho) = \Pi^{BM}$. Given that

(A-9)
$$\frac{d\rho}{d\tau} = -\frac{\dfrac{\partial \Pi^P}{\partial \tau}}{\dfrac{\partial \Pi^P}{\partial \rho}} < 0$$

and Π^P is concave, E must have the form of a decreasing convex curve on the $\tau\rho$-plane. Next, we check that E lies within $[0,1]^2$, as shown in Figure 4. To this end, we define a new function $\phi(\tau, \rho) \equiv \Pi^P - \Pi^{BM}$ and then check the signs of ϕ on the four vertexes of the square of $[0,1]^2$.

(A-10)
$$\phi(0,0) = -\theta\{\Delta^P + \beta(\Delta^D - \Delta^P)\} < 0$$
$$\phi(1,0) = -\theta\{\Delta^P + \beta(\Delta^D - \Delta^P)\} < 0$$
$$\phi(0,1) = \theta\beta F - \theta T\{\Delta^P + \beta(\Delta^D - \Delta^P)\}$$
$$\phi(1,1) = \theta\beta F + \theta\beta T(\Delta^P - \Delta^D) > 0$$

Because $\phi(1,0)$ is negative, $\phi(1,1)$ is positive and ϕ is continuous in ρ, there exists a unique $\rho^* \in (0,1)$ such that $\Pi^P(1, \rho^*) = \Pi^{BM}$. Meanwhile, as the sign of $\phi(0,1)$ is not deterministic, E can take two different forms, as shown in Figure 4. If

(A-11)
$$\phi(0,1) > 0 \Leftrightarrow F > T\{\Delta^P / \beta + (\Delta^D - \Delta^P)\},$$

there exists a unique $\rho^{**} \in (0,1)$ such that $\Pi^P(1, \rho^{**}) = \Pi^{BM}$, which corresponds to panel (b). In contrast, if

(A-12) $\phi(0,1) < 0 \Leftrightarrow F < T\{\Delta^P / \beta + (\Delta^D - \Delta^P)\}$,

there exists a unique $\tau^* \in (0,1)$ such that $\Pi^P(\tau^*,1) = \Pi^{BM}$, which corresponds to panel (a). It is clear that the patent holder is over-compensated in the region to the upper right of curve E because Π^P is increasing in τ and ρ.

Lastly, we show that the region in which P's litigation threat is not credible is a subset of the region in which P is under-compensated. The litigation threat is credible if $\Pi^P - \pi^P \geq L^P \Leftrightarrow \Pi^P \geq \pi^P + L^P$. Then, it follows that the above statement is true because $\Pi^{BM} \geq \pi^P + L^P$ according to Assumption 3. *Q.E.D.*

Proof of Lemma 4.

In redesign states, i.e., $\Delta^D + \dfrac{F}{1-T} < \Delta^P$, $r^{BM} = \Delta^P$, which implies that equation (11) is the same as equation (16). If equation (16) does not hold, it is easy to see that $\Pi^P = \pi^P$, and it thus remains to investigate the opposite case.

If equation (16) holds, the disagreement payoffs to the patent holder and the downstream firm are

(A-13)
$$\Pi^{P|suit} = \pi^P + \rho\theta[1 - (1-\tau)T]\Delta^P - L^P,$$
$$\Pi^{D|suit} = \pi^D - \rho\theta[T\tau\Delta^P + (1-T)\Delta^D + F] - L^D,$$

respectively. There are gains from trade if and only if $\pi^P + \pi^D \geq \Pi^{P|suit} + \Pi^{D|suit}$. Using (A-13) and rearranging the terms, equation (17) can be obtained. Therefore, if equation (17) holds, ex-ante negotiations are successful and

(A-14)
$$\Pi^P = \Pi^{P|suit} + \beta(\pi^P + \pi^D - \Pi^{P|suit} - \Pi^{D|suit})$$
$$= \pi^P + [\{1 - (1-\tau)T\}\Delta^P - \beta\{(1-T)(\Delta^P - \Delta^D) - F\}] + \beta L^D - (1-\beta)L^P.$$

Because we assume that the redesign costs are neutral, equation (A-14) coincides with the second line in equation (18). If equation (17) does not hold, the patent holder earns its disagreement payoff such that $\Pi^P = \Pi^{P|suit}$, which is the first line in equation (18).

The method used to determine the equilibrium payoff of the downstream firm is similar. *Q.E.D.*

Proof of Proposition 2.

We show that $\Pi^P \leq \Pi^{BM}$ in all three possible cases; (i) if equation (16) holds but (17) does not hold,

$$(\text{A-15}) \qquad \Pi^P - \Pi^{P|BM} = -\theta[1 - \rho\{1 - (1 - \tau)T\}]\Delta^P - L^P.$$

Thus, $\Pi^P = \Pi^{P|BM}$ only when $\tau = \rho = 1$ and $L^P = 0$, and $\Pi^P < \Pi^{P|BM}$ otherwise. (ii) If both equation (16) and (17) hold,

$$(\text{A-16}) \quad \Pi^P - \Pi^{P|BM} = -\theta[\{1 - \rho(1 - (1 - \tau)T)\}\Delta^P + \rho\beta\{(1 - T)(\Delta^P - \Delta^D) - F\}].$$

Thus, $\Pi^P = \Pi^{P|BM}$ only when $\tau = \rho = 1$ and $(1 - T)(\Delta^P - \Delta^D) - F = 0$, and $\Pi^P < \Pi^{P|BM}$ otherwise. (iii) If equation (16) does not hold, clearly $\Pi^P = \pi^P < \Pi^{P|BM}$. *Q.E.D.*

Proof of Lemma 5 and Proposition 3.

From the results derived in section III and the discussion in section IV, it is straightforward to derive the results in Lemma 5 and Proposition 3. That being so, we only present the conditions under which the downstream firm chooses to design around the feature. Designing around is optimal (i) if equation (12) and

$$(\text{A-17}) \qquad \rho\theta[\{1 - (1 - \tau)T\}\Delta^P + \beta F] + L^D > [1 - \rho\theta\beta\{1 - (1 - \tau)T\}]\Delta^D$$

hold in licensing states, (ii) if equation (12) and

$$(\text{A-18}) \qquad \rho\theta[\{1 - \beta - (1 - \beta - \tau)T\}\Delta^P + \beta F] + L^D > [1 - \rho\theta\beta(1 - \tau)]\Delta^D$$

hold in lock-in states, and (iii) if equation (16) and

$$(\text{A-19}) \qquad \rho\theta[T\tau\Delta^P + F] + L^D > [1 - \rho\theta(1 - T)]\Delta^D$$

hold in redesign states. *Q.E.D.*

Proof of Proposition 4.

The court sets the ongoing royalty rate to $r^{BM} = \Delta^P + \beta\max\{\Delta^D - \Delta^P, 0\}$. Therefore, the downstream firm's marginal loss from paying the ongoing royalties is equal to $(1 - T)r^{BM}$ for the remaining period. In contrast, the marginal loss from

redesigning is equal to $(1-T)\Delta^D + F$. The downstream firm redesigns if the former marginal loss is greater than the latter, and pays the ongoing royalties otherwise. In cases such that $\Delta^P \leq \Delta^D$, $r^{BM} = \Delta^P + \beta(\Delta^D - \Delta^P)$. Thus,

(A-20)　　　　$(1-T)\{\Delta^P + \beta(\Delta^D - \Delta^P)\} \leq (1-T)\Delta^D < (1-T)\Delta^D + F,$

which implies that the downstream firm would pay the ongoing royalties in this case. If we investigate the remaining cases ($\Delta^D \leq \Delta^P \leq \Delta^D + \dfrac{F}{1-T}$ and $\Delta^D + \dfrac{F}{1-T} \leq \Delta^P$) in a similar way, it is straightforward to conclude that the downstream firm's optimal decision is characterized as stated in Proposition 4. It is also straightforward to derive the patent holder's payoff based on the above result; accordingly, we omit the details of the derivation. *Q.E.D.*

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Adopting Local Languages as Official Languages: Effect on Women and Rural Individuals' Labor Force in Burkina Faso†

By SOULEYMANE YAMEOGO*

This study investigates the impact of the use of the main local languages in Burkina Faso (Moore, Dioula, Fulfulde) on labor force participation. Using Ethnologue language data, I compute the relative language distance reduction index, after which I use a probit/logit model and instrumental variable approach to account for language use policy endogeneity. This study finds that the use of the Moore language increases the likelihood of labor force participation by 36 percent, with a strong impact on women at 59 percent, nine times higher than men, and 38.3 percent for rural individuals, five times higher than individuals living in urban areas. The Dioula language exhibits comparable trends, while Fulfulde has a negative impact on individuals. The study recommends the use of local language(s) as official language(s) to improve labor force participation. However, a bilingual approach combining local and international language(s) will be of use to account for globalization and international competitiveness. The findings here may be of use to researchers and policymakers as part of their effort to increase the labor force participation rates of women and rural individuals. Moreover, this research has significant implications with regard to the implementation of language use policies in a variety of postcolonial language contexts.

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I. Introduction

Language-related human capital matters in that is affects individuals' socioeconomic outcomes (Isphording, 2014; Seid, 2017). Language is a means of communication between individuals, allowing interaction and strengthening the social fabric. From a sociolinguistic perspective, a language is a vehicle of national identity and cultural identification. That is why language use policy has been a very sensitive issue throughout time and within countries (Hamel, 2013; James and Lambert, 2009; Yameogo, 2019). Why is language use policy so important? Language issues are important: first, for multicultural and multilingual countries that seek to implement a language use policy in their country, taking into account ethnic diversity and sometimes different antagonisms between ethnic groups. Second, for monolingual countries, such as South Korea, which use their mother-tongue as the official language, while also implementing an international language as a second official language for international competitiveness, and economic purposes is necessary (Chang, 2018; Lee, 2018). Finally, for immigrants who must learn the host country's language to ease integration and participate efficiently in the labor market (Dustmann and Fabbri, 2003). For these and other reasons, the importance of language affects many aspects of life and is straightforward.

Over the past few years, a growing body of work has closely investigated the impact of language skills on individuals' outcomes, and economic growth (Hall and Jones, 1999; Crystal, 2003; Chong, Guillen, and Rios, 2009; Lee, 2012; Laitin and Ramachandran, 2014; 2015; Seid, 2017; Chang, 2018; Di Paolo and Tansel, 2019; Yameogo, 2019). These studies shed light on the importance of language not only for economic growth but also for individual-level outcomes. Although most of these studies find that language proficiency is a key determinant of country-level or individual-level outcomes, they only focused on the use of English as an international lingua-franca. Many of them failed to take into account single country characteristics, such as a country's local languages in a multilingual country and the ability of individuals in the country to speak English or any other international languages and how this may affect the country's overall efficiency. Laitin *et al.* (2014; 2015) provide an interesting framework with which to analyze the relationship between local languages and economic outcomes in multilingual countries by computing an index, known as the language distance between two languages. Using this index, I investigated the relationship between the official languages used in African countries and their impact on industrialization in Africa (Yameogo, 2019). I found a negative, significant and strong impact of the non-indigenous languages when they are used as the official languages on African industrial performance outcomes. If these studies helped us to understand the impact of non-indigenous languages on economic outcomes, apart from Laitin *et al.* (2014; 2015), none of them have yet to predict the impact of the use of local languages on individuals' outcomes, and how the local language use policies may affect the entire society. This study seeks to address this research gap and provide a firm foundation on which to study the socioeconomic effects of adopting a local language as a national language. Although the focus of this study is Burkina Faso, the findings here may be generalized and applicable to other contexts. Certainly, the methodological

approach taken in this paper can be applied to other language groups. The relative language distance change index developed in this study can be computed for all language groups.

This article seeks to extend the reach of previous studies by providing empirical evidence of the importance of using the local language(s) as the official language(s) in the labor market in Burkina Faso. For this purpose, the article presents the following questions: how will the use of one or more local language(s) spoken in Burkina Faso, instead of French, as the official language affect individual access to the labor market, particularly for women and rural individuals? Because Burkina Faso has more than 60 different ethnic groups, how will the choice of the official language(s) be made and how could this choice reinforce the social fabric instead of tearing it? What initial condition(s) should be met to allow the development of a sound local language use policy in Burkina Faso?

To answer these important questions, I hypothesize that (1) the use of local language(s) as the official language, because it will reduce the language distance between the chosen official language(s) and other local languages, will have a positive effect on labor force participation in Burkina Faso; (2) given that most local languages belong to the Niger-Congo language family, the choice of the official languages should be based on the magnitude of the impact of each language on access to the job market and the proportion of individuals speaking the local language(s); (3) local language use policymakers in Burkina Faso could conduct deep institutional reforms in the country to reinforce the trust between ethnic groups and encourage and incentivize exogamy (marriage between different ethnic groups) to increase interaction between ethnic groups at all levels. Additionally, the use of French and English in early childhood education will improve proficiency, as long-term exposure to only one's mother tongue can hinder foreign language learning and proficiency acquisition (Isphording, 2014; Seid, 2017). To the best of my knowledge, no previous studies have attempted to predict the outcome of the use of a local language as the official language in Burkina Faso, nor indeed in most African countries. Accordingly, this study will provides researchers and policymakers with an empirical framework to develop a sound and useful language use policy in Burkina Faso and in other multilingual countries looking to implement such a policy.

This article utilizes a logit method with data from IPUMS and the language family classification from Ethnologue (Lewis, 2009); the study also uses labor force participation data from Burkina Faso for individuals between 15 and 64 years old as a dependent variable, with the relative language distance reduction as the main variable of interest. Furthermore, to account for potential endogeneity and measurement error in the language use policy, an instrumental variable approach is adopted.

The remainder of this article is structured as follows: the next section discusses theoretical and empirical studies of languages and labor force participation; section 3 presents the empirical strategy, section 4 the findings and discussion, and section 5 the summary as well as recommendations related to this study.

II. Language Distance, Labor Market Institutions, and Economic Outcomes

A. *Institutions and Economic Outcomes*

Institutions matter (North, 1991; Acemoglu, Johnson, and Robinson, 2005; Acemoglu and Robinson, 2012). Since the study of North (1991), institutions have gained importance and the roles played by institutions in explaining socioeconomics outcomes have become a matter of debate. Indeed, the contentious debate between those holding institutionalist and distortionist views about the roles and places of institutions are ongoing. For institutionalists, institutions are important because they reduce transaction costs, allow equity in the distribution of revenue, moderate crises and protect economic agents (e.g., workers, investors). Conversely, for distortionists, "institutions impede economic efficiency" (Betcherman, 2013, p.3). Betcherman (2013) highlighted the main difficulties in considering the impact of institutions on socioeconomic outcomes. The first problem is how to measure institutions, as they are qualitative entities and measurement error can easily occur. The second problem relates to the endogeneity of institutions given that they can affect socioeconomic outcomes through local average effects of certain other factors. With regard to such cases, Betcherman (2013) argues that the effects of institutions may be ambiguous and hence not directly captured. These problems related to institutional variables have also been discussed by Thomas (2010), who reached the conclusion that researchers should use institutional variables, particularly, World Governance indicators, cautiously when drawing policy recommendations. Surely, we are far from the day economists reach a unanimous position on how best to measure institutions and how to present compelling results. Betcherman (2013), however, recognizes that the use of new empirical methodologies can help to resolve the problems mentioned above and that sound results can be obtained with these new tools. In the same vein, Portes (2006) argued that institutions are important for fostering growth, though the concept of an institution remains complex and economists should work closely with sociologists and historians for a better understanding of what institutions really are. Despite these controversies, one can agree with North (1991) that institutions matter and that countries which exhibit high economic performance are those which have good institutions (Acemoglu *et al.*, 2005; Acemoglu and Robinson, 2012). The next question to ask is how labor market institutions affect socioeconomic outcomes.

Labor market institutions play a key role in the functioning of labor markets. According to Betcherman (2013, p.2), the "laws, practices, policies, and conventions that fall under the umbrella of 'labor market institutions' determine inter alia what kind of employment contracts are permissible; set boundaries for wages and benefits, hours, and working conditions; define the rules for collective representation and bargaining; proscribe certain employment practices; and provide for social protection for workers." This definition clearly highlights formal institutions, instead of informal institutions, which are the "invisible" unobservable values and norms and culture and social ties that have a deep impact on economic outcomes. It clearly appears that while previous studies demonstrated the importance of institutions on

labor markets or on the overall economy, most failed to provide an in-depth analysis of the importance of informal institutions, considered by North (1991) to be much more important than formal institutions. Betcherman (2013) also recognized that informal institutions are not well investigated; hence one cannot assess how informal institutions affect the labor market. However, language-related human capital, an informal institution, is said to play a key role in economic growth and individuals' socioeconomic outcomes.

B. *Language and Labor Force Participation*

The languages spoken by a community or ethnic groups in a given geographical region play a crucial role in enabling interactions between individuals. Most importantly, language is said to foster individuals' creativity and to strengthen their national identity. In contrast, when a society fails to keep its identity, it leads to acculturation by individuals. Diop (1974) and Thiong'o (1986) used the concept of cultural alienation to qualify the situation that arises in African countries when they use foreign language(s) too distant to the most commonly spoken local languages. They argue that it is difficult and even impossible for Africans to innovate and develop their creativity because they are not thinking in a language which captures their reality, their environment, and their history. This can explain why the authors supported the argument that "decolonizing the mind" is the key to improve individuals' creativity and efficiency. In the same vain, Chong *et al*. (2009) find that "commonality in spoken language elicits cultural identification" (p.2), with cultural affinity reflected in the strengthening of the social fabric. A society or community where this exists thus exhibits a high level of trust. The resulting effects of high trust among individuals are low transaction costs and fewer disputes, helping "operate markets and other economic and social institutions" (Chong *et al*. 2009, p.3). The link between language and economic performance through the effect of trust is interesting and may explain the low economic performance of African countries (Nunn and Wantchekon, 2011). Nunn and Wantchekon (2011) find that the slave trade has created high mistrust among ethnic groups in Africa and has led to low economic growth.

Language-related human capital and ethnic fragmentation are informal institutions which play a key role in multilingual countries. Easterley and Levine (1997) and Nunn *et al*. (2011) found, respectively, that ethnic fragmentation has a significant, negative impact on economic growth, and high mistrust within ethnic groups in Africa - due to the slave trade - has a negative impact on current African economic growth. Thus, the relatively weak economic performance of African countries is due to ethnic fragmentation and mistrust among ethnic groups. Therefore, an analysis of the impact of language in a multicultural and multilingual country is crucial. The importance of language use policies has been advocated by history, and countries all over the world have sought to implement language use policies which can ease policy implementation, bolster human capital accumulation, and strengthen the social fabric (James and Lambert, 2009; Záhořík and Teshome, 2009; Laitin and Ramachandran, 2014, 2015; Marwa, 2014; Hamel, 2013; Yameogo, 2019). James and Lambert (2009) presented an insightful historical analysis of language policies in France. They argued that France has approximately 70 ethnic groups and that during the

French Revolution, the French language was imposed on the population. Non-acceptance of the French language was considered to be a denial of French national identity and was severely punished. The French language use policy in France was coercively introduced, and coercive language use policies were also used in Spain under Franco. Thus, non-democratic regimes imposed monolingual language use policies in France and Spain, and debates over language use policies in France and the issue of minorities are still ongoing and strong. James and Lambert (2009) cited a survey that estimated the number of languages spoken in France in 2009 to be 400. In this case, national identity appears to be the main argument for monolingualism. Other countries have different language use policy histories. Hamel (2013) examined language use policies in Latin America. After a coercive attempt to impose an international language (Spanish) on a monolingual basis, Latin American countries had to change their language use policies from monolingual to multilingual considering minorities present within their borders. Hamel's (2013) study sheds light on the ideological and political biases in language use policies. The roles played by elites and politics are crucial for a proper identification of proper language use policies.

An identical situation arose in Ethiopia (Záhořík and Teshome, 2009), where the official language, Amharic, is considered to be the language of the King. However, after 1994 the country found it necessary to consider minorities' will to use their mother tongue in schools. Ethiopia shifted from a monolingual language use policy for Amharic to a multilingual language use policy, with Amharic as the official language and other languages, such as Oromo, as regional languages. Seid (2017), analyzing the use of mother-tongue languages in later labor market outcomes in Ethiopia, finds a statistical and positive relationship. Schooling in the mother tongue increases the likelihood of later labor market participation, with a language use policy favorable to the use of local language providing better outcomes as well. The idea is that individuals with better language skills are likely to have jobs and better wages. Here, one should consider the structure of the labor market of the chosen country; proficiency in a language is conducive to a better employment outcome when this language is the language used in the labor market. If the labor market is controlled by foreign companies, where the use of an international language is mandatory for employment, being proficient in the local language will clearly play a marginal role in accessing the labor market and in some cases may have a negative impact on individual employment. This is the case of Morocco, where Angrist and Lavy (2018) find that the change of the official language from French to Arabic led to reductions in earnings. Therefore, a language use policy is also a labor market reform. This can explain why immigrants must learn the host country's language. Immigrant case studies in the United Kingdom showed that immigrants with proficiency in English are more likely to participate in the labor market than others, as the labor market language is English (Dustmann and Fabbri, 2003). In the same vein, Di Paolo and Tansel (2019) find a positive and significant impact of English proficiency on women's employment in Turkey.

The use of local language(s) may be a barrier to some when they attempt to access the labor market. Indeed, Seid (2017) highlighted the fact that long-term exposure to one mother tongue may hinder the acquisition of proficiency of other national and international languages and may have a negative impact on the labor market for

sectors in which international languages are needed. International competitiveness is reduced and individuals in these situations are less likely to enter the international labor market. Countries such as Burkina Faso have a small private sector, and multinational companies using international languages are dominant; consequently, the shift from French to a local language should take into account international competitiveness. Lee (2018) showed that the South Korean government, although it failed to use English as the second official language (Choe, 2016), implemented English language reforms in order to increase the international competitiveness of Koreans. Therefore, the use of local languages should occur simultaneously with international languages at an early age to simplify make the learning process (Isphording, 2014).

Having highlighted the importance of language in labor force participation and summarized the main ideas in relation to institutions and economic outcomes at the country or individual level, let us now review the empirical strategy used in this study to analyze the impact of the local language use policy in Burkina Faso and its effects on labor force participation.

III. Data analysis and empirical strategy

A. *Overview of Labor Market and Language Issues in Burkina Faso*

Table 1 presents the descriptive statistics of the data. In the dataset, 74.8 percent of the individuals surveyed were in the labor force as of 2006, with 84.3 percent on average having less than a primary school education, 26.1 percent at the primary school education level, 5.3 percent at the secondary school level and 1.97 percent at the university level of education. The labor market in Burkina Faso is dominated by the informal sector, which hires the least educated individuals and pays them lower salaries. Correspondingly, given the difficult access to schooling, numerous individuals must be involved in the labor market while also lacking a higher level of education. The dataset shows that around 72.92 percent of individuals live in rural

TABLE 1— DESCRIPTIVE STATISTICS

	(1)	(2)	(3)	(4)	(5)
Variables	N	mean	sd	min	max
Labor Force Participation	606,701	0.748	0.434	0	1
Relative language distance reduction to Moore	606,701	0.979	0.0400	0.845	1
Relative language distance reduction to Fulfulde	606,701	0.963	0.0296	0.877	1
Relative language distance reduction to Dioula	606,701	0.936	0.0433	0.791	1
Male	606,701	0.457	0.498	0	1
Less than primary school	606,701	0.843	0.363	0	1
Primary school	606,701	0.261	0.674	0	2
Secondary school	606,701	0.0530	0.395	0	3
University	606,701	0.0197	0.280	0	4
Number of children	606,701	1.789	2.169	0	9
Age 15-64	606,701	31.31	12.97	15	64
Living in urban area	606,701	1.271	0.444	1	2

TABLE 2— LABOR FORCE PARTICIPATION BY GENDER IN BURKINA FASO, 2006

Moore	All		Female		Male	
Labor force participation	Total	Percentage	Total	Percentage	Total	Percentage
No	83,520	24%	62,437	34%	21,083	13%
Yes	269,784	76%	131,753	67%	138,031	87%
Dioula	All		Female		Male	
Labor force participation	Total	Percentage	Total	Percentage	Total	Percentage
No	15,602	40%	11,486	59%	4,116	22%
Yes	23,063	60%	8,108	41%	14,955	78%
Fulfulde	All		Female		Male	
Labor force participation	Total	Percentage	Total	Percentage	Total	Percentage
No	22,675	35%	20,718	63%	1,957	6%
Yes	41,595	65%	12,158	37%	29,441	94%
Total labor participation	456,239	100	246,660	100	209,583	100
No	121,797	27%	94,641	38%	27,156	13%
Yes	334,442	73%	152,019	62%	182,427	87%

areas; due to difficult access to education in such areas, lacking sometimes the basic infrastructure, the school dropout rate is generally higher.

Table 2 presents the labor force participation by ethnic group and gender in Burkina Faso for the three main spoken languages. The overall labor force participation rate of individuals for these languages is high (73 percent), with 76 percent for Moore, 65 percent for Fulfulde and 60 percent for Dioula. Moreover, 87 percent of males and 62 percent of females are in the labor force. Although a cross-ethnic group analysis appears to show an advantage for those who speak the Moore language (76 percent), while a cross-gender analysis indicates a higher rate for males (87 percent), it is difficult to assert that the differences in labor force participation according to ethnic group and gender are based on ethnicity. It is important to note that labor market access may require proficiency in French and local language(s) depending on factors such as the location of the jobs and firm targets. Due to the particular labor market conditions in multilingual countries with low proficiency in the official language (French), such as Burkina Faso, a local language-based premium is more reliable than an ethnicity-based perspective. Consequently, the ethnic advantage is indirectly related to the use of this particular ethnic group's language, and any individual proficient in this language, native or not, enjoys an increased likelihood of being in the labor force. Therefore, proficiency in the labor market language should be mainly considered during recruitment as compared to an individual's ethnic background. One's ethnic background should be analyzed from the perspective of how it affects their language proficiency.

The data shows that 94 percent of Fulfulde males are in the labor force compared to 37 percent of females. This ethnic group exhibits the highest male participation rate in the labor force and the lowest female participation rate. This higher level of labor market activity by males in the Fulfulde group may be explained by the pastoralist nature of this ethnic group. Males are active and self-employed early. In contrast, females engage more in house and family work. Table 3 sheds light on the share of inactive females involved in domestic tasks across ethnic groups, alongside the literacy rate in each group. Among the 37 percent of inactive Fulfulde females,

TABLE 3— LITERACY AND INACTIVE FEMALES ENGAGED IN DOMESTIC WORK

(UNIT: %)

	Literate Males	Literate Females	Inactive Females in Domestic Work
Moore	33	17	23
Fulfulde	7	4	56
Dioula	60	44	40

56 percent are engaged in domestic tasks. Compared to Moore and Dioula speakers, one can assert that the labor of Fulfulde females is home-oriented; therefore, schooling is not seen as valuable.

Also, as expected, the literacy rate of the Fulfulde ethnic group is very low. As nomads, school attendance is negatively affected, with most of them outside the formal education system. As a result, individuals' levels of proficiency in the labor market language (French) are lower. A change in the language policy from French to a local language will lead to a withdrawal of many active Fulfulde (both males and females) from the labor force, as compared to other ethnic groups. The changes in education programs induced by such a language policy are likely to increase job opportunities in local languages. Thus, the strong return of education in local languages will mainly affect the Fulfulde ethnic group, who are mostly outside the formal education system, as compared to the Moore and Dioula. Consequently, in the short term, labor force participation may be reduced for the Fulfulde, as literacy in French will be important to read and write in local language(s) and, as literate Francophones, most of whom are from the Moore and Dioula ethnic groups, will be able to acquire literacy in local languages more easily than Fulfulde individuals.

The difference in literacy between the Dioula and Fulfulde is high and may be significant in explaining the difference in the impact of the language use policy on the labor force participation rate.

Burkina Faso has more than 60 ethnics groups, with local languages belonging mainly to the Niger-Congo language family. Only a few of them, located in the northern part of the country are from the Nilo-Saharan language family. In the dataset, there are 13 most commonly spoken languages in the country (see Table 4). The most commonly spoken language is Moore, spoken by around 58 percent of people, followed by Fulfulde with 11 percent native speakers and then Dioula with 7 percent being native speakers. These numbers from the dataset mirror the country's language representation. These three languages are therefore used as official language candidates in this study.

Combining Tables 1 and 4, the shift from French to the local language as the official language shows that the language distance reduction is greater when using Moore, followed by Fulfulde and then Dioula. This means that if the country uses, for instance, Moore as the official language instead of French, the relative language distance reduction from French to Moore will be on average 98 percent: 96 percent for Fulfulde and 94 percent for Dioula. The higher the relative language distance reduction to Moore, Fulfulde and Dioula, the shorter the language distance from the local languages to Moore, Fulfulde and Dioula. The language distance reduction indexes all exceed 90 percent, which means that the cost of using a non-indigenous language is higher and that this cost may be reduced by changing the policy adopted in relation to the use of local language(s). Note that the distance from each local

TABLE 4—LANGUAGE SPOKEN IN BURKINA FASO (SPOKEN BY AT LEAST 1% OF THE POPULATION)

Language Spoken, Burkina Faso	Freq.	Percent	Cum.
Bissa	20,584	3.39	3.39
Bobo	10,054	1.66	5.05
Bwamu (or Bwamou)	14,569	2.40	7.45
Dagara	13,598	2.24	9.69
Dioula (or Bambara)	38,655	6.37	16.07
Fulfulde (or Peulh)	64,274	10.59	26.66
Goulmancema (or Gourmanché)	39,990	6.59	33.25
Lyele	11,058	1.82	35.07
Lobiri	11,033	1.82	36.89
Moore	353,304	58.23	95.13
Nuni (or Nounouma)	7,776	1.28	96.41
San (or Samogho, Samo)	12,652	2.09	98.49
Senoufo	9,144	1.51	100.00
Total	606,701	100.00	

language to French is 1, as the local languages and French belong to different language families. Certainly, it is difficult for individuals speaking local languages in Burkina Faso to speak French. Less than 20 percent of Burkinabe speak, read and write in French, despite the fact that the country has long been under France control and was eventually influenced by the language and culture of France. In the next section, the article discusses the empirical strategy utilized here.

B. *Empirical Strategy*

In this article, I investigate the importance of a local language use policy with regard to labor force participation in Burkina Faso. In Burkina Faso, the formal labor market language is French, the official language of the country. It is important to note that because the most commonly spoken languages in Burkina Faso belong to the Niger-Congo family and that the current official language, French, belongs to the Indo-European language family, it is difficult for individuals in Burkina Faso to learn the French language. The underlying idea behind this strategy is that if the country reduces the distance between individuals' mother tongues and the language of administration, education, and the labor market, one can expect a considerable improvement in individuals' outcomes, such as a high labor force participation rate, high education levels, good health, and longer life expectancies. For this purpose, I compute the relative language distance reduction from French to the three local languages which serve as candidates for the official language. Of course, if the computed relative language distance reduction index increases, the distance between the most commonly spoken language in the country and the local language candidates for the official language will be reduced. This will therefore improve individuals' outcomes. This study borrows the concept of the language distance index from previous studies (Laitin and Ramachandran, 2014; 2015; Yameogo, 2019), as expressed below,

$$d_{ij} = 1 - \left(\frac{\text{\# of common nodes between i and j}}{\frac{1}{2}\left(\text{\# of nodes for language i} + \text{\# of nodes for language j}\right)} \right)^{\lambda},$$

where the index d_{ij} computes the distance between two languages i and j, and the value λ shows how rapidly the distance between the two languages declines as the number of shares increases. The idea is that when individuals speaking different languages interact, they are likely to share some words. Fearon (2003) suggested a value of 0.5. The language distance index is between 0 and 1. A distance of zero means that the two languages belong to the same family and sub-family group. Thus, they share numerous common words and the language structures bear many similarities. In such a case, it is easier for two individuals who speak these languages to interact and to learn one another's language. Conversely, when the distance equals 1 or is closer to 1, the two languages do not have common nodes or share few common words, and they have different structures. In such a case, learning one another's language can be challenging. We can consider a South Korean learning English and a French speaker learning English. Obviously, it will be easier for the French speaker to learn English than for the Korean speaker to learn English. French and English belong to the same language family (Indo-European) while Korean belongs to the Koreanic language family.

Figure 1 presents the method used to compute the number of nodes. For example, for the two languages spoken in Burkina Faso (Moore and Birifor), there are 11 nodes from Moore to Niger-Congo and 12 from Birifor to Niger-Congo. There are thus 11 common nodes between them. Additionally, the two languages of Moore and Farefare belong to the same sub-group. However, the ethnic group that speaks Farefare lives generally in Ghana, a country neighboring Burkina Faso. Theoretically, it should be easier for an individual who speaks Moore to speak Farefare, spoken in Ghana, than for such an individual to speak Birifor in Burkina Faso. However, because Birifor and Moore are generally spoken in the same country, where speakers


```
[1] Niger-Congo (1542)
[2] Atlantic-Congo (1444)
[3] Volta-Congo (1372)
[4] North (255)
[5] Gur (97)
[6] Central (69)
[7] Northern (38)
[8] Oti-Volta (33)
[9] Western (16)
     [9-1]Northwest (9)
                         [9-1-1] Farefare [gur] (A language of Ghana)
                         [9-1-2] Mòoré [mos] (A language of Burkina Faso)
                         [9-1-3] Safaliba [saf] (A language of Ghana)
                         [9-1-4] Wali [wlx] (A language of Ghana)
     [9-2]Dagaari-Birifor (5)
     [9-3]Birifor (2)
                         [9-3-1] Birifor, Malba [bfo] (A language of Burkina Faso)
                         [9-3-2] Birifor, Southern [biv] (A language of Ghana)
```

FIGURE 1—FAMILY TREE AND NODES COMPUTATION

are more likely to interact, the number of common nodes may increase more rapidly than that associated with the language in Ghana. Moreover, due to the fact that the two countries have been separated by a language barrier (Burkina Faso uses French as an official language while Ghana uses English), the populations in both countries are less likely to interact compared to a country such as Cote d'Ivoire, which shares French as an official language with Burkina Faso. The official languages inherited from colonial countries have created barriers between individuals whose official languages are different.

The strategy in this article is first to use the indicator described above to compute the language distances between the 13 most commonly spoken languages in Burkina Faso and the three local languages candidate as official language Moore, Fulfulde, and Dioula (d_{iJ}); and second to compute the distance between the most commonly spoken languages in Burkina Faso and French (d_{iF}). Then, the relative language distance reduction index (Rd_{ij}) is computed as follows: $Rd_{ij} = \dfrac{d_{iF} - d_{iJ}}{d_{iF}}$, where

d_{iF} is the language distance from local language i to French (F), and d_{iJ} is the language distance from local language i to the local language used as the official language instead of French ($J = Moore, Fulfulde, Dioula$). The relative language distance reduction indexes from French to the three local languages are computed as follows:

For Moore: $Rd_{im} = \dfrac{d_{iF} - d_{im}}{d_{iF}}$; Fulfulde: $Rd_{if} = \dfrac{d_{iF} - d_{if}}{d_{iF}}$;

and Dioula: $Rd_{id} = \dfrac{d_{iF} - d_{id}}{d_{iF}}$.

Here, [1] represents the distance between the different local languages used in the country and the current official language, French. In addition, [2] is the distance between the local language candidates for the official language in the country and other local languages spoken in the country. The use of these local languages reduces the language distance from [1] to [2], making it shorter. The relative language distance reduction index captures the distance [3], computing it using the following formula ([1]-[2])/[1]). This relative language distance reduction index captures the gain in distance, [3], when using local languages instead of an international language as the official language. [4] measures the effect of the increase in the distance [3] on the labor force participation rate in Burkina Faso. This effect is assumed to be positive, as the reduction of the distance between the languages spoken in the country and the local official language is shortened to [2]. An increase of [3] reduces [2]. In other words, the distance [3], the relative language distance reduction index, measures the effect of a change in the language policy.

After computing the relative language distance reduction index, this study uses the probit/logit model to measure the impact of the language distance reduction (Rd_{ij}) on labor force participation in Burkina Faso. Moreover, due to the potential

[1]

| Local languages | [2] | Local languages candidate as official language [Moore-Fulfulde-Dioula] | [3] | Current official language [French] |

[4]

Labor force participation
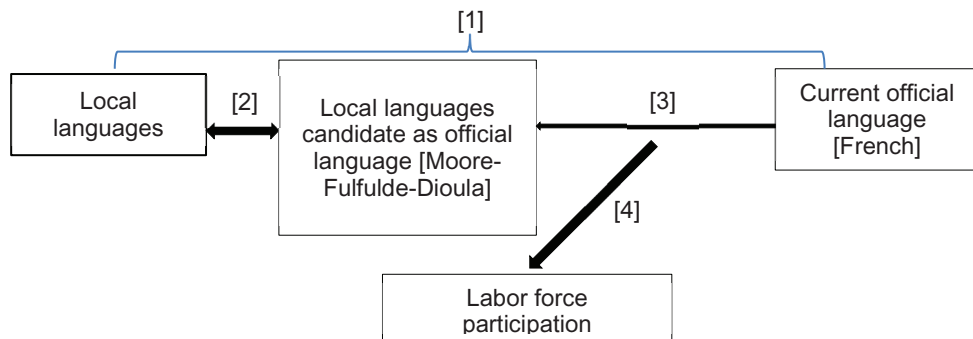
FIGURE 2—THEORETICAL FRAMEWORK

endogeneity of the language use policy and the potential for measurement errors, an instrumental variable is used to tackle these problems (Adkins and Hill, 2008; Cameron and Trivedi, 2010; Greene, 2012; Wooldridge, 2013).

The theoretical model is based on Bowen and Finegan (1969), who developed a comprehensive framework for modeling and regressing labor force participation (LFP). Bowen and Finegan (1969) analyzed labor force participation under the General Theory of Choice. In their detailed study, they found that the decision to be part of the labor force depends on "four broad classes of variables: (1) tastes, (2) expected market earnings rates, (3) expected non-market earnings rates, and (4) the household's total source constraint" (p.16). In other words, the decision to be part of the labor force depends on individual characteristics and market conditions. (Sackey, 2005), using population census data instead of labor data, focused more on rich demographic information to highlight female labor force participation in Ghana. Due to the lack of labor survey information in Burkina Faso, the approach developed by Sackey (2005) will be of great importance to capture the key determinants of labor force participation using demographic characteristics. Clearly, the lack of data relative to the market conditions is a limitation of this study. However, the results will provide us with a comprehensive understanding of the labor force dynamics in Burkina Faso using cell phone possession and electricity availability as proxies of individual income, though they could be enriched further with labor data.

This regression model is based on work by Laitin and Ramachandran (2014) on the effect of the local languages on Indian individuals' employment prospects.

The regression model is as follows:

The outcomes variable (y = labor force participation) takes one of two values:

$$Laborforce\ (y) = \begin{cases} 1 & \textit{if the individual participate to the labor market} \\ 0 & \textit{if the individual does not participate to the labor market} \end{cases}.$$

The latent-variable:

$$Laborforce_i = X_i\beta + u_i, \quad i = 1, 2, \cdots, N \text{ and } \Pr(y = 1 \mid x) = X_i\beta + u_i$$

Because the model is not linear, OLS cannot be used to estimate the coefficient β. The maximum likelihood estimation of logit and probit models is used. To interpret the coefficient, the marginal effect at the mean is used to compare the variable to the average individual in the population. The robust standard error is used to address the heteroskedasticity issue. In this study, standard errors should be clustered by ethnic groups; however, given that the number of groups is small (13 ethnic groups in the dataset) the cluster standard error (CSE) does not provide a sound standard error. According to the rule of thumb, the number of groups should be higher than or equal to 50 to allow for clustering (Wooldridge, 2013).

Having stated the empirical framework of this study, let us now turn to the regression analysis of this article. Equation (1) is the main equation of this regression, where the dependent variable is the labor force participation rate in Burkina Faso.

$$(1) \qquad\qquad Laborforce_i = \beta_0 + \beta_J Rd_{iJ} + \beta X_i + u_i, \quad i = 1, 2, \cdots, N$$

Here, the index Rd_{ij} represents the relative language distance reduction from French to the targeted local official language J for individual i speaking his/her local language. β_J is the coefficient of the language distance reduction of each local language used as the official language. Because this study focuses on the three most widely spoken language in the country (Moore, Fulfulde and Dioula), $J = 3$, and the model regresses three different equations. β_J is expected to have a positive sign. An increase in the distances between Moore, Fulfulde and Dioula and the current official language French, means a reduction in the distances between the local languages and the local language used as the official language. This reduction in the distance reduces the transaction costs and facilitates access to information necessary to gain a job; moreover, the reduced language distance provides opportunities to people excluded from the labor market due to the language barrier, allowing them to increase their language-related human capital and bolster their competitiveness in the labor market.

The covariates X_i represent the set of explanatory variables having an impact on labor force participation. Educational attainment, the number of children, gender, age, age square, marital status, religion, place of birth and living areas are the main individual characteristics I controlled for. To capture the market conditions, cell phone possession and electricity availability are used as proxies for income/wage. A good market condition should allow an individual to be able to afford a cell phone and electricity. As mentioned earlier, the standard errors are heteroskedastic-robust. The results are summarized in Tables 5 and 6. Tables A1, A2, and A3 present the regression tables for the main control variables.

In this study, I also utilized an instrumental variable approach due to the potential endogeneity of the language use policy and due to the possible measurement error which can arise when reporting and computing the different language distance reduction indexes. The language use policy is said to be endogenous. According to Hamel (2013), language use policies are strongly dependent on the factors of

political will and ideology, as seen in France, Spain, Japan, and Ethiopia, among other countries. The historical background of the country also factors into the choice of language use policy. Nunn and Wantchekon (2011) clearly highlighted that countries which have historically experienced high mistrust between ethnic groups, mostly African countries, find it difficult to choose a local language as an official language in the country. Individuals in such countries may prefer a foreign language to other local languages.

An instrumental variable is thus necessary to address these main empirical issues. The idea is to find an instrument which does not belong to the main equation (1) [instrument exclusion: $\mathrm{cov}(z, u) = 0$] but which is strongly correlated with the main variable of interest [instrument relevance: $\mathrm{cov}(z, x) \neq 0$]. In this article, for each local official language, I use a dummy variable as an instrumental variable.

Instrumental exclusion or instrumental exogeneity is difficult to prove; hence, a researcher should rely on intuition and theory (Wooldridge, 2013). The second assumption means that the first stage exists. In addition, a weak instrument test is used to ensure that the instrument is good enough to capture the local average effect. Because this study uses one instrument per interest variable, there is no need to test for over-identification; accordingly, the F-statistic of the first stage is sufficient to use to test whether the instrument is weak or not. The F-statistic value of ≥ 10 shows that the instrument is good and not weak.

$$ivrd = \begin{cases} 1 & \textit{if the individual speaks the local language used as the official language} \\ 0 & \textit{if the individual does not speak the local language used as the official language} \end{cases}$$

For instance, if assuming that Moore is the local language used as the official language in Burkina Faso, the instrumental variable consists of the native speakers of Moore. The idea is that if Moore is used as the official language and has a positive impact on labor force participation, then its native speakers should benefit from labor market access. It can therefore be asserted that there is a strong correlation between belonging to the Moore ethnic group and the use of Moore as the official language in the country. Instrument relevancy then is expected to hold. For instrumental exclusion or exogeneity, this article assumes that there is no direct link between the ethnic group and labor market access. There is no ethnic premium in the labor market in Burkina Faso; however, this study assumes that the only ethnic premium in the labor market should be through the use of the particular ethnic group's language in the labor market. For example, for some jobs, proficiency in a particular local language, along with French, increases the chance of getting hired. Even if in some cases certain individuals may be likely to hire workers from the same ethnic group, these cases are marginal and may not be significant enough to guide labor market trends. Thus, for the purposes of this study, it is assumed that there is not an ethnicity-based premium and that ethnic group origin does not determine hiring in Burkina Faso unless the labor market language is this ethnic group's language or requires this language along with French. Moreover, being part of a certain ethnic group is exogenous. Instrumental exclusion therefore holds here. The underlying intuition is that if individuals whose mother tongue is used as the official language are more likely to participate in the labor force, then those who are not natives but could easily

speak this language will also easily enter the labor market. The IV probit model is used to perform the regression, as IV logit does not exist.

Although it is important to investigate the potential endogeneity of the language use policy and how it may affect labor force participation, this article follows the hypothesis of Laitin and Ramachandran (2014). In their study of the impact of local languages on Indians' employment, upon which approach my paper is based, endogeneity is not an important factor. They state "[We] …omitted variable bias and reverse causality in our setting is not likely to be an important factor" (p. 36).

The next section presents and discusses the results

IV. Results and discussion

Table 5 summarizes the main findings of this study. This study measures the impact of Moore, Fulfulde and Dioula on labor force participation. For each language, the table shows an overall effect, a gender-specific effect and a living area effect. Table 6 presents the instrumental variable results.

For the Moore language, the study found a positive effect of a relative language distance reduction on labor force participation for the population. These results are statistically significant at the 1 percent level. The overall model regression results show that the relative language distance reduction index is positively correlated with labor force participation. A 1 percent increase in the relative language distance reduction index improves the chance of labor force participation by 36 percent. Moreover, being in a rural area increases the likelihood of labor force participation by 16.1 percent. Considering the gender and living area effects, the study found that the use of Moore as an official language has a greater impact on females than on males; in addition, rural individuals are more strongly affected than those living in urban areas. In general, the chance of being part of the labor force in Burkina Faso for females is 58.9 percent, against 7 percent for males. The outcome for female participation is approximately nine times greater than that for males. Rural individuals' labor force participation likelihood is around five times higher compared to the result for urban individuals (38.3 percent for rural individuals against 8.7 percent for those in urban areas). In addition, we note that the urban effect is not significant. Citizens in urban areas are bilingual in French and local languages. A change of the official language from French to a local language is not expected to have a strong or significant impact on their labor force participation rate. In contrast, rural individuals, mostly monolingual in local languages, are significantly and positively affected by the language change from French to a local language.

The use of the Dioula language as an official language in Burkina Faso increases the labor force participation likelihood by 32 percent. Again, the impact of the use of a local language on the likelihood of labor participation by females is higher than that for men, at 50.7 percent to 4.4 percent, respectively, a difference of more than tenfold. Additionally, 25.3 percent of rural individuals are likely to participate in the labor force, against 12.2 percent for urban people. These results are in good agreement with several previous studies (Chong, Guillen, and Rios, 2010; Laitin and Ramachandran, 2014; 2015; Seid, 2017; Yameogo, 2019). The use of the two local languages (Moore and Dioula) reduces transaction costs and importantly increases

TABLE 5—LOGIT AND PROBIT REGRESSION RESULTS (MARGINAL EFFECT AT THE MEAN)

Interest variables	Logit					Probit				
	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban
Relative language distance reduction index [Moore]	0.357*** (0.019)	0.067*** (0.010)	0.589*** (0.032)	0.383*** (0.018)	0.079 (0.051)	0.371*** (0.019)	0.106*** (0.014)	0.577*** (0.031)	0.414*** (0.019)	0.075 (0.048)
Relative language distance reduction index [Fulfulde]	-0.472*** (0.025)	0.066*** (0.013)	-0.994*** (0.044)	-0.509*** (0.025)	0.004 (0.066)	-0.465*** (0.026)	0.091*** (0.019)	-0.974*** (0.042)	-0.519*** (0.026)	0.003 (0.063)
Relative language distance reduction index [Dioula]	0.322*** (0.016)	0.044*** (0.008)	0.507*** (0.027)	0.253*** (0.015)	0.122** (0.040)	0.327*** (0.016)	0.070*** (0.012)	0.492*** (0.026)	0.272*** (0.017)	0.117** (0.038)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	598,629	273,492	325,137	436,554	162,075	598,629	273,492	325,137	436,554	162,075

Note: Robust-standard errors in parentheses, *p<0.05, **p<0.01, ***p<0.001.

TABLE 6—INSTRUMENTAL VARIABLE REGRESSION RESULTS (MARGINAL EFFECT AT THE MEAN)

Interest variables	IV-Probit- First stage [First-stage independent variable: Dummy variables]*					IV-Probit - Second stage				
	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban
Relative language distance reduction index [Moore]	0.054*** (0.000)	0.053*** (0.000)	0.055*** (0.000)	0.051*** (0.000)	0.061*** (0.000)	3.563*** (0.110)	0.841*** (0.212)	4.832*** (0.132)	6.078*** (0.143)	-0.140 (0.172)
Relative language distance reduction index [Fulfulde]	0.039*** (0.000)	0.039*** (0.000)	0.039*** (0.000)	0.038*** (0.000)	0.043*** (0.000)	-12.44*** (0.184)	-1.646*** (0.484)	-16.73*** (0.219)	-14.32*** (0.197)	-2.298*** (0.581)
Relative language distance reduction index [Dioula]	0.083*** (0.000)	0.083*** (0.000)	0.083*** (0.000)	0.093*** (0.000)	0.075*** (0.000)	0.909*** (0.113)	0.319 (0.192)	0.766*** (0.145)	-0.753*** (0.178)	0.408* (0.161)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	598,629	273,492	325,137	436,554	162,075	598,629	273,492	325,137	436,554	162,075

Note: Robust-standard errors in parentheses, *p<0.05, **p<0.01, ***p<0.001.

labor force participation likelihood of individuals with a great and positive impact on women and rural individuals.

Fulfulde provides contradictory results. The use of Fulfulde, while reducing the language distance between the ethnic languages in Burkina Faso and the official language, has a negative effect on labor force participation likelihood with a 47.2 percent reduction for all. Moreover, the results show that Fulfulde impacts females and males differently. While men are positively affected by the use of Fulfulde, with a 7 percent increase in labor force participation likelihood; women are negatively affected, with a 99 percent reduction in the chance of their being a part of the labor force. Seid (2017) noted that the use of one's mother tongue may have a negative effect on later labor force participation if the individual is overly exposed to the mother tongue and is not exposed enough to other languages. However, in this study, this explanation does not hold because males are positively affected and females are not. Moreover, in contrast to Moore and Dioula, rural individuals are less likely to join the labor force than urban individuals. The likelihood of labor participation for rural people is negative, and a reduction of approximately 50 percent in their chance at participation is observed, while the urban effect is not statistically significant for the above-mentioned reason. Given that the natives of Fulfulde are nomadic people and historically pastoralist and that they have less schooling and lower literacy rates, the use of a local language, reducing the learning cost and increasing job opportunities, may increase the number of Fulfulde individuals in the formal education system, thus increasing the number of inactive people and then reducing labor force participation. Indeed, Fulfulde exhibits the lowest level of literacy (for both males and females). The high impact on females can be explained by the fact that the small number of active females may be attracted to wage/paid work and be involved for a while in schools/literacy programs and therefore leave the labor force. One can expect a negative effect in the short term followed by a positive effect on the labor force in the mid and long term.

Another interesting finding is that animists have a greater opportunity to participate in the labor force than Protestants, Catholics and Muslims. This result is predictable because animism, as an endogenous religion, shapes the society's identity, culture and codifies interpretations of the universe. The local languages' effects along with the endogenous religion therefore develop and strengthen individual identities.

Table 6 summarizes the instrumental variable results. The instrumental variable approach shows that the impact of the use of Moore and Dioula is positive and statistically significant at the level of 1 percent. Additionally, the test of the weak instrument shows that the dummy variables for Moore, Dioula and Fulfulde are good instruments with which to test the relative language distance reductions for these three languages. The first-stage F-statistic exceeds 10 in all cases. The gender-specific and living area trends remain the same, except for Dioula, where rural areas become negatively affected; women and rural individuals are strongly affected by the language change policy, and Fulfulde exhibits the same contrary results due to the pastoralist and nomadic nature of this ethnic group.

Additional results show that when the local language effect is parsed out, first, the number of children in a family has a negative effect on the likelihood of labor participation, though the result is different between genders. Indeed, the number of

children increases the likelihood of males' participation in the labor market, while females are negatively affected by the number of children. Males in Burkina Faso are expected to work in order to provide for their families with sufficient financial support, while females are expected to stay home and take care of the family. Second, labor participation is affected differently depending on the education level. Those with less education and individuals with a university-level education are positively affected and are more likely to enter the labor force, whereas individuals with a primary school education and secondary-school education are less likely to participate in the labor force.

Moreover, the findings of this article show that the use of local languages (Moore and Dioula) has a positive and significant impact on labor force participation; women are most affected by the use of a local language, and their participation in the labor force is increased. Additionally, rural individuals are more likely to participate in the labor force than those living in urban areas. The use of an official language close to the most commonly spoken language in a country improves economic outcomes, particularly the labor force participation of individuals. Conversely, the use of Fulfulde has a negative effect on women and rural individuals, while men and urban individuals are positively affected.

V. Summary and recommendations

In this article, I investigate the impact of the use of local languages as official language(s) in Burkina Faso on labor force participation. The country has approximately 60 ethnic groups and local languages, and less than 20 percent of the population can speak French, the current official language. According to previous studies, the use of a language as an official language has an impact on socio-economic outcomes; the impact is negative when this official language is too distant to the most commonly spoken language in the country (Laitin and Ramachandran, 2014; 2015; Yameogo, 2019). Based on the language distance index developed by Laitin *et al*. (2014), this article develops and computes the relative language distance reduction index to take into account a language use policy change from a remote official language to a closer local language when used as an official language. The data was sourced from the IPUMS survey and from the Ethnologue language classification. A probit/logit model and an instrumental variable approach were used to measure the impact of the use of the three main local languages (Moore, Fulfulde and Dioula) as candidates for the official language on labor force participation in Burkina Faso.

The findings are consistent with those from theoretical and empirical studies; the use of local languages has a positive and significant impact on labor force participation by individuals in Burkina Faso. An unexpected result came from the female and rural individuals' labor force participation rates when using Fulfulde as the official language. Thus, to be precise, the study finds that if Burkina Faso changes it language use policy by adopting Moore as the official language instead of French, the language distance will be reduced by more than 98 percent, and this reduction will in turn have a positive impact on labor force participation (nearly a 40 percent increase). From a gender-specific perspective, the impact is nine times higher for

females than for males. Individuals living in rural areas will see their chance of participating in the labor force increased by nearly five times than urban individuals. The use of Dioula led to a language distance reduction of 93.6 percent; a 1 percent increase in the language distance reduction index improves labor force participation likelihood by around 32 percent. Again, the impact of the use of a local language on the labor participation rate for women is higher than that for men by more than ten times. The likelihood of entering the labor force for rural individuals is two times greater than it is for those living in urban areas. Regarding the case of Fulfulde, although the language distance is reduced by 96.3 percent, the language effect on labor force participation is negative. A 1 percent increase in the language distance reduction decreases the labor force participation likelihood by 50.9 percent. However, a gender-specific analysis shows that the impact of Fulfulde is positive on men and negative on women. Rural individuals are negatively affected by the use of Fulfulde as the official language. The negative effect in the short term may be due to the pastoralist and nomadic nature of this ethnic group, where males are active and self-employed earlier and females are engaged in housework. The use of a local language will lead to an increase of inactive individuals due to greater involvement in formal education. However, this study predicts a positive effect on labor force participation in the mid and long term.

Finally, the overall positive effect of the local language on females is explained by the fact that women in Burkina Faso are less educated than men. Additionally, rural individuals compared to urban individuals are less favored with regard to access to education and to basic infrastructure. In fact, there is a gender gap and geographical discrimination that affect access to education; therefore, the removal of the language barrier will strongly and positively affect females and rural individuals' access to the labor market.

The instrumental variable approach shows statistically significant results at the level of 1 percent. The coefficients are higher than in the probit/logit estimation.

The study also shows that among the three languages, Moore exhibits the shortest language distance to the other local languages, followed by Fulfulde and then Dioula. Moreover, the contribution to the labor force is higher when using Moore. Dioula has the second highest impact on individuals' labor force participation rates. We also note that the most commonly spoken language in the country is Moore, spoken by more than 50 percent as native speakers. If one considers labor force participation, the language use policy should stipulate the use of Moore as the official/national language in the country. However, the strategy suggested by this study is to use the other languages as regional languages given findings that show that the use of a mother tongue has a positive impact on labor force participation (Seid, 2017). Nevertheless, since Seid (2017) argued that extended exposure to one's mother tongue can hinder the acquisition of proficiency in other languages, this study suggests the use of French and English as foreign languages, with these languages to be taught at an early stage along with regional and local official languages (Isphording, 2014).

One precondition when implementing a language policy is to build strong institutions in the country to accommodate ethnic diversity and reduce mistrust between ethnic groups (Karnane and Quinn, 2017; Nunn and Wantchekon, 2011; Yameogo, 2019). Encouraging exogamy and protecting endangered languages will

be of great importance to create social links and strengthen the social fabric. Moreover, the country should clearly amend the constitution to protect the status of all languages, as in Ethiopia (Záhořík and Teshome, 2009), and to promote minorities as a foundation of a strong society. The language policy should be implemented with the acceptance and participation of the population, meaning that a national consensus is needed. This topic is sensitive and should be implemented in different steps and on a mid- to long-term basis, as failure can lead to ethnic conflicts. A stakeholder analysis is crucial to draw a map of the interests and powers involved in the policy implementation process.

This study did not consider whether it is easier to standardize certain languages for education purposes, particularly in relation to the links (historical and current) between ethnic groups in the country. Further work should focus on these characteristics and should also increase the number of dependent variables to measure the impact of language reduction on the socioeconomic outcomes of various groups.

Lastly, because this study has shown that the adoption of a local language has the potential to increase labor participation by women and rural individuals substantially, the findings here may have some far-reaching implications for governments and organizations seeking to broaden labor participation. Moreover, the methodology presented in this article may be generalized and applied to multilingual contexts where policymakers are seeking to make changes in language policies. The language distance reduction (change) index developed here, based on the language family classification method (Lewis, 2009) and the language distance index of Laitin and Ramachandran (2014), will be of significant use for policymakers looking to implement language use policy changes.

APPENDIX

TABLE A1—LOGIT RESULT (MARGINAL EFFECTS AT MEAN)

	Moore					Fulfulde					Dioula				
	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban
Relative language distance reduction indexes (RdiI)	0.357*** (0.019)	0.067*** (0.010)	0.589*** (0.032)	0.383*** (0.018)	0.079 (0.051)	-0.472*** (0.025)	0.066*** (0.013)	-0.994*** (0.044)	-0.509*** (0.025)	0.004 (0.066)	0.322*** (0.016)	0.044*** (0.008)	0.507*** (0.027)	0.253*** (0.015)	0.122** (0.040)
Male	0.307*** (0.001)			0.249*** (0.001)	0.433*** (0.003)	0.308*** (0.001)			0.250*** (0.001)	0.433*** (0.003)	0.307*** (0.001)			0.250*** (0.001)	0.433*** (0.003)
# of Children	-0.004*** (0.000)	0.002*** (0.000)	-0.003*** (0.001)	0.001* (0.000)	-0.018*** (0.001)	-0.004*** (0.000)	0.002*** (0.000)	-0.003*** (0.001)	0.001* (0.000)	-0.018*** (0.001)	-0.004*** (0.000)	0.002*** (0.000)	-0.003*** (0.001)	0.001* (0.000)	-0.018*** (0.001)
Less than primary	0.030*** (0.009)	0.025*** (0.005)	0.025 (0.015)	0.026** (0.008)	0.025 (0.024)	0.030*** (0.009)	0.025*** (0.005)	0.024 (0.015)	0.027*** (0.008)	0.025 (0.024)	0.030*** (0.009)	0.025*** (0.005)	0.025 (0.015)	0.026** (0.008)	0.025 (0.024)
Primary	-0.084*** (0.004)	-0.028*** (0.003)	-0.069*** (0.008)	-0.095*** (0.004)	-0.092*** (0.012)	-0.085*** (0.004)	-0.028*** (0.003)	-0.072*** (0.008)	-0.097*** (0.004)	-0.092*** (0.012)	-0.084*** (0.004)	-0.029*** (0.003)	-0.070*** (0.008)	-0.096*** (0.004)	-0.092*** (0.012)
Secondary	-0.034*** (0.003)	-0.022*** (0.002)	0.011 (0.006)	-0.020*** (0.004)	-0.061*** (0.008)	-0.035*** (0.003)	-0.022*** (0.002)	0.010 (0.006)	-0.021*** (0.004)	-0.061*** (0.008)	-0.035*** (0.003)	-0.022*** (0.002)	0.010 (0.006)	-0.021*** (0.004)	-0.061*** (0.008)
University	0.057*** (0.004)	0.004* (0.002)	0.120*** (0.007)	0.009 (0.007)	0.085*** (0.008)	0.057*** (0.004)	0.004* (0.002)	0.119*** (0.007)	0.009 (0.007)	0.085*** (0.008)	0.057*** (0.004)	0.004* (0.002)	0.119*** (0.007)	0.008 (0.007)	0.085*** (0.008)
Age	0.025*** (0.000)	0.017*** (0.000)	0.021*** (0.001)	0.011*** (0.000)	0.070*** (0.001)	0.025*** (0.000)	0.017*** (0.000)	0.021*** (0.001)	0.010*** (0.000)	0.070*** (0.001)	0.025*** (0.000)	0.017*** (0.000)	0.021*** (0.001)	0.010*** (0.000)	0.070*** (0.001)
Age square	-0.033*** (0.000)	-0.022*** (0.000)	-0.029*** (0.001)	-0.014*** (0.000)	-0.087*** (0.001)	-0.032*** (0.000)	-0.022*** (0.000)	-0.029*** (0.001)	-0.014*** (0.000)	-0.087*** (0.001)	-0.032*** (0.000)	-0.022*** (0.000)	-0.029*** (0.001)	-0.014*** (0.000)	-0.087*** (0.001)
Muslims	0.016 (0.010)	0.013 (0.007)	0.002 (0.017)	0.019* (0.009)	-0.050 (0.032)	0.017 (0.010)	0.013 (0.007)	0.004 (0.017)	0.022* (0.009)	-0.050 (0.032)	0.015 (0.010)	0.013 (0.007)	0.000 (0.017)	0.019* (0.009)	-0.052 (0.032)
Catholics	0.041*** (0.010)	0.009 (0.007)	0.059*** (0.017)	0.053*** (0.009)	-0.052 (0.032)	0.042*** (0.010)	0.009 (0.007)	0.061*** (0.017)	0.054*** (0.009)	-0.051 (0.032)	0.041*** (0.010)	0.009 (0.007)	0.059*** (0.017)	0.053*** (0.009)	-0.052 (0.032)
Protestants	0.032** (0.011)	-0.003 (0.007)	0.057*** (0.017)	0.051*** (0.009)	-0.079* (0.033)	0.034** (0.011)	-0.003 (0.007)	0.060*** (0.017)	0.053*** (0.009)	-0.078** (0.033)	0.032** (0.011)	-0.003 (0.007)	0.057*** (0.017)	0.052*** (0.009)	-0.079* (0.033)
Animists	0.074*** (0.010)	0.020** (0.007)	0.107*** (0.017)	0.067*** (0.009)	0.017 (0.034)	0.072*** (0.010)	0.020** (0.007)	0.104*** (0.017)	0.067*** (0.009)	0.017 (0.034)	0.074*** (0.010)	0.020*** (0.007)	0.106*** (0.017)	0.067*** (0.009)	0.018 (0.034)
Rural areas	0.150*** (0.002)	0.035*** (0.001)	0.249*** (0.003)			0.150*** (0.002)	0.035*** (0.001)	0.249*** (0.003)			0.153*** (0.002)	0.035*** (0.001)	0.253*** (0.003)		
Electricity	0.009*** (0.002)	0.004*** (0.001)	0.023*** (0.004)	0.051*** (0.005)	0.034*** (0.003)	0.012*** (0.002)	0.004*** (0.001)	0.028*** (0.004)	0.052*** (0.005)	0.034*** (0.003)	0.013*** (0.002)	0.005*** (0.001)	0.028*** (0.004)	0.053*** (0.005)	0.035*** (0.003)
Cell phone	0.021*** (0.002)	0.003*** (0.001)	0.043*** (0.003)	0.017*** (0.002)	0.023*** (0.003)	0.022*** (0.002)	0.003*** (0.001)	0.045*** (0.003)	0.020*** (0.002)	0.023*** (0.003)	0.021*** (0.002)	0.003*** (0.001)	0.043*** (0.003)	0.018*** (0.002)	0.023*** (0.003)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	598629	273492	325137	436554	162075	598629	273492	325137	436554	162075	598629	273492	325137	436554	162075

Note: Robust-standard errors in parentheses, *p<0.05, **p<0.01, ***p<0.001.

TABLE A2—PROBIT (MARGINAL EFFECTS AT MEAN)

	Moore					Fulfulde					Dioula				
	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban
Relative Language distance reduction indexes (RdiJ)	0.371*** (0.019)	0.106*** (0.014)	0.577*** (0.031)	0.414*** (0.019)	0.075 (0.048)	-0.465*** (0.026)	0.091*** (0.019)	-0.974*** (0.042)	-0.519*** (0.026)	0.003 (0.063)	0.327*** (0.016)	0.070*** (0.012)	0.492*** (0.026)	0.272*** (0.017)	0.117** (0.038)
Male	0.319*** (0.001)			0.267*** (0.001)	0.422*** (0.003)	0.320*** (0.001)			0.267*** (0.001)	0.422*** (0.003)	0.320*** (0.001)			0.267*** (0.001)	0.422*** (0.003)
# of Children	-0.004*** (0.000)	0.002*** (0.000)	-0.003*** (0.001)	0.001* (0.000)	-0.016*** (0.001)	-0.004*** (0.000)	0.002*** (0.000)	-0.003*** (0.001)	0.001* (0.000)	-0.016*** (0.001)	-0.004*** (0.000)	0.002*** (0.000)	-0.003*** (0.001)	0.001* (0.000)	-0.016*** (0.001)
Less than primary	0.033*** (0.009)	0.033*** (0.007)	0.024 (0.015)	0.029** (0.009)	0.027 (0.022)	0.033*** (0.009)	0.033*** (0.007)	0.023 (0.015)	0.030*** (0.009)	0.027 (0.022)	0.033*** (0.009)	0.033*** (0.007)	0.024 (0.015)	0.029** (0.009)	0.027 (0.022)
Primary	-0.086*** (0.005)	-0.039*** (0.004)	-0.069*** (0.008)	-0.102*** (0.005)	-0.086*** (0.011)	-0.087*** (0.005)	-0.039*** (0.004)	-0.071*** (0.008)	-0.103*** (0.005)	-0.086*** (0.011)	-0.087*** (0.005)	-0.039*** (0.004)	-0.070*** (0.008)	-0.103*** (0.005)	-0.086*** (0.011)
Secondary	-0.036*** (0.003)	-0.027*** (0.002)	0.010 (0.006)	-0.023*** (0.004)	-0.058*** (0.008)	-0.036*** (0.003)	-0.027*** (0.002)	0.009 (0.006)	-0.024*** (0.004)	-0.058*** (0.008)	-0.036*** (0.003)	-0.028*** (0.002)	0.010 (0.006)	-0.024*** (0.004)	-0.058*** (0.008)
University	0.054*** (0.004)	0.008*** (0.002)	0.114*** (0.007)	0.008 (0.007)	0.074*** (0.007)	0.054*** (0.004)	0.008*** (0.002)	0.113*** (0.007)	0.007 (0.007)	0.074*** (0.007)	0.054*** (0.004)	0.008*** (0.002)	0.113*** (0.007)	0.007 (0.007)	0.074*** (0.007)
Age	0.026*** (0.000)	0.020*** (0.000)	0.021*** (0.001)	0.012*** (0.000)	0.067*** (0.001)	0.026*** (0.000)	0.020*** (0.000)	0.020*** (0.001)	0.012*** (0.000)	0.067*** (0.001)	0.026*** (0.000)	0.020*** (0.000)	0.020*** (0.001)	0.012*** (0.000)	0.067*** (0.001)
Age square	-0.034*** (0.000)	-0.027*** (0.000)	-0.028*** (0.001)	-0.016*** (0.000)	-0.084*** (0.001)	-0.034*** (0.000)	-0.027*** (0.000)	-0.028*** (0.001)	-0.016*** (0.000)	-0.084*** (0.001)	-0.034*** (0.000)	-0.027*** (0.000)	-0.028*** (0.001)	-0.016*** (0.000)	-0.084*** (0.001)
Muslims	0.021* (0.011)	0.022* (0.009)	0.004 (0.016)	0.025* (0.010)	-0.046 (0.031)	0.023* (0.011)	0.022* (0.009)	0.006 (0.016)	0.028*** (0.010)	-0.046 (0.031)	0.020 (0.011)	0.022* (0.009)	0.003 (0.016)	0.025* (0.010)	-0.047 (0.031)
Catholics	0.046*** (0.011)	0.017 (0.009)	0.060*** (0.016)	0.060*** (0.010)	-0.048 (0.031)	0.047*** (0.011)	0.017 (0.009)	0.061*** (0.016)	0.062*** (0.010)	-0.047 (0.031)	0.046*** (0.011)	0.017 (0.009)	0.060*** (0.016)	0.061*** (0.010)	-0.048 (0.031)
Protestants	0.037*** (0.011)	0.001 (0.010)	0.058*** (0.016)	0.058*** (0.010)	-0.073* (0.032)	0.039*** (0.011)	0.001 (0.010)	0.061*** (0.016)	0.060*** (0.010)	-0.072* (0.032)	0.037*** (0.011)	0.002 (0.010)	0.059*** (0.016)	0.059*** (0.010)	-0.074* (0.032)
Animists	0.080*** (0.011)	0.031*** (0.009)	0.106*** (0.016)	0.076*** (0.010)	0.020 (0.033)	0.078*** (0.011)	0.031*** (0.009)	0.102*** (0.016)	0.075*** (0.010)	0.019 (0.033)	0.080*** (0.011)	0.031*** (0.009)	0.105*** (0.016)	0.076*** (0.010)	0.020 (0.033)
Rural areas	0.156*** (0.002)	0.049*** (0.001)	0.248*** (0.003)			0.155*** (0.002)	0.048*** (0.001)	0.249*** (0.003)			0.158*** (0.002)	0.049*** (0.001)	0.252*** (0.003)		
electricity	0.010*** (0.002)	0.006*** (0.001)	0.023*** (0.004)	0.056*** (0.005)	0.032*** (0.003)	0.013*** (0.002)	0.006*** (0.001)	0.027*** (0.004)	0.057*** (0.005)	0.032*** (0.003)	0.013*** (0.002)	0.007*** (0.001)	0.028*** (0.004)	0.058*** (0.005)	0.033*** (0.003)
Cell phone	0.022*** (0.002)	0.004*** (0.001)	0.042*** (0.003)	0.019*** (0.002)	0.021*** (0.003)	0.023*** (0.002)	0.004*** (0.001)	0.044*** (0.003)	0.022*** (0.002)	0.021*** (0.003)	0.022*** (0.002)	0.004*** (0.001)	0.042*** (0.003)	0.020*** (0.002)	0.021*** (0.003)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	598629	273492	325137	436554	162075	598629	273492	325137	436554	162075	598629	273492	325137	436554	162075

Note: Robust-standard errors in parentheses, *p<0.05, **p<0.01, ***p<0.001.

TABLE A3—INSTRUMENTAL VARIABLE RESULT PROBIT (MARGINAL EFFECTS AT MEAN)

	Moore					Fulfulde					Dioula				
	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban	All	Male	Female	Rural	Urban
Relative language distance reduction indexes (RdiJ)	3.563*** (0.110)	0.841*** (0.212)	4.832*** (0.132)	6.078*** (0.143)	-0.140 (0.172)	-12.435*** (0.184)	-1.646*** (0.484)	-16.733*** (0.219)	-14.321*** (0.197)	-2.298*** (0.581)	0.909*** (0.113)	0.319 (0.192)	0.766*** (0.145)	-0.753*** (0.178)	0.408* (0.161)
Male	1.151*** (0.005)			1.205*** (0.006)	1.094*** (0.007)	1.132*** (0.005)			1.184*** (0.006)	1.095*** (0.007)	1.157*** (0.005)			1.213*** (0.006)	1.095*** (0.007)
# of Children	-0.015*** (0.001)	0.022*** (0.004)	-0.009*** (0.002)	0.004** (0.002)	-0.042*** (0.003)	-0.015*** (0.001)	0.022*** (0.004)	-0.006*** (0.002)	0.003 (0.001)	-0.042*** (0.003)	-0.015*** (0.001)	0.022*** (0.004)	-0.008*** (0.002)	0.003* (0.002)	-0.042*** (0.003)
Less than primary	0.117*** (0.034)	0.310*** (0.068)	0.064 (0.041)	0.125*** (0.041)	0.071 (0.058)	0.123*** (0.033)	0.314*** (0.068)	0.058 (0.039)	0.136*** (0.041)	0.070 (0.058)	0.120*** (0.034)	0.311*** (0.068)	0.065 (0.041)	0.137*** (0.041)	0.071 (0.058)
Primary	-0.310*** (0.017)	-0.370*** (0.034)	-0.182*** (0.021)	-0.463*** (0.021)	-0.224*** (0.029)	-0.319*** (0.017)	-0.370*** (0.034)	-0.202*** (0.020)	-0.471*** (0.021)	-0.227*** (0.029)	-0.313*** (0.017)	-0.370*** (0.034)	-0.189*** (0.021)	-0.466*** (0.021)	-0.224*** (0.029)
Secondary	-0.128*** (0.012)	-0.260*** (0.023)	0.029 (0.016)	-0.108*** (0.019)	-0.150*** (0.020)	-0.135*** (0.012)	-0.260*** (0.023)	0.014 (0.015)	-0.120*** (0.018)	-0.151*** (0.020)	-0.130*** (0.012)	-0.260*** (0.023)	0.027 (0.015)	-0.101*** (0.019)	-0.150*** (0.020)
University	0.195*** (0.013)	0.076*** (0.021)	0.309*** (0.019)	0.030 (0.031)	0.191*** (0.018)	0.182*** (0.013)	0.075*** (0.021)	0.277*** (0.018)	0.023 (0.030)	0.189*** (0.018)	0.194*** (0.013)	0.076*** (0.021)	0.308*** (0.018)	0.042 (0.031)	0.191*** (0.018)
Age	0.096*** (0.001)	0.193*** (0.002)	0.057*** (0.001)	0.055*** (0.001)	0.175*** (0.002)	0.090*** (0.001)	0.193*** (0.002)	0.047*** (0.001)	0.050*** (0.001)	0.174*** (0.002)	0.095*** (0.001)	0.193*** (0.002)	0.056*** (0.001)	0.054*** (0.001)	0.174*** (0.002)
Age square	-0.124*** (0.001)	-0.256*** (0.003)	-0.077*** (0.002)	-0.074*** (0.002)	-0.217*** (0.002)	-0.117*** (0.001)	-0.255*** (0.003)	-0.066*** (0.002)	-0.069*** (0.002)	-0.216*** (0.002)	-0.123*** (0.001)	-0.256*** (0.003)	-0.076*** (0.002)	-0.074*** (0.002)	-0.217*** (0.002)
Muslims	0.070* (0.035)	0.184*** (0.068)	0.008 (0.042)	0.094* (0.038)	-0.121 (0.084)	0.098*** (0.034)	0.186*** (0.068)	0.043 (0.040)	0.169*** (0.037)	-0.124 (0.084)	0.070* (0.035)	0.184*** (0.068)	0.009 (0.042)	0.106*** (0.038)	-0.127 (0.084)
Catholics	0.156*** (0.035)	0.136* (0.068)	0.152*** (0.042)	0.250*** (0.038)	-0.124 (0.084)	0.170*** (0.034)	0.139* (0.068)	0.161*** (0.040)	0.263*** (0.037)	-0.124 (0.084)	0.162*** (0.035)	0.138* (0.068)	0.164*** (0.042)	0.266*** (0.038)	-0.128 (0.084)
Protestants	0.120*** (0.036)	0.010 (0.070)	0.144*** (0.043)	0.239*** (0.039)	-0.189* (0.086)	0.147*** (0.035)	0.015 (0.070)	0.174*** (0.042)	0.262*** (0.038)	-0.185* (0.085)	0.128*** (0.036)	0.012 (0.070)	0.160*** (0.043)	0.252*** (0.039)	-0.194* (0.085)
Animisms	0.301*** (0.035)	0.274*** (0.069)	0.301*** (0.042)	0.350*** (0.038)	0.052 (0.089)	0.260*** (0.034)	0.269*** (0.069)	0.233*** (0.041)	0.315*** (0.037)	0.053 (0.089)	0.295*** (0.035)	0.273*** (0.069)	0.292*** (0.042)	0.339*** (0.038)	0.056 (0.089)
electricity	0.033*** (0.008)	0.057*** (0.012)	0.058*** (0.010)	0.261*** (0.024)	0.084*** (0.008)	0.086*** (0.008)	0.065*** (0.012)	0.122*** (0.010)	0.271*** (0.023)	0.091*** (0.008)	0.046*** (0.008)	0.061*** (0.012)	0.071*** (0.010)	0.248*** (0.024)	0.086*** (0.008)
Cell phone	0.078*** (0.006)	0.041*** (0.011)	0.111*** (0.008)	0.078*** (0.011)	0.055*** (0.008)	0.095*** (0.006)	0.042*** (0.011)	0.138*** (0.008)	0.150*** (0.011)	0.054*** (0.008)	0.079*** (0.006)	0.040*** (0.011)	0.114*** (0.008)	0.092*** (0.011)	0.056*** (0.008)
Rural areas	0.571*** (0.006)	0.461*** (0.011)	0.686*** (0.007)			0.578*** (0.006)	0.462*** (0.011)	0.677*** (0.007)			0.569*** (0.006)	0.462*** (0.011)	0.677*** (0.008)		
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	598629	273492	325137	436554	162075	598629	273492	325137	436554	162075	598629	273492	325137	436554	162075

Note: Robust-standard errors in parentheses, *p<0.05, **p<0.01, ***p<0.001.

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International Inflation Synchronization and Implications[†]

By SORA CHON[*]

This study analyzes global inflation synchronization and derives policy implications for the Korean economy. Unlike previous studies that assume a single global inflation factor, this study investigates if inflation in Korea can be explained further by other global inflation factors. Our principal component analysis provides three principal components for global inflation that are linked to the Korea inflation rate — the first component is closely related to OECD inflation, and the second and third components reflect China's inflation. This study empirically demonstrates via in-sample fitting and out-of-sample forecasting that the three principal components of global inflation play a significant role in explaining and predicting Korean inflation in the short-term, while their role is limited in the mid-term. Domestic macroeconomic variables are found to be more important for the mid-term movements of the Korean inflation rate. The empirical results here suggest that the Bank of Korea should focus more on domestic economic conditions than on global inflation when implementing monetary policy because global factors are likely to be already reflected in domestic macro-variables in the mid-term.

Key Word: Inflation Rates, Monetary Policy, Forecasting,
              Principal Component Model, LASSO
JEL Code: E31, E37, E5

I. Introduction

Many theoretical inflation models, represented by the Phillips curve, predict that there exists a meaningful relationship between economy activity and inflation. However, recent studies provide empirical evidence that the link between the real economy and inflation has weakened or disappeared since early 2000s. The macroeconomic phenomenon which casts doubt on the theoretical prediction is referred to as the *'missing disinflation puzzle'*. Regarding new empirical findings, special attention is paid to the role of a global inflation factor that triggers simultaneous

movements in many countries' inflation rates. Many studies in the literature argue that the missing disinflation puzzle is partially attributed to the changed importance of the global inflation factor in recent decades (e.g., Ciccarelli and Mojon, 2010; Mumtaz and Surico, 2012; Mikolajun and Lodge, 2016).

Global inflation synchronization is also linked to the low inflation rates commonly observed in major developed countries approximately since 2012. For instance, inflation rates were close to 0% in European countries and in the United States during this period. Sluggish inflation raises concern about deflation along with prolonged economic downturns, motivating central banks to implement non-traditional monetary policies such as massive quantitative easing to bring inflation rates up to their target rates. This new policy instrument has led to a sharp rise in asset prices in the capital markets via the excessive liquidity supply and low interest rates. As such, global inflation synchronization has a deep connection not only to inflation but also to various parts of the economy. Currently, many studies, such as that by Constâncio (2014), are underway. Moreover, central banks and international organizations are closely watching this unprecedented phenomenon. Related to this Hall (2011) and Christiano *et al*. (2015) study how low inflation and a slow economic recovery are connected to the causes of the Great Recession.

The aim of this study is to suggest policy implications for the Korean economy associated with global inflation synchronization. Considering that the Korean economy heavily relies on international trade, it would be important to understand how the global phenomenon affects inflation in Korea. The Korea inflation rate has continued to fall below the Bank of Korea's inflation target rate in recent years. This could be a natural consequence of Korea being more affected by the low level of the global inflation factor rather than by certain domestic factors.

This study is related to previous studies in the literature. Ciccarelli and Mojon (2010) empirically demonstrate that a single global inflation factor can suitably explain the inflation rates of many countries and allows for improved inflation forecasting. Borio and Filardo (2007) show that structural changes in the global aggregate demand explain global inflation dynamics. Melitz and Ottaviano (2008) point to trade liberalization as a source of global inflation synchronization. Cecchetti *et al.* (2007), Rogoff (2003), Mumtaz and Surico (2012), and Conti *et al.* (2017) emphasize the role of traditional monetary policies on inflation synchronization and low inflation. Mumtaz and Surico (2012) show that the low inflation has been commonly observed in many developed countries since 1980s and argue that such a change in the inflation dynamics is directly linked to global currency depreciation. Lastly, Mikolajun and Lodge (2016) provide evidence that a global inflation factor explains the inflation rates of individual countries well, but the influence of the global factor is already absorbed in domestic macro-variables. They conclude that there is no need to consider the global factor separately when explaining the inflation rates of individual countries.

Unlike the aforementioned papers, this study considers the possibility that there exist several global inflation factors rather than just one. To extract potential factors, a principal component analysis (PCA) is applied to panel data of inflation rates and the estimated principal components are then employed to explain and predict Korean inflation rates. A particularly striking result is that the first principal component is closely related to the OECD weighted average inflation rate, while the second and

third principal components are closely related to China's inflation rate.

One of the difficulties in an empirical analysis of Korean inflation is that the sample size of Korean macroeconomic variables is not yet sufficiently accumulated for reliable statistical inference, as the Bank of Korea changed its monetary policy base to inflation targeting in 1998. Due to the lack of data information, it is practically difficult to carry out a precise quantitative analysis in empirical models in which both global inflation factors and domestic macro-variables are included. This study resolves this practical issue by employing the LASSO (Least Absolute Shrinkage and Selection Operator) methodology of Tibshirani (1996). LASSO is a widely used technique in the machine learning literature in cases involving a limited amount of data compared to the number of coefficients.

The main empirical findings of this study are as follows. The global inflation principal components play important roles in explaining and predicting Korea's inflation rate in the short-term. However, in the mid-term, the performance of the global inflation principal components in terms of in-sample fitting and out-of-sample forecasting substantially diminishes. On the other hand, Korean macro-variables provide better explanatory and prediction power in the mid-term than the global inflation principal components. In light of this point, the recent economic downturn in the global economy and the resulting low global inflation may have only a limited effect on the inflation rate in Korea in the mid-term. In addition, the Bank of Korea, whose policy goal is to keep domestic prices stable, appears to be more apt to adjust its monetary policy in accordance with Korean economic situations. However, this does not necessarily mean that the Bank of Korea should ignore global inflation factors. Rather, it means that because global factors change Korean macro-variables in the mid-term, it is better carefully to monitor the macro-variables which already reflect global economic conditions when enacting its monetary policies.

The composition of this paper is as follows. In Section 2, we examine the inflation synchronization phenomenon using panel data for inflation rates. Also, we estimate the global inflation factors via PCA and shows how inflation in each individual country is explained by common factors. In Section 3, international and domestic macro-variables relevant to the inflation rate of Korea are extracted from LASSO. Section 4 discusses policy implications based on the results of Sections 2 and 3. Section 5 provides concluding remarks.

II. Inflation Synchronization Phenomenon

Researchers have been actively investigating global synchronization in the real economy and inflation since the early 2000s. A representative study is that by Ciccarelli and Mojon (2010). They argue that similar patterns in long-term inflation trends are observed in many developed countries.

Figure 1 and Figure 2 show the inflation trends of major developed countries (G7) and Korea. As shown in the figure, inflation in developed countries has shown a highly consistent trend since the late 1990s. Clearer co-movements are observed during the financial crisis. The Korean inflation rate has also been characterized by inflation synchronization since the late 1990s. One noticeable feature is that inflation synchronization exists not only in the mid-term (annual inflation rate in Figure 2)
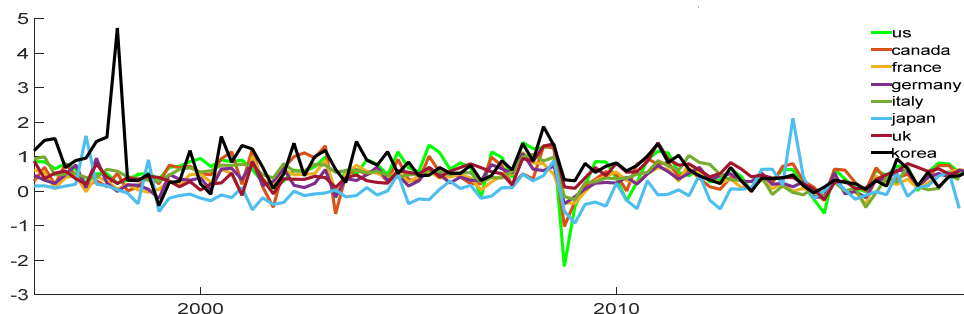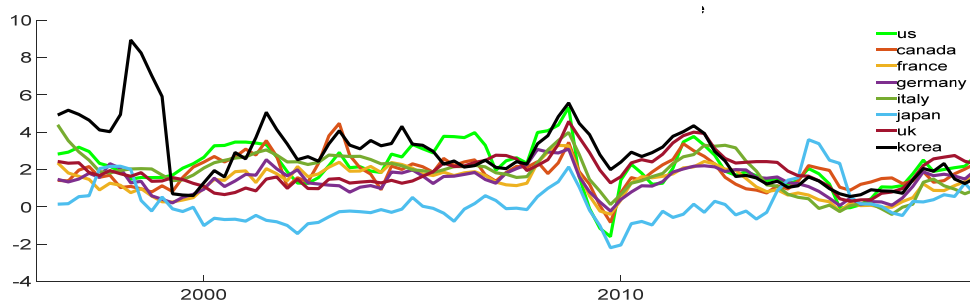
FIGURE 1— INADVERTENT INFRINGEMENT

Note: The solid black line indicates the inflation rate of Korea.

Source: OECD (https://data.oecd.org/price/inflation-cpi.htm, accessed: 15 October 2018). Sample period: Q1 1985 to Q2 2018.

FIGURE 2— CPI INFLATION RATE COMPARED TO THE SAME QUARTER IN THE PREVIOUS YEAR: G7 COUNTRIES AND KOREA

Note: The solid black line indicates the inflation rate of Korea.

Source: OECD (https://data.oecd.org/price/inflation-cpi.htm, accessed: 15 October 2018). Sample period: Q4 1985 to Q2 2018.

but also in the very short-term (quarterly inflation rate in Figure 1).

To demonstrate empirically the rise of inflation synchronization further, the inflation rates of 22 OECD countries and China are reported in Figure 3. The 22 OECD countries are Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Japan, Luxembourg, Netherland, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, U.K., and the United States. The OECD countries were also used in the study of Ciccarelli and Mojon (2010).

It is clear that inflation in OECD countries has seen constantly showing very similar movements since the late 1990s, as in the case of the G7 countries. Next, in Figure 4 we report how the cross-sectional variance of the inflation rates changes over time. At each quarter, the sample variance is calculated using the inflation rates in Figure 3. The inflation variance continues to fall since the mid-1980s, reaching 0.5 and less since the late 1990s. This can be interpreted as meaning that the inflation rates have varied similarly relative to each other for the last 20 years.

In order to check how the correlation between Korean inflation and other OECD countries' inflation rates has been changing over time properly, which is the main
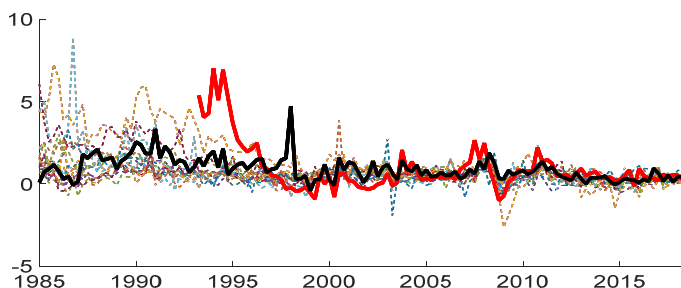
FIGURE 3— CPI INFLATION RATE: OECD COUNTRIES AND CHINA

Note: 1) The solid black line indicates the inflation rate of Korea, 2) The dotted lines indicate the inflation rates of other OECD countries, 3) Only OECD countries included in the study by Ciccarelli and Mojon (2010) are included in the data.

Source: OECD (https://data.oecd.org/price/inflation-cpi.htm, accessed: 15 October 2018). Sample period: Q1 1985 to Q2 2018.
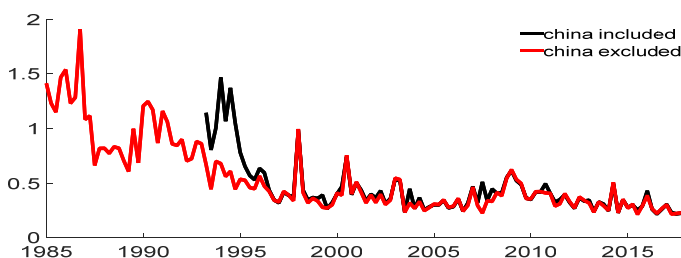
FIGURE 4— CROSS-SECTIONAL VARIANCE OF INFLATION RATES

Source: OECD (https://data.oecd.org/price/inflation-cpi.htm, accessed: 15 October 2018). Sample period: Q1 1985 to Q2 2018.

goal of this study, the full sample period is divided into sections before and after 1998. Note that the Bank of Korea began inflation targeting in 1998. The sample correlation is computed using pairs of the inflation rates between Korea and each OECD country. The average of the sample correlations is used for the analysis. Before 1998, China's inflation rate is excluded in the computation. The average correlation before 1998 is only 0.098, while it is 0.27 after 1998. This means that the correlation between Korean inflation and inflation in other OECD countries has increased dramatically over the last 20 years.

In order to check how the correlation between Korean inflation and other OECD countries' inflation rates has been changing over time properly, which is the main goal of this study, the full sample period is divided into sections before and after 1998. Note that the Bank of Korea began inflation targeting in 1998. The sample correlation is computed using pairs of the inflation rates between Korea and each OECD country. The average of the sample correlations is used for the analysis. Before 1998, China's inflation rate is excluded in the computation. The average correlation before 1998 is only 0.098, while it is 0.27 after 1998. This means that the correlation between Korean inflation and inflation in other OECD countries has increased dramatically over the last 20 years.

Currently, the central banks of major developed countries are implementing

TABLE 1— INFLATION STABILIZATION GOALS: MAJOR DEVELOPED COUNTRIES AND KOREA

Year	US	Canada	Japan	EU	Korea
2012	2	2	1	2	3
2013	2	2	2	2	3
2014	2	2	2	2	3
2015	2	2	2	2	3
2016	2	2	2	2	2

Note: When the inflation stability target is reported as a range, i.e., other than a single point, the median value of the range is reported here.

Source: 1) The inflation stability targets for the major developed countries are described in Contessi *et al.* (2014). 2) The Bank of Korea (https://ecos.bok.or.kr/, accessed: 15 October 2018). 3) OECD (https://data.oecd.org/price/inflation-cpi.htm, accessed: October 15, 2018).
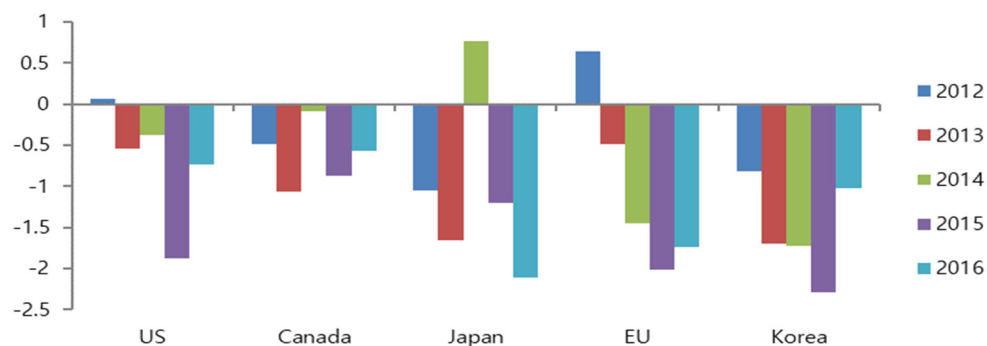
FIGURE 5— DEVIATION OF THE INFLATION RATE FROM THE TARGET LEVEL

Note: When the inflation stability target is reported as a range, i.e., other than a single point, the median value of the range is reported here. The numbers in the left column are years for the data.

Source: 1) The inflation stability targets for the major developed countries are described in Contessi *et al*. (2014). 2) The Bank of Korea (https://ecos.bok.or.kr/, accessed: 15 October 2018). 3) OECD (https://data.oecd.org/price/inflation-cpi.htm, accessed: October 15, 2018).

inflation targeting, that is, monetary policy intended to hold inflation to a moderate level. However, these central bank policies have not been successful. Table 1 shows the annual inflation target levels of selected major countries and Korea from 2012 to 2016. Also see Figure 5 for how much actual inflation rates deviate from the target rates in the developed countries. It is clearly shown in Figure 5 that the actual inflation rate in Korea substantially differs from the target rate set by the Bank of Korea from 2012 to 2016. Despite the fact that the deviation of actual inflation from its target rate is persistent, its underlying cause has not yet been identified. However, the global inflation synchronization shown in Figures 1-4 suggests the possibility that some global factors not controlled by the monetary policy of the Bank of Korea may influence the inflation rate in Korea.

A. *Inflation Principal Components*

This section focuses on the effect of global inflation synchronization on CPI (consumer price index) inflation in Korea. To extract a global inflation factor, Ciccarelli and Mojon (2010) conducted a dynamic factor analysis to the 22 OECD

countries mentioned in the previous section. Their study provides evidence that a single global inflation factor accounts for 50% to 90% of inflation movements in many countries. The result is especially noticeable for developed countries.

Ciccarelli and Mojon (2010) assume that only one global inflation factor matters in the explanation of the inflation rates of individual countries. In order to validate this assumption empirically, this study carefully examines five independent principal components as potential global factors that can explain Korean inflation. It is important to note that the main goal of this analysis is not statistically to choose the correct number of common factors. A principal component that does not have strong in-sample explanatory power for other countries may have strong in-sample explanatory or out-of-sample forecasting power with regard to Korean inflation.

This study estimates several global inflation factors through a principal component analysis (PCA). The factor analysis used in Ciccarelli and Mojon (2010) is relatively easy to interpret in that it assumes that while a global factor affects all individual countries, idiosyncratic shocks to individual countries cannot affect the global factor. However, as the number of common factors increases in the factor model, the number of coefficients to be estimated rapidly increases. It is also necessary to make strong assumptions about how each common factor evolves over time and about how common factors differ from each other. China's inflation data used in our analysis are available only from the mid-1990s in the World Bank database. Therefore, inaccurate estimates are likely due to the lack of data if we adopt the dynamic factor model of Ciccarelli and Mojon (2010). On the other hand, PCA, which is a non-parametric estimation method, does not require us to estimate many coefficients for statistical inference compared to the number of observations. Many papers, such as that by Stock and Watson (2011), theoretically show that the principal components of PCA well approximate common factors of a factor analysis when the cross-section sample size is large enough. Although the cross-section sample size of the data of this study is not that large, we obtain empirical evidence by which the first principal component resembles the OECD average inflation rate, consistent with other studies showing that the common factor estimated by dynamic factor models is nearly identical to the OECD average inflation rate.

The j-th principal component is given by a linear function of the inflation rates $(y_{1,t}, y_{2,t}, \cdots, y_{n,t})$ of n countries, and each principal component is constructed by different weights $(w_{j,1}, w_{j,2}, \cdots, y_{j,n}, \ j = 1, 2, \cdots, 5)$, as follows:

(1)
$$f_{j,t} = w_{j,1}y_{1,t} + w_{j,2}y_{2,t} + \cdots + w_{j,n}y_{n,t}.$$

The first principal component ($f_{1,t}$) is the component that best describes the inflation rates of n countries collectively. The order of the other principal components is determined according to their in-sample explanatory power levels.

In addition to the inflation data from the 22 OECD countries used in Ciccarelli and Mojon (2010), our study estimates the principal components with China's CPI inflation rate. China's share of exports in international trade has increased significantly over the past two decades. This simply means that the Chinese economy now has a non-negligible influence in the global market. Therefore, excluding China in the

analysis, as in Ciccarelli and Mojon (2010), could result in misleading policy implications. Therefore, this study additionally considers the linkage of the global economy with China.

Table 2 shows how well the five principal components account for the inflation rates for all countries in the sample and for certain selected developed countries. The first component accounts for approximately 50% of the inflation rate panel data. The second and third components account for 7.6% and 5.2% of the data, respectively. On average, the first three components explain about 63% of the world's inflation rates.

From the third column to the last column, Table 2 shows the in-sample explanatory power levels of the five components for the major developed countries. Ciccarelli and Mojon (2010) argue that a single global inflation factor (or the first principal component) has more explanatory power compared to the result in Table 2. There are two reasons for this difference. Firstly, Ciccarelli and Mojon (2010) intensively analyze the inflation dynamics before the 2008 financial crisis, while this study adds more data collected over the past ten years. Secondly, unlike the common factor analysis of Ciccarelli and Mojon (2010), PCA assumes several independent components; consequently, each component could have less explanatory power than a single common factor extracted by their common factor analysis.

A drawback of PCA is that interpretations of the estimated principal components are difficult. To resolve the interpretation issue, we examine how countries' first, second and third principal components are largely reflected. Figure 6 reports the absolute values of the estimated weights of the principal components.

Figure 6 shows that the first principal component widely reflects inflation in the major developed countries. The second and third principal components reflect China's inflation. This implies that an empirical analysis without China's inflation data could lead to statistical errors. This result may be viewed as a natural consequence of the Chinese economy having significant impacts on the global economy since the 1990s.

TABLE 2— IN-SAMPLE EXPLANATORY POWER VALUES OF PRINCIPAL COMPONENTS (PC)

Country	Average	US	China	Canada	France	Germany	Italy	Japan	UK
PC 1 ($f_{1,t}$)	49.8	63.6	19.4	50.2	75.2	64.3	67.1	2.0	32.1
PC 2 ($f_{2,t}$)	7.6	3.7	51.6	2.6	0.3	6	4.6	24.1	7.6
PC 3 ($f_{3,t}$)	5.2	0.7	19.7	5.4	0.0	0.0	0.6	3.3	4.3
PC 4 ($f_{4,t}$)	3.9	0.0	0.5	0.0	1.4	0.6	0.2	10.2	8.8
PC 5 ($f_{5,t}$)	3.9	0.0	5.9	9.8	0.3	0.4	0.0	16.8	0.3

Note: 1) The weights that construct the principal components are estimated using data from the first quarter of 1998 to the second quarter of 2018. 2) In order to avoid the quantitative problem of the domestic price prediction model to be used in Section 2, such as the redundant use of data, the domestic consumer price is not used to estimate the principal component.

Source: CPI inflation rate data - World Bank (https://data.worldbank.org/, accessed: October 15, 2018), Estimates – author's calculations.
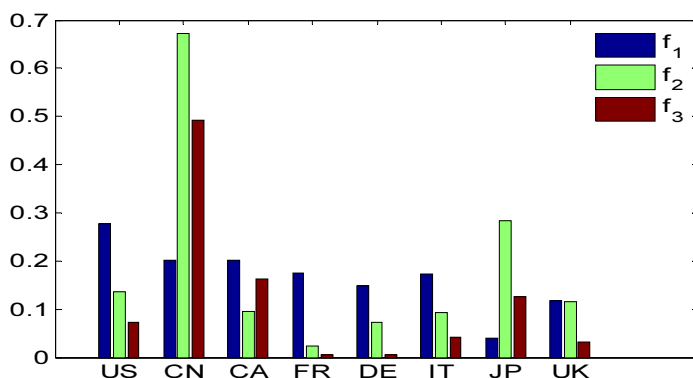
FIGURE 6— ABSOLUTE VALUES OF WEIGHTS FOR PRINCIPAL COMPONENTS: MAJOR DEVELOPED COUNTRIES

Note: f_i represents the ith component.

Source: Inflation data - World Bank, weights for principal components - author's calculations.

Figure 7 shows the weighted average of OECD countries' inflation rates according to the real GDP and the estimated first principal component. Except one or two years in the late 1990s, the two series show nearly identical movements. Ciccarelli and Mojon (2010) also empirically demonstrate that the single global inflation factor is nearly identical to the OECD inflation rate. Figure 7 implies that the first principal component estimated in this study also can be interpreted as the global inflation factor estimated by Ciccarelli and Mojon (2010).

Figure 8 shows that the second and third principal components collectively contain information about China's inflation. In Figure 8, the blue line represents the difference between the second and third principal components, and the red line represents China's inflation rate. The result that the linear combination of the two principal components represents inflation in China and these components explain inflation at a rate of approximately 13% of the major OECD countries has not been published in previous studies.

Lastly, in PCA, a mathematical sign is not meaningless. Consequently, it is possible to multiply the second principal component by -1 and define it as a new
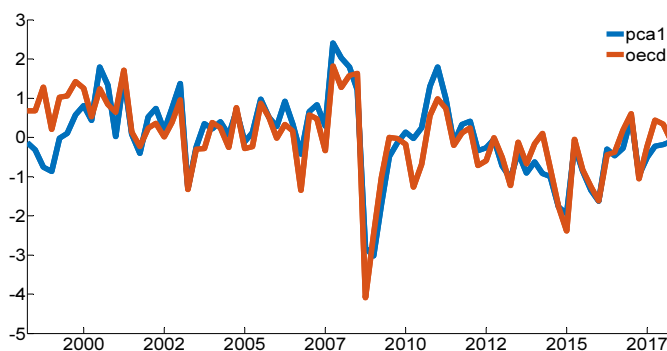
FIGURE 7— FIRST PRINCIPAL COMPONENT AND OECD AVERAGE INFLATION RATE

Note: pca1: first principal component; OECD: OECD Inflation.

Source: author's calculations.
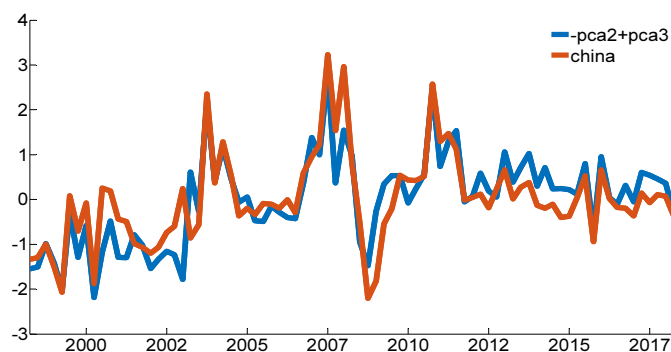
FIGURE 8— DIFFERENCE BETWEEN THE SECOND AND THIRD PRINCIPAL COMPONENTS AND CHINESE INFLATION

Note: pca2: second principal component; pca3: third principal component; china: China's inflation rate.

Source: author's calculations.

principal component. Accordingly, China's inflation rate can be seen as the sum of the third and newly defined second principal component.

The fourth and fifth principal components may also have important meanings, but a direct interpretation is not necessary because they are not selected by our statistical procedure in the models that explain Korea's inflation rate in the next section.

The parallel analysis developed by Horn (1965) has been widely used to determine the number of principal components or common factors in practice. See O'Connor (2000), Dinno (2009), and Dobriban and Owen (2019) for details about this implementation and recent developments. The method is based on the eigenvalues of the covariance matrix for bootstrapped samples. In the test, each eigenvalue extracted from the actual data is compared to a set of counterpart eigenvalues extracted from randomly generated data sets via bootstrapping. If the actual eigenvalue is larger than a percentile of the simulated eigenvalues pre-specified by a researcher, the principal component corresponding to the tested eigenvalue is statistically significant. With a cutoff percentile of 0.95, the parallel analysis indicates that only the first principal component is statistically significant, whereas the second and third principal components are not. The critical values are estimated to be 2.178, 1.952, and 1.796 for the first three principal components. The actual eigenvalues are estimated to be 10.906, 1.788 and 1.188 for the first three principal components. This result is not surprising given that the second and third principal components explain only 7.6% and 5.2% of the whole dataset, as shown in Table 2. However, the main objective of this study is not to determine the number of statistically significant principal components. Instead, the main goal is to determine the presence of one or more common factors that can explain the Korea inflation rate. Despite the fact that the parallel analysis suggests only a single common factor, it does not necessarily mean that other factors are meaningless with regard to the Korean inflation rate.

Korea's inflation and the three estimated principal components are compared directly in Figure 9. To simplify this comparison, Korea's inflation rate and the estimated principal components are normalized. The first principal component shows movements similar to those of Korea's inflation rate in the short-term and long-term. However, it is difficult to find direct relationships between the second or
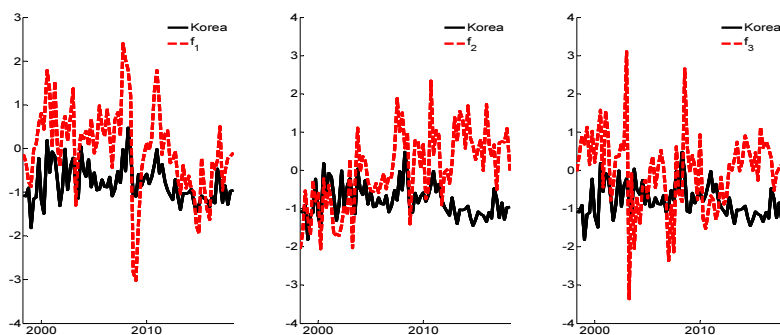
FIGURE 9— KOREAN CPI INFLATION RATE AND THE FIRST THREE PRINCIPAL COMPONENTS

Note: Korea CPI price - Bank of Korea.

Source: author's calculations.

third principal component and Korea's inflation rate through a visual inspection. In the next section, a detailed statistical analysis of the relationship between Korea's inflation rate and the principal components will be conducted. Another interesting finding in this section is that the correlation between Korea's inflation rate and the first principal component changes before and after 1998. The sample correlation is -0.17 before 1998 and increases to 0.63 after 1998.

For a robustness check, PCA is conducted using expanded inflation rate data from the Czech Republic, Mexico, Poland, and Korea in addition to the 22 OECD countries used in Ciccarelli and Mojon (2010). This result is reported in Table 3 and Figure 10. As before, the first principal component accounts for 45% of the inflation rate movements in all of the countries included in the analysis.

A notable difference can be found in the interpretation of the second and third principal components. As shown in Figure 10, the second principal component is mainly formed by China's inflation rate, as before. However, the third principal component is driven in large part by Japan's inflation rate. The third principal component reported in Figure 10 is most likely related to the fourth or fifth principal

TABLE 3— AVERAGE AND INDIVIDUAL EXPLANATORY POWER VALUES OF THE PRINCIPAL COMPONENTS

Country	Average	Korea	US	China	Canada	France	Germany	Italy	Japan	UK
PC 1 ($f_{1,t}$)	45.5	41.1	59.4	14.2	43.3	70.7	61.5	70.1	1.0	28.3
PC 2 ($f_{2,t}$)	9.0	6.1	2.9	39.7	3.3	5.4	7.7	0.0	5.8	6.1
PC 3 ($f_{3,t}$)	5.6	0.0	5.1	0.2	11.6	0.0	0.3	3.0	23.1	2.2
PC 4 ($f_{4,t}$)	3.5	1.1	0.0	17.9	5.6	0.0	1.2	0.2	0.0	2.2
PC 5 ($f_{5,t}$)	3.4	4.3	0.0	13.7	0.7	0.9	0.0	0.4	18.9	0.3

Note: 1) The weights used to construct the principal components are estimated using data from the first quarter of 1998 to the second quarter of 2018.

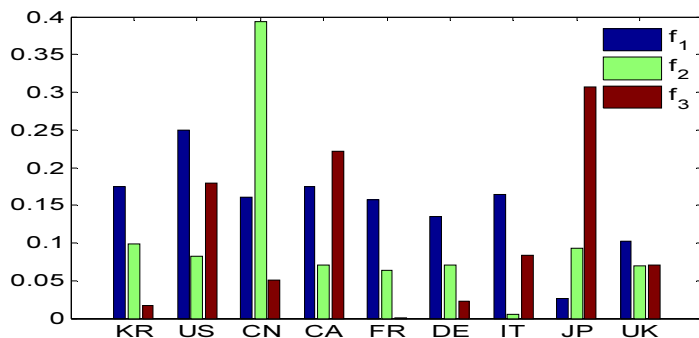*Source:* CPI - World Bank; Estimates - author's calculations.

FIGURE 10— ABSOLUTE VALUES OF WEIGHTS FOR PRINCIPAL COMPONENTS:
MAJOR DEVELOPED COUNTRIES (ROBUSTNESS CHECK)

Note: f_i represents the ith component.

Source: Inflation data - World Bank, weights for principal components - author's calculations.

component obtained from the previous PCA. This can be deduced from the result in Table 3, which shows that the fourth and fifth principal components well explain Japan's inflation rate.

Next, we compare the first and second principal components estimated by the expanded data. Figure 11 clearly shows that the first principal component and the OECD inflation rate are nearly identical, as before. Moreover, in Figure 12, the second principal component and China's inflation rate move very similarly in the mid-term and long-term. This means that although there are subtle differences between the results of the original data and the expanded data, China's inflation rate is directly related to the underlying principal components.
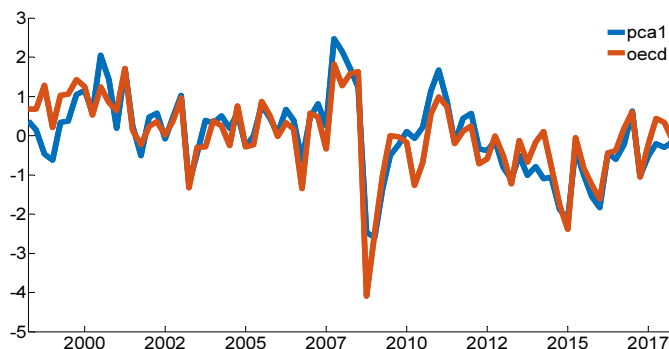
FIGURE 11— FIRST PRINCIPAL COMPONENT AND THE OECD AVERAGE INFLATION RATE

Note: pca1: first principal component; OECD: OECD Inflation.

Source: author's calculations.
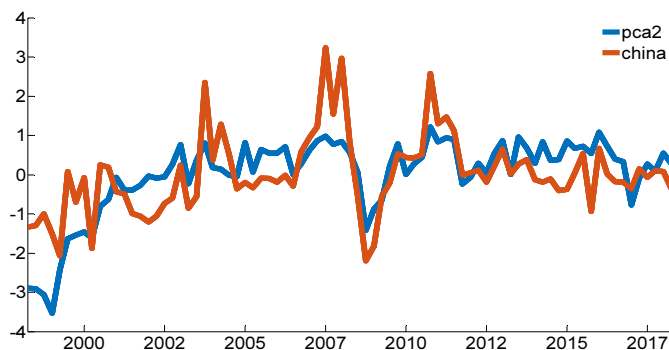
FIGURE 12— FIRST PRINCIPAL COMPONENT AND OECD AVERAGE INFLATION RATE

Note: pca2: Second principal component; china: China's Inflation.

Source: author's calculations.

B. *Determinants of Global Inflation Factors*

The goal of this section is to analyze the economic variables that explain global inflation. To this end, we adopt a simple linear regression model. Table 4 describes the explanatory and dependent variables included in the model. The dependent variable is the average (annual) OECD inflation rate. When computing the average, we use individual inflation rates weighted by corresponding real GDPs. Based on the result of the PCA in Section 2 and the results of Ciccarelli and Mojon (2010), both the first principal component and the OECD inflation rate can be interpreted as a global inflation factor. Because most explanatory variables are only observed annually, the annual OECD inflation rate is used instead of the first principal component estimated with quarterly data in Section 2.

The first explanatory variable represents the aggregate labor supply of OECD countries. The second explanatory variable represents the indicator of the internal trade importance. The third variable presents the monetary policy in OECD countries. The fourth and fifth variables indicate the aggregate production activity in OECD countries. The last variable is the global oil price, which is an important production factor. The two variables for the OECD economic activity participation rate and the OECD trade volume are observed annually. Thus, the observations of the other explanatory variables are adjusted to an annual frequency. The empirical data begin from 1981 because the aggregate OECD currency volume (M2) has been reported since 1981.

Table 5 shows the ordinary least squares (OLS) estimates based on the data from 1995 to 2016. To avoid the multicollinearity problem, only one of the two variables that represent production activity (OECD Industrial Production Index and OECD Real GDP Cycle) is included in the model. Of the five explanatory variables, only two are statistically significant. The most important variable is the OECD M2 growth rate, which represents the monetary policy. As shown in Table 5, the estimated coefficient for the OECD M2 growth rate is statistically significant at the 1% significance level. Additionally, the absolute value of the estimate is highest among all of the other estimated coefficients. This result is in line with economic theory.

TABLE 4— EXPLANATORY VARIABLES FOR OECD INFLATION

Dependent variable: annual OECD inflation		
Explanatory variable	Source	Definition and remarks
OECD Economic Activity Participation Rate (z_{1t})	OECD	(Employed + Unemployed) / Population Aged 15 and Over, Annual rate of Change
OECD Trade Volume Relative to GDP (z_{2t})	World Bank	Trade Amount / GDP
OECD M2 (z_{3t})	OECD	Annual Change Rate
OECD Industrial Production Index (z_{4t})	OECD	Annual Change Rate
OECD Real GDP Cycle (z_{5t})	World Bank	Hodrick–Prescott filter ($\lambda = 7$)
Dubai Oil Prices (z_{6t})	Federal Reserve Bank, St. Louis	Annual Change Rate

Note: The variable collection corresponds to the suggestion of Ravn and Uhlig (2002).

Source: OECD; Data period: 1981 to 2016.

TABLE 5— OLE ESTIMATES - 1

Dependent variable: OECD inflation					
Variables	z_{1t}	z_{2t}	z_{3t}	z_{4t}	z_{5t}
Estimates (Standard error)	0.03 (0.277)	-0.102** (0.047)	0.341** (0.134)	0.306 (0.225)	0.014* (0.007)
Period: 1995 ~ 2016; Number of Observations: 22; R-squared = 0.78					
Estimates (Standard error)	-0.178 (0.349)	-0.147*** (0.039)	0.453*** (0.082)	0.195 (0.268)	70.005 (0.009)

Period: 1981 ~ 2016; Number of Observations: 36; R-squared=0.82

z_{1t}: OECD Economic Activity Participation Rate
z_{2t}: OECD Trade volume relative to GDP
z_{3t}: OECD M2
z_{4t}: OECD Industrial Production Index
z_{5t} OECD real GDP Cycle
z_{6t}: Dubai Oil Prices

Note: ***: 1% statistical significance, **: 5% statistical significance, *: 10% statistical significance.

The second most important explanatory variable is the trade/GDP ratio. An increase in the trade/GDP ratio can be seen as a sign of global trade liberalization. A study by Melitz and Ottaviano (2008) theoretically shows that trade liberalization triggers commodity competition and as a result lowers the price levels of many countries. They also provide empirical evidence for the theoretical prediction. Other variables can be interpreted, but their estimated coefficients are not statistically significant. Thus, I omit them here.

For a robustness check, the sample period is extended to from 1981 to 2016. As before, the M2 growth rate and the trade/GDP ratio are statistically significant at the 1% significance level. The Dubai oil price is a statistically significant variable at the 10% significance level only when using the recent sample from 1995 to 2016.

TABLE 6— OLE ESTIMATES - 2

Dependent variable: OECD inflation					
Variables	z_{1t-1}	z_{2t-1}	z_{3t-1}	z_{4t-1}	z_{6t-1}
Estimates	0.32	-0.182***	0.317***	-0.089	0.003
(Standard error)	(0.328)	(0.037)	(0.076)	(0.251)	(0.009)
Period: 1981 ~ 2016; Number of observations:36; R-squared=0.82					
Variables	z_{1t}	z_{2t}	z_{3t}	z_{4t}	z_{6t}
Estimates	-0.147	-0.147***	0.455***	0.040	0.005
(Standard error)	(0.346)	(0.039)	(0.082)	(0.073)	(0.009)
Period: 1981 ~ 2016; Number of observations:36; R-squared=0.82					
Variables	z_{1t-1}	z_{2t-1}	z_{3t-1}	z_{4t-1}	z_{6t-1}
Estimates	0.294	-0.188***	0.308***	0.044	-0.000
(Standard error)	(0.323)	(0.037)	(0.076)	(0.067)	(0.009)
Period: 1982~2016; Number of observations:35; R-squared==0.82					

z_{1t}: OECD Economic Activity Participation Rate
z_{2t}: OECD Trade volume relative to GDP
z_{3t}: OECD M2
z_{4t}: OECD Industrial Production Index
z_{5t}: OECD real GDP Cycle
z_{6t}: Dubai Oil Prices

Note: ***: 1% statistical significance, **: 5% statistical significance, *: 10% statistical significance.

Because variables of the same year are used in the regression model, one may be concerned about reverse causality. Therefore, Table 6 reports the result of a model with one-year lagged explanatory variables. The new model with the lagged values of the explanatory variables produces no meaningful change in the estimated coefficients. Furthermore, the result is robust if the OECD Industrial Production Index is used instead of the OECD Real GDP Cycle (OECD Real GDP Cycle results are not reported here).

It is consistent with the traditional theory that an increase in M2 in OECD countries leads to an increase in global inflation. The central banks of many countries have been aggressively using expansionary monetary policy instruments since the 2008 financial crisis. The monetary policy stance has been maintained for more than ten years in the EU and Japan. While as of 2019, the Federal Reserve Bank (Fed) moved from an expansionary policy and started to tighten their balance sheet, many experts expected that the tightening monetary policy cannot last long due to signs of an economic recession.

It is difficult to find a reasonable explanation for the globally low inflation for recent years. For example, from 2012 to 2016, many developed countries experienced low inflation despite the use of aggressive expansionary monetary policies. During most of the time period, actual inflation rates were lower than the corresponding inflation targets.

This study suggests that the rapid growth in international trade is an important driver of the low global inflation. Figure 13 shows the explained part of the OECD inflation rate according to the OECD M2 growth rate. The long-term inflation trend looks similar to the OECD M2 growth trend. However, since the mid-1990s, the OECD inflation rate has declined more rapidly than what the OECD M2 growth suggests.
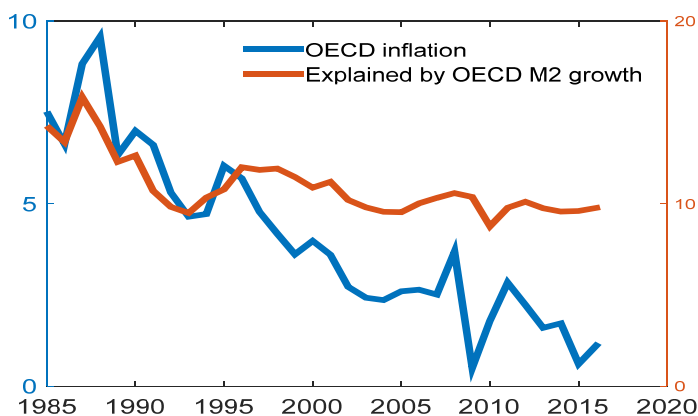
FIGURE 13— OECD INFLATION RATE AND OECD M2 GROWTH

Note: The vertical axis on the left represents the unit of the OECD inflation rate, and the vertical axis on the right represents the unit of the product of the rate of increase in the amount of currency in the OECD and the corresponding coefficient.

Figure 14 plots the unexplained part of the OECD inflation rate according to OECD M2 growth along with the OECD trade/GDP ratio. In the mid-1990s, the OECD trade/GDP ratio dramatically increases. Although China is not a member of OECD, this trend is very similar to China's growth in trade volume since the opening of their economy. Figure 14 shows that the OECD trade/GDP ratio inversely moves together with the unexplained part of the OECD inflation rate. The sharp increase in international trade is linked to global trade liberalization. Melitz and Ottaviano (2008) theoretically show that trade liberalization can trigger product competition and can lower the aggregate price level of a country. The result in Figure 14 provides evidence of this theoretical prediction.

The U.S. government has attempted to resolve the long-lasting trade imbalance with China by imposing high tariffs. Many scholars and policymakers believe that
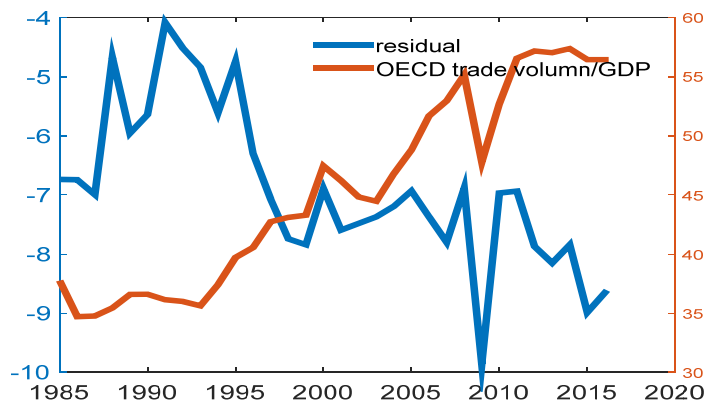

FIGURE 14— RESIDUALS OF THE OECD INFLATION RATE AND OECD TRADE/GDP RATIO

Note: The vertical axis on the left represents the unit for the residual term, where the rate of increase in the amount of OECD currency in OECD inflation is eliminated, and the vertical axis on the right represents the unit for trade against the OECD GDP.

such trade barriers can decrease the aggregate trade volume in the global economy. The aforementioned result predicts that a sharp decrease in international trade can exert strong inflation pressure on many countries in the long-term.

III. In-sample Fitting and Out-of-sample Forecasting Analysis for Korean Inflation

A. *Variable Selection via LASSO (Least Absolute Shrinkage and Selection Operator)*

For a quantitative analysis, this study considers the first five principal components estimated in the previous section and six macro-variables in a linear regression model:

$$\pi_t = \beta_0 + \sum_{p=1}^{4} (\beta_{1,p} f_{1,t-p} + \beta_{2,p} f_{2,t-p} + \cdots + \beta_{5,p} f_{5,t-p})$$
$$+ \sum_{p=1}^{4} (\beta_{6,p} x_{1,t-p} + \beta_{7,p} x_{2,t-p} + \cdots + \beta_{11,p} x_{5,t-p})$$
$$+ \beta_{12} \pi_{t-1} + \beta_{13} \pi_{t-2} + \beta_{14} \pi_{t-3} + \beta_{15} \pi_{t-4} + e_t, \quad E[e_t] = 0,$$

where e_t represents the residual term of the linear regression model. The dependent variable is the QoQ Korea CPI inflation rate. For each variable, including the dependent variable, four lagged values are used as additional explanatory variables.[1]

The macro-variables in the model are explained in detail in Table 7. Domestic macro-variables for the Korean economy included in the model represent the domestic monetary policy, production activity, labor market, and exchange rate. The international macro-variable included in the model is the Dubai oil price. Including the lagged Korea inflation rates, in total 44 explanatory variables are used in the model. The main sample period is from the second quarter of 1998 to the second quarter of 2018, and only quarterly data are used in the analysis. The beginning period is determined by considering the time when the bank of Korea's inflation targeting began.

In the sample, there are only 81 observations. This means that only two observations can be used to estimate one coefficient in the model. Therefore, reasonable statistical inference is not possible with the standard OLS method. Moreover, even if a researcher attempts to reduce the number of variables in the model by excluding unnecessary variables, there are tens of thousands of models that can be constructed from a subset of 44 variables. In this context, choosing an

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[1]A variable having predictive power does not necessarily mean that the variable has a definite causal effect on the dependent variable. In order for the interpretation to hold, we must make a couple of assumptions. The first is that in the empirical model, some of the variations for Korea's inflation rate that are derived by domestic macro-shocks are well controlled by lagged domestic macro-variables. The error term in the model will then be a combination of domestic and global shocks. If a global shock persistently affects a global factor and the global factor affects the Korean inflation rate, the lagged values of the global factor will have predictive power. Thus, the predictive power is indirect evidence of a causal effect under these assumptions. This study implicitly uses these assumptions.

TABLE 7— REGRESSION MODEL VARIABLES FOR DOMESTIC CONSUMER PRICES

Dependent variable: Korea Inflation rate QoQ (π_t)			
Explanatory Variables	Source	Period	Definition and Notes
First Five Principal Components (PC) for Global Inflation (f_t)	Author's calculation	1985:Q3~	The inflation rates of 22 OECD countries and China are used to estimate the principal components. Only the first five components are used for the analysis.
Call rate (x_{1t})	Bank of Korea	1991:Q1~	Daily data, annual interest, quarterly average
M2 (x_{2t})	Bank of Korea	1986:Q1~	Quarterly change rate
Real GDP (x_{3t})	Bank of Korea	1965:Q2~	Quarterly change rate
KRW / dollar exchange rate (x_{4t})	Bank of Korea	1964:Q1~	Average (monthly data) trading base rate Quarterly change rate
Dubai Oil Price (x_{5t})	Federal Reserve Bank, St. Louis	1980:Q2~	Quarterly change rate

Note: The vertical axis on the left represents the unit for the residual term, where the rate of increase in the amount of OECD currency in OECD inflation is eliminated, and the vertical axis on the right represents the unit for trade against the OECD GDP.

Source: Bank of Korea, Period: 1975:Q1~.

optimal model could be a very difficult task. This study adopts a big data technique, the LASSO (Least Absolute Shrinkage and Selection Operator) method, for model selection.[2]

The LASSO method minimizes the following objective function:

$$\min_{\beta} \left[\sum_{t=1}^{T} (\widehat{e_t})^2 + \lambda \left(\sum_{p=1}^{4} \sum_{k=1}^{11} | \tilde{\beta}_{k,p} | + \sum_{k=12}^{15} | \tilde{\beta}_k | \right) \right],$$

$$\widehat{e_t} = \widetilde{\pi_t} - \sum_{p=1}^{4} \left(\widetilde{\beta_{1,p}} \widetilde{f_{1,t-p}} + \widetilde{\beta_{2,p}} \widetilde{f_{2,t-p}} + \cdots + \widetilde{\beta_{5,p}} \widetilde{f_{5,t-p}} \right)$$
$$- \sum_{p=1}^{4} \left(\widetilde{\beta_{6,p}} \widetilde{x_{1,t}} + \widetilde{\beta_{7,p}} \widetilde{x_{2,t}} + \cdots + \widetilde{\beta_{11,p}} \widetilde{x_{5,t}} \right)$$
$$- \widetilde{\beta_{12}} \widetilde{\pi_{t-1}} - \widetilde{\beta_{13}} \widetilde{\pi_{t-2}} - \widetilde{\beta_{14}} \widetilde{\pi_{t-3}} - \widetilde{\beta_{15}} \widetilde{\pi_{t-4}}.$$

In the equation above, λ is a penalty parameter that is set by the researcher. If the OLS estimate of a coefficient for an explanatory variable is close to 0, this penalty term forces the estimated coefficient value to be exactly 0 and automatically estimates the model after excluding the corresponding variable. In the opposite case, if the OLS estimate of a coefficient is significantly different from zero, the penalty term does not greatly affect the estimated value of the coefficient. That is, the LASSO method divides the entire set of explanatory variables into two groups: one group composed of variables with zero coefficients and the other group composed of variables with non-zero coefficients. If the standard OLS method is applied to the

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[2]The elastic net method, which is a combination of LASSO and the ridge regression method, can provide more stable results than LASSO because it can efficiently handle the multicollinearity issue in the data. I leave this important extension for future researchers.

model while excluding variables with zero coefficients, the final estimation result would be very similar to that obtained by LASSO.

All of the explanatory variables are normalized using their sample means and standard deviations before applying the LASSO method such that the means and standard deviations of the normalized variables are zero and one, respectively. In the equation above, the upper bar attached to each variable and coefficient means that the corresponding variable is normalized before the estimation. This normalization ensures that the effect of the penalty term on each variable is not affected by the variable's mean or standard deviation.

B. *Short-term Influence of the Principal Components*

1. In-sample fitting analysis

In the LASSO method, variable selection or model selection depends on the penalty parameter λ. For instance, if the value of λ is large, LASSO does not include any variables in the model. Conversely, if the value of λ is close to 0, all variables are included in the model. Therefore, by changing the value of λ from a very large value to a small value, one can easily check which variables have significant effects on a target dependent variable.

Table 8 shows which variables are selected by LASSO for the Korean inflation rate. The first selected variables are the first and third principal components. Next, the third lagged Korean inflation rate is included, followed by the Korean call rate. Korea's M2 growth rate and the second principal component are also selected next. Note that the principal components are estimated while excluding the Korean inflation rate to avoid using the same data information twice.

Figure 15 shows how the LASSO estimates change depending on the value of λ. As explained above, the LASSO estimates deviate from 0 as the value of λ decreases. The variables selected by LASSO are mostly statistically significant, but these estimates may not be easy to interpret economically because all variables are normalized before the estimation. In order to assess the actual relationships between the explanatory variables and the Korean inflation rate, OLS estimation is performed without the normalization step using the eight variables selected by LASSO in Table 8.

Table 9 shows the result of the OLS estimation. The OLS estimate indicates that the selected principal components with different lagged orders suitably explain the

TABLE 8— EXPLANATORY VARIABLES SELECTED BY LASSO

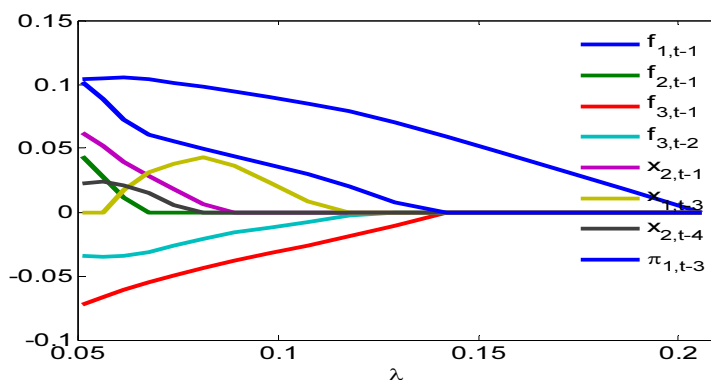| Dependent variable: Korea CPI inflation rate QoQ			
Selected explanatory variables			
1~4	$f_{1,t-1}$	$f_{3,t-1}$	π_{t-3}	$f_{3,t-2}$
5~8	$x_{1,t-3}$	$x_{2,t-1}$	$x_{2,t-4}$	$f_{2,t-1}$
Period: 1998: Q2~2018: Q2			
f_1: PC1, f_2: PC2, f_3: PC3, x_1: Call rate, x_2: M2			

FIGURE 15— LASSO ESTIMATES

Source: LASSO estimates - Author's calculations.

TABLE 9— OLS ESTIMATES

	Dependent variable: Korea CPI inflation rate QoQ							
Variables	$f_{1,t-1}$	$f_{2,t-1}$	$f_{3,t-1}$	$f_{3,t-2}$	$x_{2,t-1}$	$x_{1,t-3}$	$x_{2,t-4}$	π_{t-3}
Estimates (Standard error)	0.087*** (0.025)	0.182*** (0.063)	-0.216*** (0.058)	-0.114** (0.066)	0.096*** (0.045)	0.003 (0.038)	0.069** (0.039)	0.259*** (0.102)
	Period: 1998 Q2~2018 Q2; Number of observation: 81; R^2= 0.617							
	f_1: PC1, f_2: PC2, f_3: PC3, x_1: Call rate, x_2: M2							

Note: ***: 1% statistical significance, **: 5% statistical significance, *: 10% statistical significance.

short-term movements of the Korean inflation rate. In particular, one quarter of the lagged principal components have significant effects on the Korean inflation rate. Among many macro-variables, Korea's M2 growth rate is found to be statistically significant. Indeed, in Table 9, most of the variables selected by LASSO are statistically significant, except the three-quarter lagged call rate. According to the R-squared outcome, the selected variables account for 62% of Korea's inflation rate for last 20 years.

2. Out-of-sample Forecasting Analysis

The previous section employs LASSO to select important variables that explain Korean inflation. However, due to the limited amount of the data, various statistical errors and issues may occur. Moreover, the statistically significant variables in the in-sample estimation may not provide strong predictive power. Thus, it is necessary to evaluate whether the selected variables can predict the future inflation rate. The prediction performance is evaluated using the sample from the fourth quarter of 2007 to the second quarter of 2018, a period which includes the financial crisis period. The weights that are used to construct the principal components are estimated prior to the fourth quarter of 2007 and are fixed through the prediction period.

The evaluation for the forecast is summarized in Table 10. Model 1 assumes that the Korean inflation rate follows a random walk process. The model implies that the

optimal forecast for the next quarter is the current inflation rate. The random walk model is treated as a benchmark model in this section.

Model 2 is an AR(4) model that uses four lagged values of the dependent variable as explanatory variables. Models 3 to Model 10 all are AR(4) models with each explanatory variable in Table 7. Four lagged values of each explanatory variable are included in the models. Model 11 includes Korea's M2 growth rate and real GDP growth rate, which are known to be important when explaining the dynamics of the Korean inflation rate. Model 12 includes only the variables selected by LASSO in the previous section. Model 13 uses the OECD inflation rate and China's inflation rate to replace the first three principal components, reflecting the result of Section 3. For the prediction analysis, it is assumed that relevant variables are known prior to the prediction and that they are identified by LASSO. This may be a limitation in that the LASSO estimation uses the full sample. However, it is a necessary assumption because the full sample size is already relatively small compared to the number of parameters.

Table 11 shows the mean squared error (MSE) for each model along with how much the MSE of each model deviates from that of the benchmark random walk model (Model 1) in terms of the percentage. The main result is that all models except Model 12 and Model 13 show worse predictive performance than the random walk model. On the other hand, Model 12 reduces the MSE by about 30% compared to Model 1. Similarly, Model 13 reduces the MSE by about 11% compared to Model 1.

TABLE 10— PREDICTION MODELS

One-quarter ahead Korea CPI inflation rate QoQ ($\pi\_{(t+1)}$) Period: 2007 Q4~2018 Q2	
Model 1	Random Walk $\pi_{t+1} = \pi_t + e_{t+1}$
Model 2	Autoregressive Model, AR(4) Regressors: ($\pi_t, \pi_{t-1}, \pi_{t-3}, \pi_{t-4}$)
Model 3~10	AR(4) + each explanatory variable in Table 7
Model 11	AR(4) + M2 growth rate and real GDP growth rate
Model 12	Variables selected by LASSO
Model 13	A model that replaces the principal components with OECD and China's inflation rates
Out-of-sample forecasting is evaluated since the fourth quarter of 2007.	

TABLE 11— PREDICTION PERFORMANCE: MEAN SQUARED ERROR

One-quarter ahead inflation forecast (π_{t+1})						
Model	1	2	3	4	5	6	7
MSE (%)	0.158 (0.00)	0.168 (6.46)	0.168 (5.95)	0.217 (37.20)	0.215 (35.82)	0.239 (51.11)	0.187 (18.47)
Model	8	9	10	11	12	13	
MSE (%)	0.161 (1.93)	0.482 (204.34)	0.190 (19.81)	0.175 (10.703)	0.111 (-29.65)	0.140 (-11.43)	

Note: The MSE difference in percentage between Model 1 and a comparison model is shown in parentheses.

Source: Estimates - author's calculations.

TABLE 12— HYPOTHESIS TEST FOR PREDICTION PERFORMANCE

	Clark and West (2007) Test	
Model	12	13
	3.941***	3.019***
$H_0: \text{MSE}_{\text{RW}} = MSE_{CM}$, $H_a: \text{MSE}_{\text{RW}} > MSE_{CM}$		

Note: 1) ***: 1% statistical significance, **: 5% statistical significance, 2) 1% critical value: 1.28, 5% critical value: 1.645.

To test for whether the improved predictive power over the benchmark model is statistically significant, the predictive hypothesis test of Clark and West (2007) is utilized. In the hypothesis test by Clark and West (2007), the null hypothesis assumes that a compared model and the random walk model have the same predictive power. The alternative hypothesis assumes that a compared model has better predictive power than the random walk model. Table 12 reports the test statistics for Models 12 and 13. For both models, the improvement in the prediction is statistically significant at the 1% significance level.

It is easy to infer based on the hypothesis test result that the principal components or the global inflation factors play a very important role in the prediction. Note that the out-of-sample forecast is not improved by any of the models that include only Korean domestic macro-variables or the oil price. Only the models that include the principal components (or OECD and China's inflation rates) and macro-variables selected by LASSO greatly improve the prediction performance. This is consistent with the in-sample analysis, where all of the first three principal components are statistically significant.

Section 2 shows that the first principal component is nearly identical to the OECD inflation rate. Therefore, the first principal component can be interpreted as a global inflation factor, as documented by many previous studies. This study also shows that the global inflation factor is closely related to the OECD M2 growth rate and the OECD trade/GDP ratio. Another important empirical implication from Section 2 is that the second and third principal components reflect information about China's inflation rate.

The empirical analysis in this section offers us evidence that global inflation synchronization, which is potentially reflected in the principal components, has a profound effect on the Korea inflation rate in the short-term. If one needs to predict the Korean inflation rate in the short-term, the common variations in many countries' inflation rates (their lagged values) will provide valuable information.

C. *Mid-term Influence of the Principal Components*

This section extends the analysis in the previous section by considering the range from one-year to two-year forecasting periods. That is, this section focuses on predicting how much the aggregate price level in Korea will change after one or two years from the present. For the one-year-ahead (or two-years-ahead) prediction, we use the one-year (or two-year) inflation rate as the target dependent variable. When computing the mid-term inflation rates, much of the short-term movement in the aggregate price will be eliminated. Thus, only mid-term economic factors that affect

inflation for more than one year will be reflected in the observed inflation rate. Finding these factors is the main objective of this section

All models described in Table 10 are used for the predictive performance evaluation. For the explanatory variables, their annual growth rates or annual averages are used instead of the quarterly growth rates or the quarterly averages. Only the one-year lagged values of the dependent variable and the explanatory variables instead of four lagged values are included in the models. LASSO selects the first three principal components, the call rate, and the annual M2 growth rate in the in-sample estimation. All variables are included in Model 12. As before, Model 13 replaces the first three principal components with the OECD and China's inflation rates.

The prediction result is reported in Table 13. We find that models with the real GDP growth rate show better predictive power than the benchmark random walk model (Model 1). The model with the real GDP growth rate (Model 8) shows that the MSE decreases by about 42% compared to Model 1. Model 11 contains both the real GDP growth rate and the M2 growth rate. When these two variables are used together, the predictive power is further improved than when each variable is used separately. The model with the KRW / USD exchange rate (Model 9) and the model with the Dubai oil price (Model 10) also exhibit less predictive power than the models that contain the real GDP growth rate and the M2 growth rate. The change in the set of important variables compared to the previous section can be attributed to the fact that short-term inflation movements are largely eliminated when calculating the one-year inflation rate.

TABLE 13— PREDICTION PERFORMANCE: MEAN SQUARED ERROR

One-year ahead inflation forecast YoY ($\pi_{t:t+4}$)						
Model	1	2	3	4	5	6	7
MSE (%)	1.840 (0.00)	2.063 (12.11)	1.790 (-2.73)	2.364 (28.46)	2.085 (13.34)	2.044 (11.071)	2.023 (9.94)
Model	8	9	10	11	12	13	
MSE (%)	1.070 (-41.84)	1.776 (-3.49)	1.860 (1.10)	0.965 (-47.55)	1.963 (6.70)	2.922 (58.77)	

Note: The MSE difference in percentage between Model 1 and a comparing model is shown in parentheses.

Source: Estimates - author's calculations.

TABLE 14— PREDICTION PERFORMANCE: MEAN SQUARED ERROR

Two-year ahead inflation forecast YoY ($\pi_{t:t+8}$)						
Model	1	2	3	4	5	6	7
MSE (%)	5.387 (0.00)	7.005 (30.02)	6.092 (13.08)	5.220 (-3.11)	6.121 (13.61)	7.087 (31.54)	6.935 (28.72)
Model	8	9	10	11	12	13	
MSE (%)	4.855 (-9.87)	6.996 (29.84)	6.816 (26.51)	4.209 (-21.86)	5.811 (7.86)	6.317 (17.25)	

Note: The MSE difference in percentage between Model 1 and a compared model is shown in parentheses.

Source: Estimates - author's calculations.

TABLE 15— HYPOTHESIS TEST FOR PREDICTION PERFORMANCE

	Clark and West (2007) Test	
Model	11 ($\pi_{t:t+4}$)	11 ($\pi_{t:t+8}$)
	2.636***	2.282**
$H_0: \text{MSE}_{RW} = MSE_{CM}$, $H_a: \text{MSE}_{RW} > MSE_{CM}$		

Note: 1) ***: 1% statistical significance, **: 5% statistical significance, 2) 1% critical value: 1.28, 5% critical value: 1.645.

Finally, we perform an out-of-sample predictive analysis for the two-year-ahead inflation rate. Similar to the one-year-ahead prediction, Model 11's predictive power is the highest. To investigate the predictive power of Model 11 further, the statistics of Clark and West (2007) are computed and reported in Table 15. The result shows that the improved predictive power of Model 11 is statistically significant at the 1% (5%) significance level for the one-year (two-year) prediction case.

IV. Policy Implications

The previous sections provide quantitative analyses to examine whether the principal components of inflation suitably explain or predict short- and mid-term movements of the inflation rate in Korea. This section presents policy implications based on the reported results thus far.

The important empirical results of the PCA are summarized as follows. The first principal component can be interpreted as the global inflation factor documented by studies such as those by Ciccarelli and Mojon (2010) and Mumtaz and Surico (2012) because the estimated first principal component shows movements nearly identical to those of the OECD inflation rate. By looking at several OECD macro-variables, we find that the OECD inflation rate is largely determined by two factors: the M2 growth rate for OECD countries and the OECD trade/GDP ratio. Section 3 shows that the Korean inflation rate is directly affected by the first principal component or the OECD inflation rate. In particular, we can infer that the OECD inflation rate acts as a short-term driver of Korea's inflation because it predicts Korea's inflation rate one quarter ahead. In addition, the second and third principal components, which are directly related to China's inflation rate, have significant in-sample explanatory power for Korea's inflation rate in the short-term. However, the performance outcomes of the principal components for the one-year- and two-year-ahead predictions are not satisfying.

It is shown in Figure 1 and Figure 2 that Korea's inflation rate changes almost simultaneously with those of the developed countries. Figure 16 indicates that China's quarterly inflation rate tends to move one or two quarters ahead of Korea's quarterly inflation rate. In particular, this phenomenon is observed for about five years before and after the 2008 financial crisis. Figure 17 compares Korea's and China's yearly inflation rates. The pointed pattern seems clearer in the yearly data. This would be other evidence suggesting that China's inflation rate can be used to explain or predict Korea's inflation in the short-term.
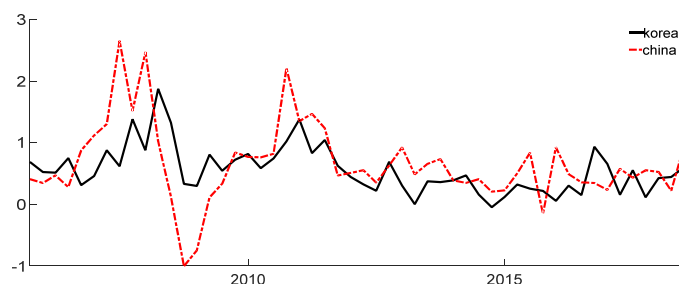
FIGURE 16— CPI INFLATION RATE QoQ: KOREA AND CHINA

Source: CPI inflation rate data - World Bank.

FIGURE 17— CPI INFLATION RATE YoY: KOREA AND CHINA

Source: CPI inflation rate data - World Bank.

The rapid increase in the trade volume between Korea and China over the last 30 years has triggered strong inflation coordination. In addition, the cheap labor and scale production of the Chinese economy appear to play an important role in reducing the prices of many Chinese products which are exported to Korea. Because China's inflation is directly related to the low production cost and Chinese products are exported to Korea, it is reasonable to conjecture that China's inflation precedes Korea's inflation. This is also consistent with the evidence that one of the main determinants of OECD inflation is the OECD trade/GDP ratio.

Many studies mentioned in the previous sections argue that the short-term and mid-term movements of inflation in each country are mainly determined by a single global inflation factor. As a result, they conclude that the global low inflation phenomenon is attributed to the low global factor, which is independent of domestic monetary policies. However, this study provides evidence that more than one global factor and their corresponding effects on the Korean inflation rate are limited in the mid-term, despite the fact that these effects are non-negligible in the short-term. Another important finding of this study is that the mid-term trend of Korea's inflation is largely determined by the monetary policy of the Bank of Korea and the Korean economic situations in that Korea's domestic macro-variables well predict its inflation rate ahead by one or two years.

Since 1998, the Bank of Korea's policy goal has been to promote price stability via inflation targeting. It is well known that a monetary policy affects the economy with some lags. Previous studies such as those by Lee *et al*. (2005) and Kim (2010)

argue that Korea's monetary policy has somewhat faster effects on the economy compared to other developed countries and that these effects last for more than a year. The characteristics of Korea's monetary policy imply that the Bank of Korea should determine the proper direction and timing of their monetary policy instruments only after carefully considering both short-term and the mid-term effects. This also requires good predictions of future inflation rates. Overall, our main empirical results suggest that the Bank of Korea should implement monetary policy in line with domestic economic conditions which have dominant mid-term effects rather than global inflation factors which have only short-term effects. In addition, in the light of the result that China's inflation rate precedes Korea's inflation rate, China's inflation rate would be a good candidate variable for policymakers to forecast Korea's inflation rate more accurately.

As of 2019, the central bank of the United States has maintained a tightening monetary policy and the U.S. inflation rate has remained close to the target rate 2%. However, at that time, there were many factors that could lead to a decline in inflation. Even before the coronavirus pandemic, the short- and long-term interest rates were reversed, which is a strong sign of an economic recession. Moreover, due to the trade dispute with China, positive outlooks for the global economy are difficult to find. In Europe, many experts noted that a sharp increase in government debt could have a strong adverse effect on the economy. Now, the coronavirus pandemic is aggressively suppressing aggregate demand. Despite the fact that the trade dispute between the US and China will have a negative impact on the global trade volume, which will create upward pressure on inflation, it appears to be more convincing that global inflation will undergo strong downward pressure in the long-run considering the global virus pandemic, which dampens both global demand and supply. We leave the effects of the virus pandemic on global and Korea inflation as an important future research agenda.

V. Conclusion

This study analyzes the recent global inflation synchronization and examines its policy implications for the Korean economy. Unlike previous studies that emphasize the importance of a single global inflation factor, it is shown here that more than one global inflation factor affect Korean inflation in the short-term, while their mid-term impacts are limited. The Bank of Korea's 2018 monetary credit policy report indicates that the link between domestic inflation and global inflation in the Korean economy has shown a rapid rise since the 2008 financial crisis. On the other hand, Kamber and Wong (2018)'s International Settlement Bank (BIS) report argues that the impact of the global inflation factor on a country's inflation lasts only in the short-term, while its long-term inflation trend is determined by the county's monetary policy stance. Regarding the important question of whether domestic inflation has become a slave to global inflation factors or whether domestic monetary policy remains a valid policy instrument, this study provides important policy implications consistent with Kamber and Wong (2018). However, this does not necessarily intend to ignore the effects of the global inflation on the Korean inflation rate in the mid-term or long-term. Rather, it means that many domestic macro-

variables well reflect global macro environments over time. Therefore, it is desirable to pay close attention to domestic macro-variables when enacting monetary policy.

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