Do stronger intellectual property rights encourage agricultural innovation?

Evidence from the Japanese Plant Variety Protection Act reform

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Do stronger intellectual property rights encourage agricultural innovation? Evidence from the Japanese Plant Variety Protection Act reform

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Abstract

Do stronger intellectual property rights encourage agricultural innovation? Plant breeder's right is the intellectual property right for plant varieties, but the effect of the plant breeder's right on innovation is mixed. This paper analyzes the impact of stronger breeder's rights on agricultural innovation by examining the policy change of Japanese Plant variety protection Act. In 1998, the Japanese government did reforms to give breeders the right to restrict self-propagation of their registered varieties, which is the reuse of seed from the previous harvest, for specific species to encourage the breeding of new plant varieties. Using the variations in the timing when the species is restricted for self-propagation, this paper analyzes the impact of the stronger breeder's right on agricultural innovation. I find the positive impact of the reform on the number of registrations in the Japanese Plant Variety Protection Act, but the results are mixed when I focus on certain groups of species.

Keywords: Intellectual property, breeder's right, self-propagation

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1 Introduction

The intellectual property rights policy is considered an important policy to encourage innovation. In agricultural innovation, the plant breeder's right is the intellectual property right for plant varieties, based on the International Union for the Protection of New Varieties of Plants (UPOV). Under the UPOV, 75 countries had a Plant Variety Protection Act in 2017(Appendix A). People think that strengthening intellectual property rights would increase the incentive of breeders to develop new varieties, but empirical estimates show ambiguous results(Moser & Rhode, 2012; Thomson, 2015; Nhemachena et al., 2019; Moscona, 2021b) For example, Moser & Rhode (2012) shows that plant patents played no significant role in encouraging innovation in rose breeding in the U.S. Since agricultural innovation is important for agricultural development, it is essential to understand the impact of the plant variety protection act on agricultural innovation[1]

This paper investigates how the policy change to make intellectual property right stronger encourages agricultural innovation by examining the policy change of the Japanese Plant variety protection Act(PVPA): policy change to give breeders the right to restrict self-propagation of their registered varieties for specific species.

Self-propagation is the farmers' activity to reuse the seeds from the previous harvest. Historically, farmers' self-propagation is one of the threats to agricultural innovation. If farmers reuse seeds from the previous harvest, farmers would not buy new seeds from breeders, which might decrease the incentive for breeders to develop new varieties. It implies a trade-off between the social benefits from a stronger incentive for invention and losses in consumer welfare as a result of monopoly pricing (Nordhaus, 1969).

Before 1998, there was no restriction of the self propagation in Japanese PVPA, but the Japan government started to give breeders the right to restrict self propagation for specific species such as mushrooms, flowers, trees, and grass in response to the UPOV 1991[2]. Japan extended the restriction of the self-propagation to other mushrooms, flowers, grasses and trees in 2007. After the several amendments, Japan gave breeders the right for all species in 2022.

To identify the strong intellectual property rights on agricultural innovation, I use variation of the scope of species of the restriction of the self propagation by the reform on 29 May, 1998, enacted in 24 December 1998(hereafter the 1998 reform). To capture the agricultural innovation, I use the registration data of plant varieties from the registration database of Japanese PVPA, which covers all registration data 1979 to 2020. It has the crop classification, Latin name, registration date, expiration date, and breeder's name and address. Since the data only has the information on new varieties which breeders registered in Japanese PVPA, there might be sample selection problem. Hence, I restrict the sample to the species where there are many registration in the Japanese PVPA. To identify the causal effect, I use the difference in difference design that exploits the variation in the timing when the species is restricted for the self propagation.

The results show that the 1998 reform increases the number of the registrations of Japanese PVPA.

[1] There are some papers to analyze the plant variety protection act on agricultural production, such as yield(Kolady et al., 2012; Nhemachena et al., 2019)

[2] In UPOV 1991, there is an article about the exceptions to the breeder's right, including the self-propagation. Some countries give breeders this right to encourage innovation, whereas other countries withold this right since self-propagation has been common among farmers for a long time. For example, the European Union does not provide breeders with this right for cereal crops and potatoes.

However, the results are mixed when I focus on certain groups of species.

This paper makes several contributions. First, this paper contributes to the literature to analyze how the incentive of the intellectual property law encourages agricultural innovation. There are growing papers that analyze the causal impact of intellectual property right on innovation such as the impact of patent on innovation(Moser, 2005).[3] Previous empirical estimates show the ambiguous results of the stronger property rights for plant varieties on agricultural innovation(Moser & Rhode, 2012; Thomson, 2015; Nhemachena et al., 2019; Moscona, 2021b). Thomson (2015) shows that the plant variety protection led to a substantial decrease in breeder's output in Australia because of low spillovers, lower release standards, and a possible reduction in total investment in breeding. Moscona (2021b) analyze the intellectual property on the agricultural development of flowers in the U.S., but the impact of the plant breeder right on agricultural innovation is still not well understood. Moreover, Sakakibara & Branstetter (2001) analyze the impact of the policy change of Japanese patent law on R & D. However, few papers analyze the policy change of the PVPA on agricultural innovation. This paper uses the policy change of the Japanese PVPA as the variation and compares the treated species and untreated species.

Second, most previous studies use the number of registration for the plant variety protection to measure the innovation. Since breeders choose to register varieties, it does not mean that the number of registration is the measure of the innovation (Thomson, 2015). In this paper, I use the number of registration in the Japanese PVPA, but I also try to solve this sample selection problem by focusing on the characteristics of species, that there is a bigger incentive to register in the Japanese PVPA. Specifically, since the species in which hybrid crosses are common have weak incentive for the registration, such as vegetables, I focus on flower, grass and ornamental trees.

Finally, this paper is related to the literature about self-propagation. The self-propagation is important, especially in developing countries. Since many farmers use the seed from the previous harvest in developing countries, Tripp et al. (2007) say that the restriction of self-propagation would be politically explosive. However, few papers analyze the impact of the restriction of self-propagation on agricultural innovation. I show that restriction of self-propagation has a positive effect on agricultural innovation.

The rest of this paper is structured as follows: Section 2 provides institutional background information about the Japanese PVPA and the reforms. Section 3 presents the data, Section 4 presents the empirical strategy, Section 5 presents the results, and Section 6 concludes the paper.

2 Institutional background

2.1 The Japanese PVPA before the 1998 reform

The Japanese PVPA is the intellectual property Act for plant varieties. The act defines (1)the genera and species to be protected, (2)the conditions for the grant of the breeder's right, (3)the rights of the breeder, and (4) the exception to the breeder's right. If new plant varieties satisfy some registration requirements such as novelty, distinctness, uniformity, and stability, breeders can apply for breeder's rights. As a result, they can restrict users from the multiplication and exporting the registered varieties in the Japanese PVPA.

[3] Other papers analyze the impact of copyright on creativity(Biasi & Moser (2021); Giorcelli & Moser (2020))

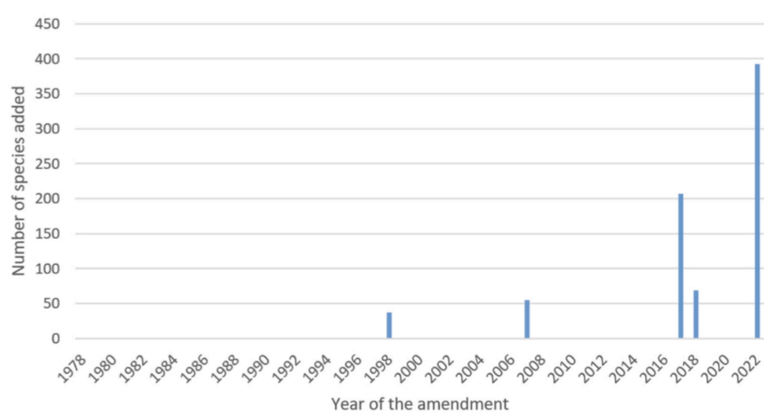
The Japanese PVPA became law in 1978. The act was made to meet the obligations of UPOV 1978. The Japanese PVPA made it possible for breeders to restrict the activities of people who use the registered varieties. For example, if people want to increase the number of seeds, they need to get permission from the breeders. However, there was no breeder's right to restrict farmer's self-propagation.

2.2 The Japanese PVPA after the 1998 reform

In 1998, the Japanese government amended the Japanese PVPA to meet the obligations under the UPOV 1991, which strengthened the plant breeder's right. There were many changes in the 1998 reform such as extending the period of the plant breeder's right, but one of the important policy changes was the restriction of self-propagation[4]. Self-propagation is the farmer's activity to reuse the seeds from the previous harvest. Not giving breeders this right might decrease the incentive for breeders to develop new varieties because farmers would not buy new seeds from breeders. To restrict the farmer's self-propagation without the breeder's consent, the Japanese government gave breeders the right to restrict farmer's self-propagation for some mushrooms, flowers, trees, and grasses in 1998. In December 2007, Japan expanded its restriction to other mushrooms, flowers, grasses and trees, and the government also made similar reforms in 2017 and 2018. In the reform in 2022, the government added all other species. The number of species for the restriction of self-propagation in each reform is described by Figure 1 and Appendix B.

The variation of the species for the restriction of self-propagation by Japanese PVPA is useful to identify the impact of the policy change on agricultural innovation. This setting gives me some advantages for the identification because each reform did not change all species simultaneously. By using this variation, I can compare the treated species with the untreated species by the policy change. Moreover, the sufficient number of years between each amendment allows analysis of long-term policy effects.

Figure 1: Distribution of the reform years



Notes: Figure shows the number of species which were restricted for the self propagation in each reform. Since 1998, there were four reforms of the Japanese PVPA to expand the scope of the species under the restriction of the self propagation.

[4]Specifically, article 15 in UPOV 1991 says that each Contracting Party may, within reasonable limits and subject to the safeguarding of the legitimate interests of the breeder, restrict the breeder's right in relation to any variety in order to permit farmers to use for propagating purposes on their holdings, the product of the harvest which they have obtained by planting, on their holdings, the protected variety.

3 Data

3.1 Data on the treatment: Law data

This paper uses several data. The first data is the history of the reforms of Japanese PVPA from the National Printing Bureau. All legal reforms are published in the Official Gazette. To identify the time and species of the reform of Japanese PVPA, I checked the species under the restriction of self-propagation. Since the government adds the Latin name of the species for the restriction of the self-propagation to Japanese PVPA in each reform, I collect this data to identify the treated species. To match the species name in Japanese with species names in English, I use the information from the Japanese PVPA database, which includes all of the names of the species covered by Japanese PVPA, both in Japanese and in English.

Appendix C shows the species list in the 1998 reform. Out of 23 species in the 1998 reform, 20 species were covered by Japanese PVPA in 1978[5]. Hence, I use the 20 species as the treatment species. Out of 20 species, 16 species are flowers, three species are ornamental trees, and one species is a mushroom.

3.2 Data on the outcome: Japanese PVPA registration data

I use the number of the new registration of Japanese PVPA per year by species to measure the agricultural innovation of species. The registration data of plant varieties comes from the Japanese government database of PVPA. It covers all registration data of all plant varieties from 1979 to 2020. It has the crop classification, Latin name, registration date, expiration date, and breeder's name and address.

I make the species level panel data based on the registration data. Specifically, I count the number of registrations per species per year. If there are no registration in a specific species and a specific year, I regard the number of registrations as zero. After this data construction, the unit of observation is species-year.

The main limitation of this data is that the data covers only varieties registered in the act. If other species are not registered in this law and used for agriculture in Japan, it causes a sample selection problem. According to the website of the database of Japanese PVPA, most of the registrations are flower. 63% are flowers and grass, 18% are ornamental trees, 6% are vegetables, 5% are food crops, 4% are fruits, and 4% are others. The number of registrations of vegetables is low. One of the reasons would be that most of the varieties of the vegetables are F1 hybrid varieties. F1 hybrid varieties are created by crossing genetically distinct parents, which means farmers cannot copy the seeds if they do not know the parents of the varieties. Since Japanese PVPA requires the breeders to show the name of the parent's varieties, they prefer to hide the parent's varieties instead of protecting the variety by the PVPA. To solve this problem, I mainly use the group of flowers, grass, and ornamental trees.

The second limitation in the data is that there are many zeros. Popular crops such as rice has many registration but there are many minor species whose number of registrations is zero.

[5]Since the species covered by the Japanese PVPA changed several times, I use the species that were covered by the act in 1978.

3.3 Sample selection

For the analysis, I restrict the sample. First, this analysis uses the data from 1979 to 2005. One reason is that this paper focuses on the 1998 reform, and does not analyze the similar reform in 2007, 2017 and 2018. Moreover, there was other reform to change the maximum protection period of breeder's right in 2005. To exclude the effect of this reform, I do not use the data from 2006 and 2008.

Second, I restrict the species to the species that the Japanese PVPA covered in 1978. This is because the scope of the species covered by Japanese PVPA changed in the 1990's[6]. Moreover, I also restrict the sample of species that have ever been registered in the PVPA during 1979-2020. By doing this, I can exclude the species which cannot be registered in the PVPA even after the reform. By doing these sample selection, the number of sample species in this analysis is 251. Specifically, the data has 123 flower, 39 ornamental trees, 39 vegetables, 16 forage crops, 12 fruits, 12 food crops and 5 mushrooms.

Third, I also divide the sample into flowers and ornamental tree groups. This is because the Japanese government changed the period of the breeder's right from 18 years to 25 years for vines, forest trees, and ornamental trees and changed it from 15 years to 20 years for other species in 1998. To exclude the different effect of the reform between the former group and the latter group, I divide the sample in the following analysis.

3.4 Summary statistics

Table 1 shows the summary statistics. The average number of new registrations per species per year is 2, which is the primary outcome of my analysis.

My basic empirical strategy is to compare the number of new registrations across species affected differently by the reform. The figure 5 shows the number of registrations of 251 species from 1979 to 2005. When comparing before and after the reform, I cannot see significant change. In the following section, I make the appropriate control group for the analysis. Moreover, I control for species fixed effect and year fixed effect to identify the impact of the reform on agricultural innovation. Since the 1998 reform focused on grass, flower, and mushroom, the control group should be similar to these species.

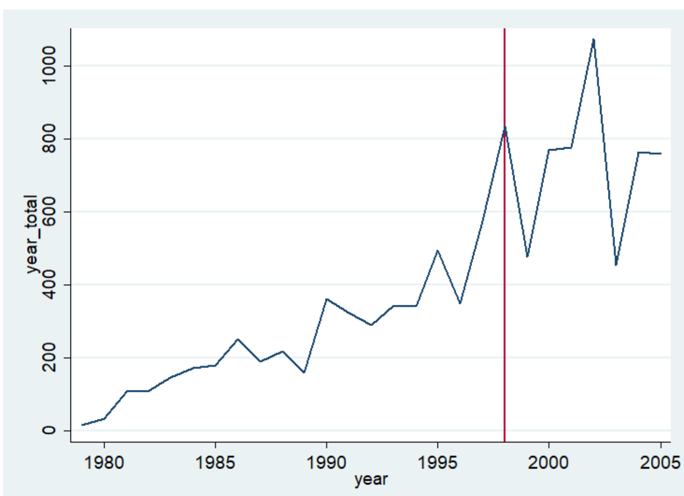
[6] In 1978, the number of species was around 365. In 1998, around 761 species were covered by the Japanese PVPA. Since I dropped the species if the number of registration of this species is zero, I use 251 species in my analysis.

Table 1: Summary statistics(1979-2005, 251 species)

	Obs	Mean	Std.Dev.	Max	Min
No. of new registrations	9538	1.98	9.95	287.00	0.00
Treatment species1998*post1998	9538	0.04	0.20	1.00	0.00
Treatment species(1998)	9538	0.08	0.27	1.00	0.00
after1998	9538	0.50	0.50	1.00	0.00
Food crop(dummy)	9538	0.05	0.21	1.00	0.00
Vegetable(dummy)	9538	0.16	0.36	1.00	0.00
Fruit(dummy)	9538	0.05	0.21	1.00	0.00
Mushroom(dummy)	9538	0.02	0.14	1.00	0.00
Forage crop(dummy)	9538	0.06	0.24	1.00	0.00
Flower or grass(dummy)	9538	0.49	0.50	1.00	0.00
ornamental tree(dummy)	9538	0.16	0.36	1.00	0.00
Forest tree(dummy)	9538	0.02	0.15	1.00	0.00

[1] Note: Table reports the summary statistics at the species level. Data on the number of new registrations comes from Japanese PVPA database for the years 1979-2005. Data on treatment species comes from the National Printing Bureau. The number of species in the data is 251.

Figure 2: Trends in the number of the new registrations of plant varieties



Notes: Figure plots the number of new registrations. Data of the number of new registrations comes from Japanese PVPA database between 1979 and 2005. Red axis represents the year of 1998.

4 Empirical strategy

To identify the impact of the reform of Japanese PVPA on agricultural innovation, it is good to have the information on breeder's R& D. Unfortunately, many breeders are individuals, so it is difficult to collect this information. Moreover, it would be possible to get the R& D data of companies but to identify the variation of the reforms, it is necessary to get the detailed R& D information such as the R &D for specific species. Unfortunately, it is difficult to collect this information. As the alternative approach, I identify the impact of the reform on the number of registration in Japanese PVPA.

4.1 Estimation framework

I exploit variation across species and examine the reform's impact on the number of patents over time. Specifically, I estimate the following equation by using the data from 1979 to 2005.

$$Y_{it} = \beta_0 + \beta_1 Species1998_i \cdot Post1998_t + \alpha_i + \gamma_t + \varepsilon_{it} \tag{1}$$

where i is species and t is the year of the registration. The dependent variable Y_{it} is the outcome of interest of species i in year t. It is the number of new varieties registered in Japanese PVPA for species i in year t. $Species1998_i$ is one if the 1988 reform restricts the self-propagation for the species i. $Post1998_t$ is one if the year of the registration is after 1998. α_i represents the species fixed effect and γ_t represents the year fixed effect. ε_{it} is error term. The main interest is the β_1. If the β_1 is positive, it means the positive impact of the reform on the agricultural innovation.

Since the outcome in this paper is the count data, that is, the number of registrations, I use the same approach as the innovation literature [7] (Azoulay et al., 2010, 2019; Giorcelli & Moser, 2020) Specifically, I use the conditional quasi maximum likelihood(QML) estimates based on the fixed-effect Poisson model. The fixed effect Poisson model is developed by Hausman et al. (1984). Since the coefficient estimate of the Poisson model is consistent as long as the mean of the dependent variable is correctly specified(Gourieroux et al., 1984), I use the QML model. The QML estimator is consistent with the fixed effect. QML model can model non-negative dependent variables without specifying a distribution. Correia et al. (2020) says that Poisson pseudo maximum likelihood regression seems like the safest bet in the presence of non-negative data with many zeros. Moreover, I also estimate the model using the OLS, Poisson fixed effect model(Hausman et al. (1984)), and the Negative binomial fixed-effect model.

[7] The conditional QML with the Poisson fixed effect is often used in the innovation literature. For example, Moscona (2021a) and San (n.d.) analyzed the impact of the labor shortage on the agricultural innovation. In other fields, Azoulay et al. (2010) analyzes the impact of the death of the academic superstars on the research output of the collaborators. They use the Poisson QML model since the outcome of the publication is the count data, and 24.80% of the data are zeros. Azoulay et al. (2019)analyzes the premature death of the eminent life scientists on the vitality of their field. Giorcelli & Moser (2020) analyzes the impact of copyrights on the creation of new operas.

Moreover, to identify the dynamic impact of the 1998 reform, I use the event study. This is because the effect of the reform might take time to affect the breeder's behavior. The event study is often used to analyze patents and academic research.

$$Y_{it} = \sum_{\tau=pre-19,\tau\neq pre-1}^{post+7} \beta_\tau D_{i\tau} + \alpha_i + \gamma_t + \varepsilon_{i,t} \tag{2}$$

The dependent variable Y_{it} is the outcome of interest of species i in year t. D_{it} is the lag or lead dummy for the event study. For example, suppose that D_{it} is +1. It means the dummy 1 year post treatment for species i. α_i represents the species fixed effect and γ_t represents the year fixed effect. $\varepsilon_{i,t}$ is error term. I use the QML estimates based on the fixed-effect Poisson model.

4.2 Identifying assumptions

There are several assumptions to identify the causal impact of the policy change. The first important assumption is the parallel trend, and I show this assumption in the result section.

The second assumption is that there are no confounders. Japan made several reforms to change the maximum period of protection of breeder's right for a registered varieties by species mainly because UPOV changed the maximum period of breeder's right. Specifically, the Japanese government changed the period of the breeder's right from 18 years to 25 years for a group of vines, forest trees, and ornamental trees and changed it from 15 years to 20 years for other groups of species in 1998. Since the change in the period of the protection in the group of forest trees, vine, and ornamental trees is longer than that of the other species, I split the sample in two such as the group of flowers and grasses and the group of the ornamental trees.

The third assumption is that treatment is almost random. Since the Japanese government added some species such as rice in 2022, the choice of the group of species might not be random. If it is the case, the unobservable error terms might be correlated to the reform and the number of the registrations. Unfortunately, there are no documents on how the government selected the species to restrict the self-propagation in the 1998 reform[8]. However, most of the species in 1998 are the group of flowers, grass, and ornamental trees, so the problem would not be severe if I focus on the group of flowers, grass, and ornamental trees.

5 Results

5.1 Effect of 1998 reform on new registered varieties

I first show the effect of the 1998 reform on newly registered varieties using the data about 251 species. Before showing the regression result, I first show the number of registration of the treatment group and the control group. Figure 3 shows a similar trend between the treated group and the control group before the reform in 1998.

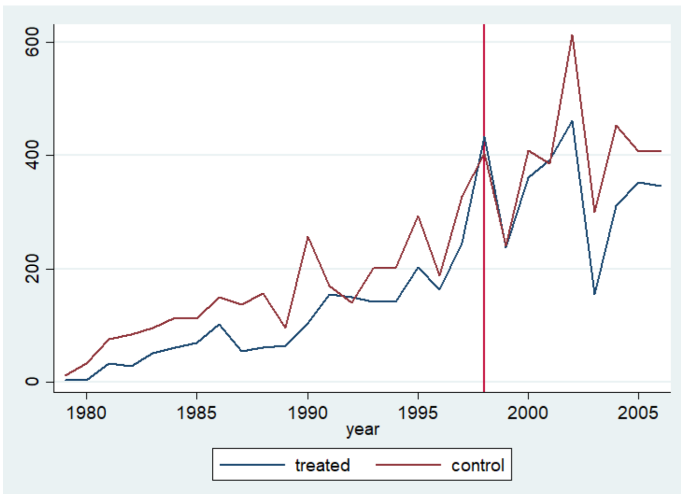
Results from Eq 1 are shown in Table 2. Table 2 shows that the 1998 reform increased the number of registration estimates of the difference in difference regression. In column (1), the result indicates that

[8] According to the document uploaded in the Japanese PVPA database, the government seemed to select the species considering the reform's harmful effect on agriculture in Japan.

the 1998 reform increased the number of registration by 10.98 when I use OLS. In column (2), I use the Poisson Quasi maximum likelihood model, and the result shows that the reform increased the number of registration. Specifically, I find that the 1998 reform increases the number of registrations in the Japanese PVPA by 30.8%. [9] In column (3), the result shows no statistically significant impact of the 1998 reform on the number of the registration when I use the negative binomial model. All of the coefficients of interest in Table 2 are positive and statistically significant, consistent with the hypothesis that the stronger intellectual property right encourages agricultural innovation. The result is consistent with the hypothesis that stronger intellectual property rights encourage agricultural innovation.

Moreover, the figure 4 show the result of Eq.2. There is no dynamic effect of the 1998 reform on the number of registrations.

Figure 3: Trends in the number of the new registrations of plant varieties



Notes: Figure plots the number of new registration. Data of the number of new registrations comes from Japanese PVPA database between 1979 and 2005. The blue line graph is the treated group and the blue line graph is the untreated group.

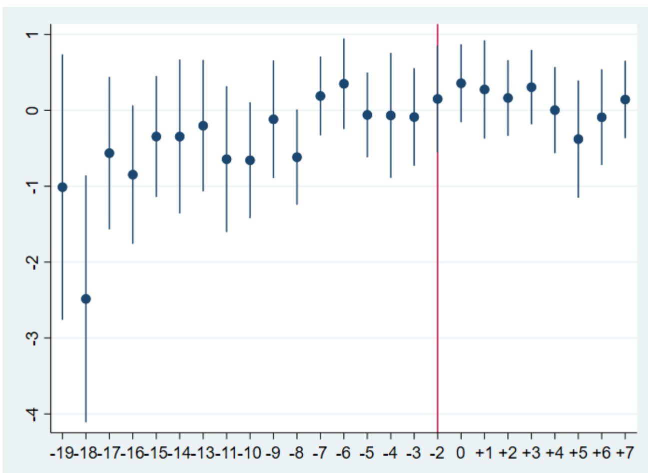
[9]Since the model uses a Poisson specification, the percentage change of the effect is calculated by exponentiating the coefficient of the variable. By subtracting one and multiplying 100, the result is given by 30.8%= $(e^(0.269) - 1) * 100$

Table 2: Effect of the 1998 reform on the No. of registrations of PVPA

	OLS	Quasi poi FE	Neg bin FE
main			
Species1998*post1998	10.987**	0.269***	0.349***
	(4.442)	(0.103)	(0.096)
Observations	6777	5940	5940
R^2	0.523		

[1] Standard errors in parentheses
[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
[3] Note: The analysis dataset covers the year 1979 to 2005. This tables contains the result from Eq.(1). All of the results include the year fixed effect and species fixed effect. The column (1) shows the result of OLS, the column (2) shows the result of Quasi Poisson fixed effect model, and the column(3) show the result of the negative binomial fixed effect model.

Figure 4: Dynamic effect of the 1998 reform on the No. of registrations of PVPA



Notes: Figure plots the result of the event study using the Quasi Poisson fixed effect model. All of the results include the year fixed effect and species fixed effect.Data of the number of new registrations comes from Japanese PVPA database between 1979 and 2005.

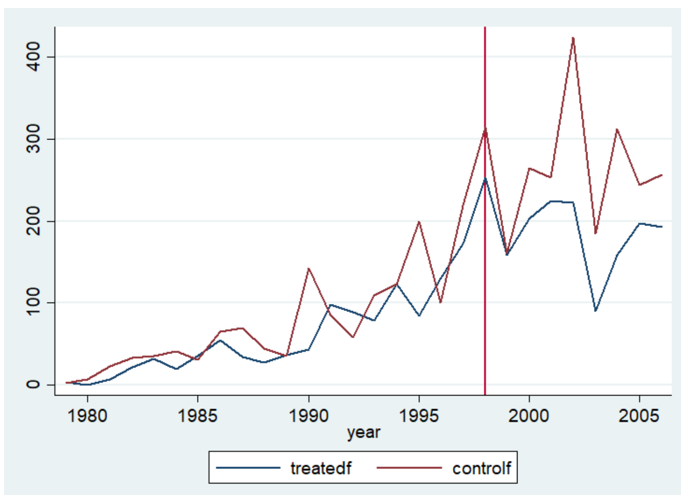
5.2 Sub sample: Flower and grass

Next, I show the effect of the 1998 reform on newly registered varieties using the data about species of flower and grass. I first show the number of registration of the treatment group and the control group. Figure 5 shows a similar trend between the treated group and the control group before the 1998 reform.

Table 3 shows that the 1998 reform increased the number of registration estimates of the difference in difference regression. In column (1), the result indicates that the 1998 reform increased the number of registration by 6.3 when I use OLS. In column (2), I use the Poisson Quasi maximum likelihood model, and the result shows no statistically significant impact on the number of registration. In column (3), the result shows no statistically significant impact of the policy change when I use the negative binomial model. The estimates in Table 3 imply that the effect of the 1998 reform on the registration of flower species is almost zero.

Moreover, the figure 6 show the result of Eq.2. There is no dynamic effect of the 1998 reform on the number of registrations.

Figure 5: Trends in the number of the new registrations of plant varieties(flower and grass)



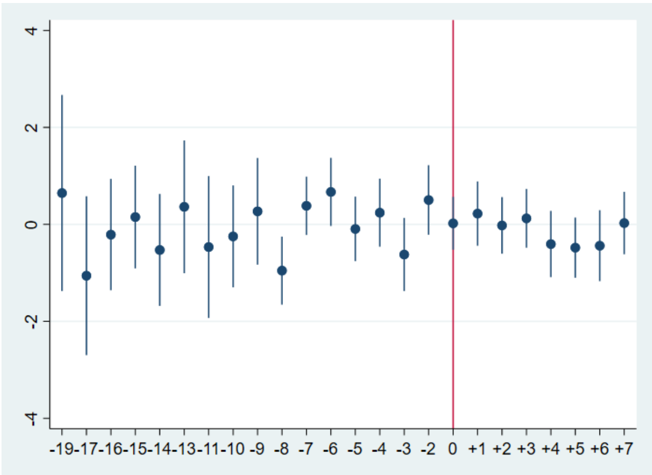
Notes: Figure plots the number of new registration. Data of the number of new registrations comes from Japanese PVPA database between 1979 and 2005. The blue line graph is the treated species of flowers and the blue line graph is the untreated species of flowers.

Table 3: Effect of the 1998 reform on the No. of registrations of PVPA(flower and grass)

	OLS	Quasi poi FE	Neg bin FE
main			
Species1998*post1998	6.373**	-0.092	0.065
	(2.556)	(0.134)	(0.125)
Observations	3321	2835	2835
R^2	0.486		

[1] Standard errors in parentheses
[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
[3] Note: The analysis dataset covers the year 1979 to 2005(flower and grass). This tables contains the result from Eq.(1). All of the results include the year fixed effect and species fixed effect. The column (1) shows the result of OLS, the column (2) shows the result of Quasi Poisson fixed effect model, and the column(3) show the result of the negative binomial fixed effect model.

Figure 6: Dynamic effect of the 1998 reform on the No. of registrations of PVPA(flower and grass)



Notes: Figure plots the result of the event study using the Quasi Poisson fixed effect model. All of the results include the year fixed effect and species fixed effect.Data of the number of new registrations comes from Japanese PVPA database between 1979 and 2005(flower and grass).

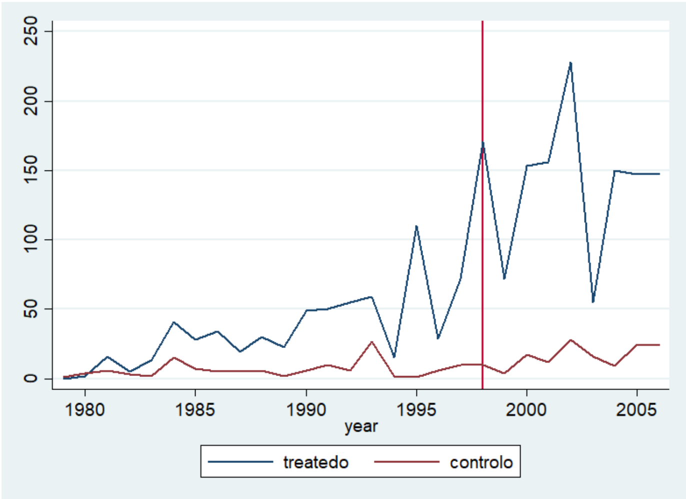
5.3 Sub sample: Ornamental tress

Next, I show the effect of the 1998 reform on newly registered varieties using the data about species of ornamental trees. Figure 7 shows that the parallel trend assumption is not satisfied.

Table 4 shows the mixed results. In column (1), the result indicates that there is no effect of the 1998 reform when I use OLS. In column (2), I use the Poisson Quasi maximum likelihood model, and the result shows that the reform increased the number of registration. Specifically, I find that the 1998 reform increases the number of registrations in the Japanese PVPA by 78.4%. [10] In column (3), the result shows the positive impact of the reform on the number of registrations when I use the negative binomial model. The estimates in Table 4 is consistent with the hypothesis that stronger intellectual property rights encourage agricultural innovation.

Moreover, the figure 8 shows the result of Eq 2. There is no dynamic effect of the 1998 reform on the number of registrations for the ornamental trees.

Figure 7: Trends in the number of the new registrations of plant varieties(ornamental tree)



Notes: Figure plots the number of new registration. Data of the number of new registrations comes from Japanese PVPA database between 1979 and 2005. The blue line graph is the treated species of ornamental trees and the blue line graph is the untreated species of the ornamental trees.

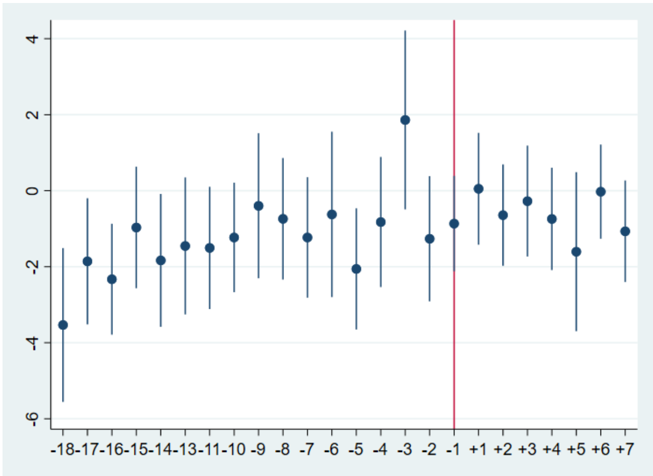
[10] The model uses a Poisson specification. Hence the percentage change of the effect is calculated by exponentiating the coefficient of the variable. By subtracting one and multiplying 100, the result is given by 78.4%$= (e^(0.579) - 1) * 100$

Table 4: Effect of the 1998 reform on the No. of registrations of PVPA(ornamental trees)

	OLS	Quasi poi FE	Neg bin FE
main			
Species1998*post1998	35.524	0.579**	0.802***
	(22.496)	(0.280)	(0.277)
Observations	1053	864	864
R^2	0.639		

[1] Standard errors in parentheses.
[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
[3] Note: The analysis dataset covers the year 1979 to 2005. This tables contains the result from Eq.(1). All of the results include the year fixed effect and species fixed effect. The column (1) shows the result of OLS, the column (2) shows the result of Quasi Poisson fixed effect model, and the column(3) show the result of the negative binomial fixed effect model.

Figure 8: Dynamic effect of the 1998 reform on the No. of registrations of PVPA(ornamental trees)



Notes: Figure plots the result of the event study using the Quasi Poisson fixed effect model. All of the results include the year fixed effect and species fixed effect.Data of the number of new registrations comes from Japanese PVPA database between 1979 and 2005(ornamental trees).

5.4 Alternative explanations

The results implies that the stronger intellectual property rights encourage agricultural innovation. However, there are some alternative explanations. First, I do not control the biotechnology development for each species. If there is a technological advance for specific species, it would affect the development of new varieties for the species.

Second, the effect of the other reforms might exist. I continue to check the other reforms in the Japanese PVPA.

Third, there may be a spillover effect. Breeders tend to be individuals, seed companies, local governments, public institutions, and foreign companies. Since the budget and resources of the breeders are limited, if the breeder change their research investment based on the 1998 reform, this would directly affect the research investment of other species. I would not get the information about research investment, but this is also problematic in my analysis.

Fourth, the variation of the 1998 reform might be too small to identify the impact of the reform. For example.Budish et al. (2016) says that the country-specific patent law change in small economies may be a relatively small source of variation in global R&D incentive. However, compared with industrial patents, plant varieties need to be developed considering the local climate conditions, so even the country-specific variation might be able to change the investment behavior.

6 Conclusion

In this study, I examine the effect of the stronger intellectual property rights on agricultural innovation by using the unique reform of the Japanese PVPA. I find the positive impact of the reform on the number of registrations in the Japanese PVPA, but the results are mixed when I focus on certain groups of species. For future analysis, I will analyze the other reform in 2007, 2017 and 2018.

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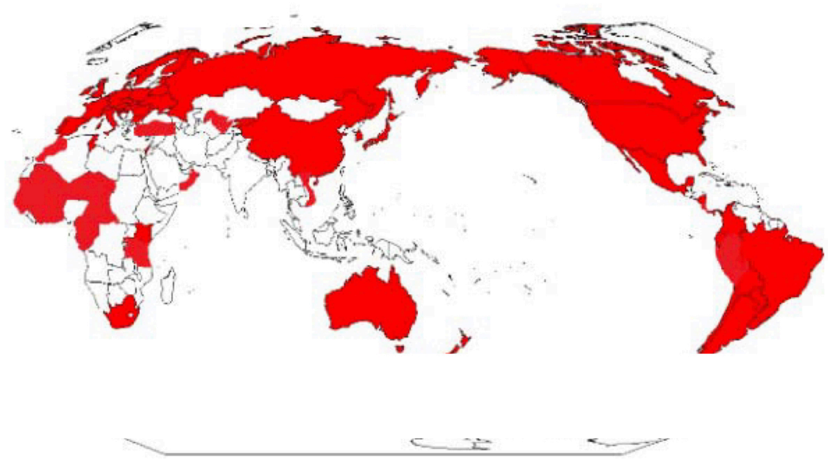
A The member countries of UPOV

Figure 9: The member countries of UPOV



Notes: The red countries mean the member countries of UPOV.

B The history of the reforms for the restriction of the self propagation

Figure 10: The history of the reform for the restriction of the self propagation

	1978	1998	2007	2017	2018	2022
23 species (flower, mushroom, grass…)						
around 50 species (flower, grass, mushroom…)						
around 200 species (flower, vegetable..)						
around 70 species (vegetable, mushroom…)						
around 350 species (rice, wheat potato…)						

Note: The gray area is the group of the species under the restriction of the self propagation in the Japanese PVPA. I use the gray area in 1998 as the treated species.

C List of the species for which self-propagation is restricted

- The reform in 1998 (23 species)
  - the date of the publication:29 May 1998
  - the date of the enforcement:24 December 1998
  - Alstroemeria L., Odontoglossum Group, Oncidium Group, Gypsophila L., Cattleya Group, Gerbera L., Kalanchoe Adans., Clematis L., Schlumbergera Lem., Cymbidium Sw., Saintpaulia H. Wendl., Tulipa L., Dendrobium Sw., Petunia Juss., Pelargonium L'Her. ex Ait., Impatiens L., Dianthus L., Iris laevigata Fisch., Dianthus caryophyllus L., Hydrangea L., Rosa L., Euphorbia pulcherrima Willd. ex Klotzsch, Lentinus edodes (Berk.) Sing.
  - Note: Schlumbergera Lem., Iris laevigata Fisch., Dianthus caryophyllus L. were not protected by Japanese PVPA in 1978, so I didn't use them for the analysis.