RESEARCH ARTICLE

Impact of farm protectionism on the use of agricultural inputs in Chile

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Abstract

Despite evidence highlighting the multiple benefits that liberalization can have in the agricultural sector, agricultural protectionism is abundant, especially in developing countries. Chile provides an interesting case on this topic because it implemented an aggressive liberalization in the agricultural sector during the 1970s and 1980s. This paper analyzes the impact of farm protectionism on the use of agricultural inputs in Chile. To do this, we estimated partial elasticities of substitution by incorporating government protectionism as a factor for agricultural production. Our findings reveal that increased protectionism decreases agricultural labor and promotes the use of fixed capital. In contrast, protectionism has no effect on the use of working capital and land. This information shows a clear transference from the government to farmers. Furthermore, our results are useful for anticipating the effects that varying levels of government protectionism can have on the Chilean agricultural sector over time.

Introduction

The agricultural sector is particularly important for developing countries. In the first steps of development, economic growth is mainly driven by the agricultural sector. Its importance diminishes as countries develop and other economic sectors become more prominent. A characteristic that distinguishes the agricultural sector from other sectors of the economy is the high level of government protection it receives. In spite of evidence supporting the liberalization of agriculture, protectionism in the agricultural sector is common across developed and developing economies alike (Swinnen, 2010; Anderson *et al*., 2013).

Anderson (1992) argues that liberalization not only promotes an increase in income in developing countries but also reduces negative impacts on the environment. Bouët *et al*. (2005) used an applied general equilibrium model to show that gains in welfare for developed countries from protectionism are contrasted by its negative effects in developing countries. Similarly, Panagariya (2005) discusses the negative impacts that

protectionism in developed countries has on developing nations. Evidence on the effect of liberalization in the agricultural sector of developing countries is not conclusive. On the one hand, when implementing a gradual liberalization process that includes a strict monitoring system, Ahmed (1995, 1996) found positive effects of liberalization on the production of rice in Bangladesh. While agricultural productivity in Nigeria was found to decrease with higher degrees of openness, the volume of its exports increased (Anowor *et al*., 2013). On the other hand, Gibbon (1999), after studying the cotton sector in Tanzania, postulated that liberalization cannot ensure sustainable production. Rafeek & Samaratunga (2000) studied the liberalization on the rice sector Sri Lanka, showing that, despite overall welfare gains in the society at-large, farmers experienced welfare losses. Jayne *et al*. (2002) discuss the cases of Ethiopia, Kenya, Malawi, Zambia, and Zimbabwe, and argue the existence of negative impacts on both the private and public sectors of these economies from liberalization. In the case of Latin American countries, convergence in non-agricultural salaries,

increases in unemployment volatility, increases in migration, and increases in the aggregate Foreign Direct Investment were found to be effects of the NAFTA trade agreement between Mexico and the USA (Lederman *et al*., 2004; Chiquiar & Hanson, 2005). For Argentina, there is evidence of a decrease in the labor share of the agricultural sector (Cavallo & Mundlak, 1982). Finally, Brazil decreased its inputs prices, causing an increase in productivity – although the overall impact on production was moderate and there was a decrease in rural employment (De Albuquerque *et al*., 2000). Chile represents an interesting case study because it experienced an aggressive liberalization on agriculture during the 1970s and 1980s, giving us the opportunity of better understand the effects of protectionism on the use of agricultural inputs.

Agricultural protectionism started in 1815 when the UK imposed strong restrictions on grain imports (Hollander, 1992). Since then, government assistance for farmers has become popular, and, nowadays, it is a common practice around the world, especially in developing countries (Swinnen, 2010). This is an interesting issue given that there is an extensive amount of literature that supports liberalization in the agricultural sector (*see, e.g*., Giannakas *et al*., 2001; McCalla, 2003; Guan & Lansink, 2006). For instance, Hertel & Keeney (2006) and Anderson *et al*. (2013) provide evidence of the positive impacts that agricultural liberalization can have on the economy. In fact, the creation of the World Trade Organization (WTO), which focuses on policies oriented at liberalizing the agricultural sector, is a consequence of this line of research (Ingco & Nash, 2004). In contrast, there is a different line of research that supports protectionism in the agricultural sector. For instance, Moon & Griffith (2011) argues the existence of diverse benefits of the agricultural production that cannot be measured or internalized by the market. For developing countries, the importance of the agricultural sector in their gross domestic product (GDP), labor force, political ideologies, and positive externalities are additional arguments used in support of agricultural protectionism (*see, e.g*., Boot & Zee, 1993; Swinnen, 1994; Binswanger & Deininger, 1997; Naoi & Kume, 2011; Lusk, 2012). As a result, agricultural protectionism is a relevant and controversial issue.

Chile is an interesting case for analyzing the effect of protectionism on agricultural production for the following reasons: First, Chile is still a developing country; however, its level of the development is among the highest in Latin America. For instance, Chile is a permanent member of the Organization for Economic Co-operation and Development (OECD) and its human development index is the highest among Latin American countries. Second, Chile had a fairly open international trade policy with moderate import tariffs until the Great Depression. After the Great Depression, though, protectionism increased as the country's dependence on unstable external markets was believed to be responsible for the economic struggles they experienced. Nevertheless, since the coup d'état in 1973, Chile has experienced an aggressive liberalization in different areas of its economy. The coup d'état, and military government that accompanied it, lowered tariff rates to try and increase international trade (Larrain, 1982). In fact, according to the 2016 Index of Economic Freedom, Chile is ranked the 7th most open economy in the world. This trend toward free-markets has affected all sectors of the economy.

The agricultural sector is an important component of the Chilean economy. The agri-food share of GDP was 7.8% in 2012, bringing in USD$13,109 million (ODEPA, 2013). Moreover, 7.1% of the total national employment comes from the agricultural sector. The main exports by sub-class are fresh fruit (28.2%), wood pulp (17.6%), wine and other alcoholic drinks (12.7%), and processed fruits and vegetables (10.2%). The Institute of Agricultural Development (INDAP) has been the organization under the Ministry of Agriculture in charge of managing resources for agrarian assistance in Chile since 1965. This institution has undergone various changes since its creation. Currently, the INDAP mainly provides indirect subsidies, credits for agricultural insurance, and training to farmers. Unlike many countries, Chile does not offer direct subsidies, like payments apart from production.

The previous discussion makes it interesting to investigate the effects of farm protectionism on the agricultural sector of a country that seems to minimize market interventions (see a deeper discussion on Chilean agricultural reforms and their results in Valdés, 1993). Finally, empirical investigation of the agricultural production is not extensive for developing countries and especially not for Latin America. Then, the objective of this paper was to investigate how farm protectionism affects the use of agricultural inputs in Chile, estimating partial elasticities of substitution, and observing how increases in the use of a specific input affect the use of others.

Empirical methodology and data

Empirical methodology

Agriculture is one of the main economic sectors for developing economies. For this reason, farm protectionism is a common practice in these nations.

As Anderson & Nelgen (2011) show, import protection has been a common source of protection for farmers in developing countries. This implies that famers face less competition in local markets and can maintain, or even increase, their level of production over time. Therefore, protection from foreign competition is believed to be a way in which protectionism stimulates agricultural production in developing countries. The effect of farm protectionism on agricultural production is supported theoretically and empirically (Henessy, 1998; Giannakas *et al.*, 2001; Karagiannis & Sarris, 2005; Guan & Lansink, 2006). Thus, we define agricultural output as:

$$Y = f\left(L, W, F, N, T, A\right) \qquad (1)$$

where Y is the gross agricultural output, which uses four inputs: labor (L), working capital (W), fixed capital (F), and land (N). T represents the aggregate technology used in the production process. These are the standard determinants of an agricultural-production function (*see e.g.*, Sharma, 1991; Kuroda, 1997). We added A which represents farm protection. Government transferences can have a direct effect on agricultural production, *i.e.*, technical efficiency, or indirect effects through productivity and technical changes. All of these effects can be captured by a log-linear functional form, which is the approach followed here (see McCloud & Kumbhakar, 2008, for a deeper discussion about ways in which government transferences to farmers can be modeled). Therefore, we followed a general specification to capture the effect of protectionism on the use of agricultural inputs. Duality implies that there is a twice-differentiable cost function that depends on the input prices (p_i) of labor ($i=L$), working capital ($i=W$), fixed capital ($i=F$), and land ($i=N$), as well as production (Y), technology (T), and government transference to farmers (A), *i.e.* farm protectionism.

Assuming a translog-functional form of the cost function (C) allows us to obtain the conditional factor demands (x_i) by using the Shepard's Lemma (Berndt & Wood, 1975; Sharma, 1991; Hadley, 2006). Therefore, the price-demand elasticity $(\partial C/\partial p_i)(p_i/C)$ can be expressed as $p_i x_i/C$, which implies that the price-demand elasticity $\partial \ln(p_i)/\partial \ln(C)$ can be interpreted as the i-th input share on the total cost (s_i). This implies that by differentiating the translog-cost function according to the four price inputs, we can obtain four share equations.

To empirically estimate the system of four share equations, it is necessary to add a stochastic term.

Given that the sum of the shares is one (left-hand side), the sum of the right-hand side will also be one, which implies that the error terms will not be independent of each other. Because conditional factor demands must be homogenous of degree one in prices, we arbitrarily dropped the equation associated with the working capital share. In fact, the estimates are invariant to the dropped equation (Barten, 1969). This allowed us to obtain the following system of equations[1]:

$$s_F = \alpha_F + \alpha_{FY} \ln Y + \alpha_{FT} \ln T + \alpha_{FA} \ln A +$$
$$+ \alpha_{FL} \ln\left(\frac{p_L}{p_W}\right) + \alpha_{FF} \ln\left(\frac{p_F}{p_W}\right) + \alpha_{FN} \ln\left(\frac{p_N}{p_W}\right) + \varepsilon_F \qquad (2)$$

$$s_L = \alpha_L + \alpha_{LY} \ln Y + \alpha_{LT} \ln T + \alpha_{LA} \ln A +$$
$$+ \alpha_{LL} \ln\left(\frac{p_L}{p_W}\right) + \alpha_{LF} \ln\left(\frac{p_F}{p_W}\right) + \alpha_{LN} \ln\left(\frac{p_N}{p_W}\right) + \varepsilon_L \qquad (3)$$

$$s_N = \alpha_N + \alpha_{NY} \ln Y + \alpha_{NT} \ln T + \alpha_{NA} \ln A +$$
$$+ \alpha_{NL} \ln\left(\frac{p_L}{p_W}\right) + \alpha_{NF} \ln\left(\frac{p_F}{p_W}\right) + \alpha_{NN} \ln\left(\frac{p_N}{p_W}\right) + \varepsilon_N \qquad (4)$$

where ε_L, ε_F, and ε_N are error terms and α_L, α_F, and α_N are constant terms. An important issue is that the residuals in system of equations (1)-(3) can be driven by the same factors over time. This implies that they can be contemporaneously correlated, leading to a biased OLS estimation. For this reason, we estimated this system of equations using Iterative Seemingly Unrelated Regressions (ITSUR).

The coefficients of the system of equations (1)-(3) contain the information relevant to the aims of this paper. First, the partial elasticities of substitution (θ_{ij}) between the four inputs can be obtained as follows:

$$\theta_{ij} = \frac{\left(\alpha_{ij} + s_i s_j\right)}{s_i s_j} \qquad (5)$$

with $i \neq j$ and $i, j = L, W, F, N$.

Conditional on the mean-share values, we can obtain the standard errors of these partial elasticities of substitution, which allows us to test their significance. Inputs i and j are considered complements (substitutes) if their corresponding partial elasticity of substitution is significantly less (greater) than zero.

Second, the α_{iY} coefficients allow us to test whether the production function is homothetic or not. Specifically, if a cost function is separable in

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[1]Note that the dependent variable is a share, *i.e.*, between 0 and 1; however, independent variables are expressed in logarithms. Therefore, a linear specification for equations (2)-(4) is not misled since coefficients capture percentage changes in the dependent variable.

input prices and output, *i.e.*, $\alpha_{LiY}=0$, the production function is homothetic (see a deeper discussion of this issue in Diewert, 1974). Therefore, a significant coefficient implies that the production function is non-homothetic, and imposing the assumption of homotheticity in these cases could cause a bias in our estimates.

Third, the α_{iT} coefficients allow us to identify whether technological changes are *i*-th input-saving or input-using – that is, if a technological change increases the use of the *i*-th input, this technological change is *i*-th input-using. On the contrary, if a technological change decreases the use of the *i*-th input, this technological change is *i*-th input-saving. This information is useful for understanding how technology affects the allocation of agricultural inputs in the production process.

Finally, the α_{iA} coefficients are crucial to our analysis because they allow us to investigate the effect of protectionism on the agricultural sector through its impact on the use of agricultural inputs. Similar to technological changes, the sign and significance of these coefficients reveals whether farm protectionism is input-using or -saving. In this way, we can identify the inputs whose use are increased or decreased by farmers when those farmers receive government transferences. This information reveals the needs or priorities of farmers and is helpful for understanding the effects of protectionism on agricultural production. For instance, increases and decreases in the demand of the inputs can be anticipated when there is an increase or decrease in farm protectionism.

Data

First of all, it is necessary to highlight that information about agricultural inputs for developing countries is limited, which is why there is little empirical research about this topic. In order to estimate the shares for the four inputs in analysis, we first needed the quantities and prices of these inputs. The data sources and proxies we used are discussed below.

Agricultural employment was quantified by the population economically active in agriculture, which is freely available on the FAO database (www.faostat. fao.org). The agricultural sector's workforce is mainly composed by low-skilled workers. Even though Chile's National Institute of Statistics (Instituto Nacional de Estadísticas, INE) has data on the average wages for this level of qualification, the data available only covers a short part of our time sample. For this reason, we used the minimum wage, which is available during the

whole period in analysis. This data was obtained from the INE website (www.ine.cl).

The amount of land was measured by data on arable land obtained from the FAO database. The price of land was obtained from three alternative sources: First, we used the average prices of agricultural land collected by Morandé & Soto (1992) during the 1975-1989 period. Second, from 1999 to 2002, we used average agricultural land prices collected by Tobar (2003). Finally, we used the database from the Office of Agricultural Studies and Policies (ODEPA, 2013) for 2003 to 2010. It is necessary to highlight that these three datasets use the same source to collect the agricultural land prices – the '*Revista del Campo*', which is a mainstream magazine with national coverage that focuses on agribusiness.

The working capital was mainly proxied by fertilizers and pesticides (*see*, *e.g.*, Sharma, 1991; Kuroda, 1997). The FAO dataset provided import values and quantities for these two variables. However, for the specific case of Chile, there is no data available for quantities of pesticides. For this reason, we applied the use of fertilizers as a proxy for working capital[2].

By following Kuroda (1997) and Suhariyanto & Thintle (2001), we used imported tractors and crawlers as a proxy for fixed capital. Prices and quantities of this input were also obtained from the FAO database.

In order to capture the evolution of aggregate technology, we followed Duguet & MacGarvie (2005) and Hadley (2006) and used patent applications as our proxy for this variable. These figures correspond to the number of patent applications emitted by residents and nonresidents. It was obtained from the World Intellectual Property Organization (WIPO, www.wipo.int). Agricultural production was proxied by the Agricultural Production Index provided by the FAO dataset.

To capture the effect of farm protectionism, we used the NRA. Chile's NRA was obtained from the world dataset elaborated by Anderson & Nelgen (2012). This measure represents the price gap caused by government distortions compared to a free market situation. It can be interpreted as the percentage in which protectionism increases the farm's gross return in relation to the absence of this intervention. The NRA covers around 67% of livestock, 75% of oilseeds and tropical crops, and 83% of grains and tubers, which corresponds to the 85% of the world's agricultural exports. The NRA considers price distortions for alternative farm products, which can be classified into import-competing and producers of exportables. As Anderson & Nelgen (2011) discuss, the source

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[2]Therefore, our results applied fertilizer as the input capturing working capital.

of protectionism depends on the country's level of development. Specifically, the main distortions for developing countries are seen in the import-competing products. This is clearly observed in Figure 1, which shows the evolution of the NRA for import and export products from 1973 to 2010. While the export NRA approaches zero during the majority of the period, the import NRA is mostly positive and varied greatly over the sample period. In spite of this issue, the export NRA is highly positive during the first and last period of our sample; this is why using an aggregate NRA is useful as it avoids misinterpreting the distortions introduced into the agricultural sector by the Chilean government.

Our sample covers the period of 1973 to 2010. All prices were measured in dollars of 2005. This time period was only chosen for availability of information. Prices and quantities of each input allowed us to compute the shares of each input as the weight over the total agricultural production. Descriptive statistics of these shares and the NRA are discussed below.

Figure 1 presents the evolution of the NRA from 1973 to 2010. At the beginning of this period, *i.e.*, from 1974 to 1976, it exhibits negative values, which seem to be driven by the coup d'état in 1973. A drastic elimination of distortions in different sectors of the economy took place during this period in order to pursue a free-market economy. Starting in 1977, the NRA began to increase until the mid-1980s. This is interesting because, despite the free-market focus, we can observe an increasing pattern of farm protectionism. The end of 1980s shows a significant drop in the NRA, suggesting that the end of the dictatorial period also put an emphasis on eliminating distortions in the agricultural sector. We thought that Chile's return to democracy in 1990 could have changed the focus of

economic policies related to the agricultural sector. Yet, while there is an increase in the NRA during the 1990s, there is a clear decrease from 2000 to 2010. The general tendency of the NRA throughout the study period was to decline; however, it remained positive throughout most of the timeframe. So, in spite of the predominance of the free-market focus, farm protectionism was not totally eliminated during the period in analysis. In this way, it is interesting to investigate the effects of the positive yet decreasing trend of the NRA on Chile's agricultural production.

Table 1 presents the average annual growth rates of labor, fixed capital, working capital, and land shares in four periods, *i.e.*, 1970s, 1980s, 1990s, and 2000s. The first period, 1973-1980, was influenced by the profound economic crisis at the beginning of the 1970s and the subsequent reforms introduced in the Chilean economy to combat that crisis. These issues seemed to affect the labor and working capital shares, which presented high growth rates. In contrast, the fixed capital and land shares had negative growth rates. This suggests that this period was dominated by an agricultural production that was intensive in labor and working capital. The second period, 1981-1990, coincides with the Latin American debt crisis at the beginning of the 1980s. It was also the beginning of the Chilean economy's impressive growth in the mid-1980s. Labor's share continued to increase, but there was a notable decrease in its growth rate. A greater decrease is observed in the working capital share, which presented a negative average in this period. Fixed capital and land share, on the other hand, presented positive and high growth rates. This implies that the agricultural production in the 1980s was dominated by the use of the land and fixed capital inputs. The 1990s was also an important decade for Chile because it is when the government
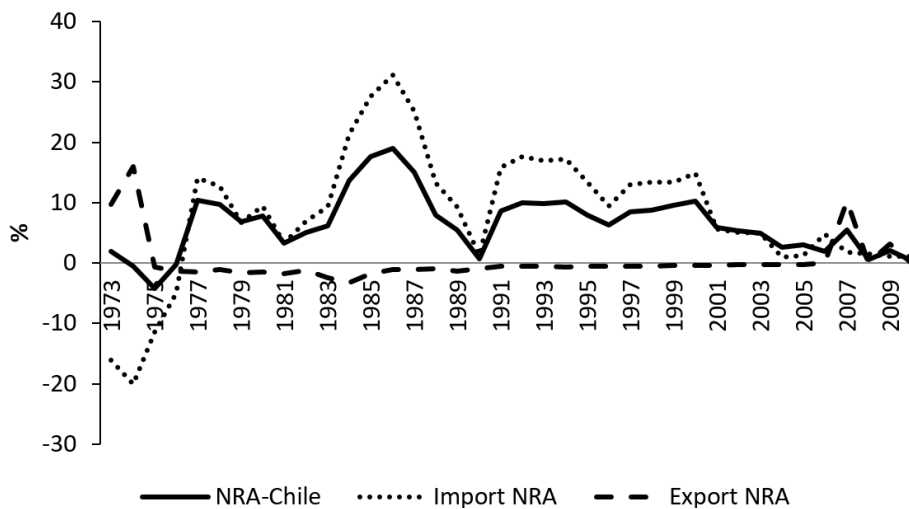

Figure 1. Evolution of nominal rate of assistance (NRA). *Source:* Anderson & Nelgen (2012).

Table 1. Average annual growth rate of input shares (%).

Share	1973-1980	1981-1990	1991-2000	2001-2010	Overall
Labor	124.1	3.9	1.5	-0.1	24.9
Fixed capital	-4.0	24.3	-2.8	-1.3	4.7
Working capital	172.4	-8.6	-5.3	23.0	35.1
Land	-2.3	10.8	-7.2	1.4	0.9

Source: Own elaboration with data from FAO (www.faostat.fao.org), ODEPA (2013), INE (www.ine.cl), Morandé & Soto (1992) and Tobar (2003).

returned to democracy. Fixed capital, working capital, and land shares decreased their relative importance in the agricultural production, as seen in their negative growth rates. The exception is the labor share, which continued to be positive. The final period, 2001-2010, revealed an increase in the importance of the working capital and land on the agricultural production since they were the only shares with positive growth rates. Interestingly, the last decade in our sample is the only period where the labor share lost importance in the agricultural production. In fact, the agricultural sector of developing countries is labor abundant (relative to land), with land being the main agricultural input. In order to analyze this issue, Figure 2 presents the evolution of the labor-land ratio. We can observe that labor took importance (relative to land) from 1973 to 2000. Nevertheless, this ratio declined in the last decade of analysis, *i.e.*, 2001-2010. The loss of importance of labor, relative to land, may suggest the beginning of a structural change in the Chilean agricultural sector. Another interesting issue is that neither of the technologies, *i.e.*, biochemical or mechanical, had a predominance in the agricultural production of Chile. Biochemical technology was more important for agricultural production during the 1970s and 2000s, while mechanical technology was dominant during the 1980s and 1990s.

Results

First of all, we should note that our estimates presented significant autocorrelation of order one in the residuals. To solve this problem, we followed Sharma (1991) and assumed that the residuals of system of equations (1)-(3) follow an autoregressive process of order one. In this way, we added a lag of each residual in the system of equations (1)-(3), which provided estimates with no-autocorrelation. Specifically, we failed to reject the null of no autocorrelation at the conventional levels of significance. Table 2 presents these results which are discussed below.

The coefficient associated with the agricultural production index was insignificant for the labor, fixed capital, and land share equations. However, this coefficient had a t-statistic of 2.14, which was significant at the 10% level (and near the 5% level) for the working capital share equation. This implies that the production function is non-homothetic. Thus, it seemed appropriate to use a function that allows non-homotheticity in order to avoid misleading our results.

Technological changes were neutral to the four inputs analyzed because all coefficients associated with the evolution of patents were insignificant at the conventional levels, and the evolution of patents was our proxy for the aggregate technology in the country.
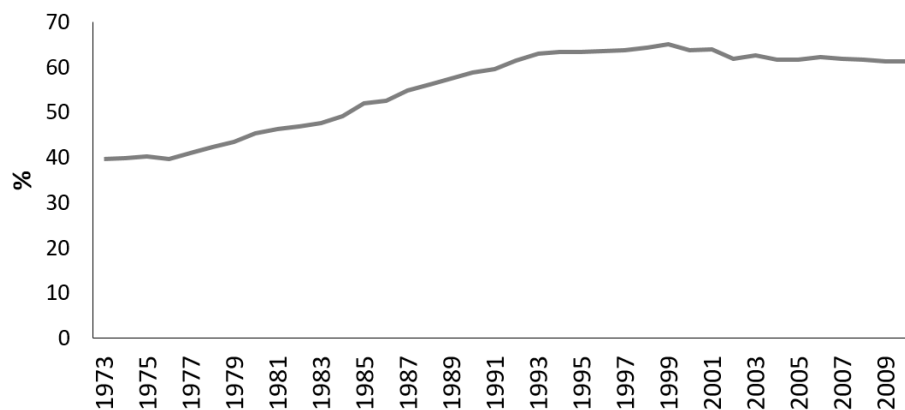

Figure 2. Evolution of the labor-land ratio. *Source:* Own elaboration with data from FAO (www.faostat.fao.org) for labor, and Morandé & Soto (1992) jointly with Tobar (2003) for land.

Table 2. Estimated coefficients for each input share equation and partial elasticities.

Labor			Land			Fixed capital			Working capital		
Coeff	Est.	SE	Coeff	Est.	SE	Coeff	Est.	SE	Coeff	Est.	SE
α_{LL}	0.12***	0.01	α_{NL}	-0.07***	0.01	α_{FL}	-0.01	0.01	α_{WL}	-0.04***	6.5E-3
α_{LF}	-5.3E-3	0.01	α_{NF}	5.5E-5	0.01	α_{FF}	-0.01	0.02	α_{WF}	0.01*	7.3E-3
α_{LN}	-0.07***	0.01	α_{NN}	0.10***	0.01	α_{FN}	5.5E-5	0.01	α_{WN}	-0.03***	6.7E-3
α_{LY}	0.12	0.13	α_{NY}	-0.05	0.10	α_{FY}	-0.22	0.15	α_{WY}	0.15*	0.07
α_{LT}	-0.01	0.05	α_{NT}	-0.03	0.04	α_{FT}	0.06	0.06	α_{WT}	-0.02	0.03
α_{LA}	-0.22*	0.12	α_{NA}	0.16	0.11	α_{FA}	0.25*	0.13	α_{WA}	-0.19	0.12
ρ_L	0.79***	0.19	ρ_L	-0.15	0.18	ρ_L	-0.98***	0.21	α_W	-0.27	0.16
ρ_F	0.36**	0.18	ρ_F	0.03	0.17	ρ_F	-0.43**	0.19			
ρ_N	0.21	0.16	ρ_N	0.62***	0.16	ρ_N	-0.67***	0.18			
α_L	0.46	0.29	α_N	0.26	0.20	α_F	0.54*	0.32			

Partial elasticities of substitution	Est.	SE
Labor- Fixed capital	0.90***	0.26
Labor-Land	0.35***	0.09
Land- Fixed capital	1.05	0.90
Working capital-Labor	4.7E-3	0.15
Working capital- Fixed capital	3.82**	1.50
Working capital-Land	-2.26***	0.67

***, **, and * denote significance at 1%, 5%, and 10%, respectively. ρ_L, ρ_F, and ρ_N correspond to the lag of the residual of land, fixed capital, and land share equations, respectively. SE stands for standard error.

The use of fixed capital, working capital, labor, and land were not affected by changes in the aggregate technology used in Chile. This outcome suggests that there is a weak link between the Chilean agricultural sector and the evolution of technology. Therefore, to stimulate technological innovation in agricultural production it is necessary to improve productivity in the Chilean agricultural sector. In fact, innovation surveys taken by the Ministry of Economy of Chile (2012) show that the agricultural sector showed the lowest degree of innovation during the 2007-2011 period.

The relationship between the four agricultural inputs is summarized in Figure 3. The partial elasticity of substitution between labor and fixed capital had a positive and significant sign. Given that improvements in mechanical technology promote the substitution between labor and fixed capital, this is an expected outcome. While the use of fixed capital, *i.e.*, mechanical technology, was more intensive, the use of labor was less so. The elasticity of substitution between working capital and labor was also positive – however, insignificant. This finding implies that these
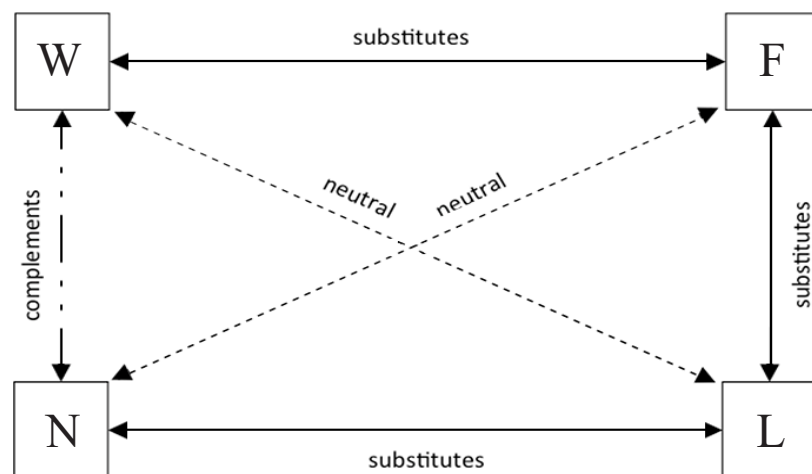

Figure 3. Relation between agricultural inputs. W, F, N, and L stand for working capital, fixed capital, land, and labor respectively.

inputs are neither substitutes nor complements. Thus, changes in the use of these inputs do not affect each other at all. Land and labor are substitutes because their elasticity of substitution was positive and significant at the 1% level. Therefore, the use of land (labor) discourages the use of labor (land). This can explain the different evolution seen in the annual growth rates of these inputs in Table 1. Land and fixed capital, on the other hand, are neither complements nor substitutes as this elasticity was insignificant at the conventional levels. This finding implies that increases in the use of mechanical technology will have no significant effect on the acquisition of agricultural land and vice versa. Working capital and land are complements at the 1% level of significance. Therefore, the use of one of these inputs stimulates the use of the other, *e.g.*, increases in the use of biochemical technology can also increase the acquisition of land. This is an interesting result given that the use of biochemical technology can also increase the scarcity of land, which can have an effect on the price of this input. Finally, the positive and significant elasticity of substitution between working capital and fixed capital implies that these inputs are substitutes. Thus, the use of biochemical and mechanical technology does not evolve simultaneously in the Chilean agricultural market. The substitution between these two inputs suggests that one of them has been more important in the agricultural production of Chile. The efficiency of biochemical and mechanical technologies depends upon the relative scarcity of labor. In particular, if labor is abundant relative to land, the use of biochemical technology is more efficient. This is the case in developing countries and should be the case in Chile as well. As the evidence in the descriptive statistic shows, the labor-land ratio increased during most of the study period. Therefore, biochemical technology (working capital) should be more important than mechanical technology (fixed capital), explaining the evolution of agricultural production in Chile.

Relevant information is provided by the magnitude of the partial elasticities of substitution. As Berhman (1972) discusses, the magnitude of the partial elasticity of substitution between labor and capital provides a measure of adjustment to international shocks. In particular, an inelastic elasticity, *i.e.*, less than one, makes a country less flexible when confronting international disturbances. In our case, all the partial elasticities of substitution between labor and the different capital inputs studied, *i.e.*, fixed capital, working capital, and land, were less than one. For this reason, we can infer a low degree of adjustment of the Chilean agricultural sector in the face of international shocks. This finding reveals fragility in the agricultural sector of Chile, and should be taken into consideration by policy makers.

In relation to farm protectionism, which is the focus of this study, important findings arose. First, farm protectionism is labor-saving. It seems that farmers do not use government transferences for additional workers. On the contrary, they seem to reallocate resources by using less agricultural labor. This issue is relevant since agricultural employment is mainly composed of low-skilled labor. Therefore, a decrease in agricultural labor can increase poverty by increasing unemployment of the poor. This effect might be more relevant in geographical areas where the agricultural sector is more important. This finding also suggests that farm protectionism could increase migration from the countryside to cities. Second, farm protectionism is fixed capital-using. This result suggests that fixed capital seems to be an important use of government transferences. Therefore, increases in farm protectionism can have an important effect on the demand for agricultural capital. In this way, an increase in agricultural capital price would be an expected outcome in an environment where government transferences to farmers are increased. This result could be driven by the different free-trade agreements signed by Chile, especially the one between China and Chile signed in 2005 that has opened the door for Chilean farmers to acquire cheap machinery, encouraging the use of fixed capital in the agricultural sector. Finally, farm protectionism is land and working capital neutral. Thus, the acquisition of agricultural land and working capital is not affected by government transferences to Chilean farmers. Hence, these two inputs do not seem to be an important endpoint for farm protectionism. The above findings indicate that there is only one clear impact of the use of government transferences: fixed capital.

In order to check the robustness of our results, we performed three robustness checks. First, because aggregate technology was identified as neutral to the four inputs, we dropped this variable from the analysis (see model 2 in Table 3). All findings related to the substitution between labor and the additional agricultural inputs remained unchanged. The partial elasticities of substitution between working capital and fixed capital and between working capital and land, however, lost their significance. Therefore, the substitution between these inputs should be taken with caution. All results for farm protectionism were supported, with the exception that it becomes working capital-saving. This implies that increases in protectionism can decrease the use of biochemical technology. Interestingly, the production index was significant for three of the share equations, supporting the assertion that the production function is not homothetic. In addition, all elasticities between labor

Table 3. Robustness checks.

Share equation	Coeff. [1]	Model 2		Model 3	
		Estimate[2]	SE	Estimate[2]	SE
Labor	α_{LL}	0.12***	0.01	0.13***	6.4E-3
	α_{LF}	-0.01*	0.01	-0.02***	4.9E-3
	α_{LN}	-0.07***	0.01	-0.07***	0.01
	α_{LY}	0.08*	0.04	-	-
	α_{LT}	-	-	0.03*	0.01
	α_{LA}	-0.24**	0.11	-0.25**	0.11
	ρ_{L}	0.79***	0.21	0.92***	0.20
	ρ_{F}	0.31	0.19	0.42**	0.18
	ρ_{N}	0.20	0.17	0.22	0.17
	α_{L}	0.55***	0.20	0.76***	0.12
Fixed capital	α_{FL}	-0.01*	0.01	-0.03***	4.9E-3
	α_{FF}	0.01	0.01	0.02***	0.01
	α_{FN}	-0.01	0.01	2.4E-3	0.01
	α_{FY}	-0.05	0.04	-	-
	α_{FT}	-	-	-9.3E-3	0.01
	α_{FA}	0.34***	0.11	0.32***	0.11
	ρ_{L}	-0.99***	0.22	-1.16***	0.20
	ρ_{F}	-0.40**	0.20	-0.52***	0.19
	ρ_{N}	-0.64***	0.17	-0.67***	0.17
	α_{F}	0.22	0.20	0.02	0.11
Land	α_{NL}	-0.07***	8.3E-3	-0.07***	7.0E-3
	α_{NF}	-8.9E-3	6.6E-3	2.4E-3	5.2E-3
	α_{NN}	0.10***	0.01	0.10***	0.01
	α_{NY}	-0.12***	0.03	-	-
	α_{NT}	-	-	-0.05***	0.01
	α_{NA}	0.10	0.10	0.21**	0.10
	ρ_{L}	-0.20	0.19	-0.11	0.19
	ρ_{F}	-0.09	0.17	-0.04	0.17
	ρ_{N}	0.65***	0.15	0.60***	0.15
	α_{N}	0.38**	0.16	0.21*	0.11
Working capital[3]	α_{WL}	-0.04***	5.8E-3	-0.03***	4.9E-3
	α_{WF}	8.2E-3	5.7E-3	5.9E-4	5.0E-3
	α_{WN}	-0.03***	6.5E-3	-0.03***	6.8E-3
	α_{WY}	0.09**	0.03	-	-
	α_{WT}	-	-	0.04**	0.01
	α_{WA}	-0.20*	0.10	-0.28**	0.11
	α_{W}	-0.16	0.14	1.6E-3	0.11
Partial elasticities of substitution					
Labor-Physical capital		0.73***	0.15	0.50***	0.09
Labor-Land		0.38***	0.08	0.34***	0.07
Land-Physical capital		-3.24	3.60	1.20**	0.45
Working capital-Labor		0.09	0.13	0.25**	0.11
Working capital-Physical capital		10.04	10.08	1.12	1.04
Working capital-Land		-7.26	11.00	-2.17**	0.69

[1] ρ_{L}, ρ_{F} and ρ_{N} correspond to the lag of the residual of land, fixed capital, and land share equations, respectively. [2] ***, **, and * denote significance at 1%, 5%, and 10%, respectively. [3] These estimates where obtained by using the estimates of the system of equations and the constraints in (4). Model 2 does not consider technology in the estimation. Model 3 assumes homotheticity, *i.e.*, does not consider production level in the estimation.

and the capital inputs remained less than one, which re-confirms the fragility of the Chilean agricultural sector.

Second, we imposed homotheticity in the production function in order to see which results were sensitive to this strong assumption (see model 3 in Table 3). Farm protectionism continued being labor-saving and fixed capital-using. Technological changes were only neutral for fixed capital, but they became labor-saving and working capital- and land-using. In relation to the partial elasticities of substitution, we noted changes in their significances but not in their signs. Labor was still a substitute of fixed capital and land, and working capital was still a complement of land. However, land and fixed capital, and also labor and working capital, became substitutes. In addition, the partial elasticity of substitution between working capital and fixed capital was insignificant. Because there was a significant coefficient for the production index, our results suggest that imposing a homothetic production function can introduce bias in the interpretation of some of our results. Interestingly, all partial elasticities of substitution between labor and capital inputs remained less than one, which confirms the weakness of the Chilean agricultural sector in the face of international disturbances.

Finally, we performed three additional experiments. First, we used pesticides rather than fertilizers as the proxy for the working capital. Since we had the value for this input but not its quantity, we used the fertilizers' quantity to estimate its share and price[3]. Second, we used an adjusted price for the fixed capital by following Kuroda (1997). The price of fixed capital was defined as P_T $(r+d)$, where P_T is the price of tractors, r is the average loan rate (obtained from Chilean Central Bank database) and d is the depreciation rate obtained from the identity $K_t \equiv I_t - (1-d)K_{t-1}$. K_t is the stock of agricultural capital (obtained from the FAO database) and I_t is the investment in the agricultural sector proxied by the total gross capital formation multiplied by the share of the agricultural sector in the GDP (obtained from the Chilean Central Bank database). Finally, because we did not have the land price for the first two years in our sample, which were forecasted by a linear trend, we dropped these two first observations from the sample period. Results from these three robustness checks are not shown for the sake of space; nevertheless, none of them changed our main results. They are available upon request.

Discussion

The objective of this paper is to investigate how farm protectionism affects the use of agricultural inputs in Chile. In order to pursue this objective, we estimated partial elasticities of substitution, which also allowed us to observe how increases in the use of a specific input affect the use of others. This paper contributes to the agricultural literature by providing empirical evidence on the impacts of farm protectionism in a country that experienced liberalization in its agricultural sector. Specifically, we investigated how Chilean farmers allocated government transferences among different agricultural inputs. This topic has important implications for policy development. Firstly, identifying farms' use of government transfers helps to anticipate effects on farm input demands, *i.e.* to anticipate changes in the prices of these inputs. Secondly, the effect of protectionism on labor input is important because a decrease in agricultural labor demand, for example, can have a harmful effect on poor workers who are mainly employed by the agricultural sector. Finally, studying partial elasticities of substitution allows for us to identify the degree of flexibility of the agricultural sector when faced with international shocks.

We used the traditional approach used to estimate the partial elasticities of substitution in the agricultural sector (Berndt & Wood, 1975; Sharma, 1991; Kuroda, 1997) by introducing farm protectionism as a factor in agricultural production. In the spirit of Henessy (1998), we allowed government assistance to affect the use of inputs. Transferences or subsidies can be used to increase the level of some inputs in order to increase productivity (Giannakas *et al.*, 2001; Karagiannis & Sarris, 2005; Guan & Lansink, 2006). Thus, farm protectionism stimulates production through its effect on labor, working capital, fixed capital, and/or land.

By using annual Chilean data from the period of 1973 to 2010, and using the Nominal Rate of Assistance (NRA) in order to capture farm protectionism, our main findings reveal that protectionism decreases the use of labor and increases the use of fixed capital; therefore, protectionism makes Chilean agricultural production more fixed capital-intensive. This finding also shows that future increases in farm transferences could have negative effects on agricultural labor. In contrast, protectionism does not affect the use of working capital and land. This indicates that demand for these inputs will not be affected when governments increase

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[3]Note that we could not add fertilizers and pesticides as a whole proxy for working capital for two reasons: First, data on pesticide quantities was not available, and, second, adding prices (or quantities) for these two inputs to obtain a proxy for the price of working capital would be a questionable assumption. Furthermore, we could not use pesticides as an additional input in our estimates since fertilizers and pesticides are proxies for the same input.

transferences to farmers[4]. Moreover, all elasticities of substitution between labor and capital, *i.e.*, fixed capital, working capital, and land, were found to be less than one. This outcome reveals a low degree of adjustment of the Chilean agricultural sector in the face of international disturbances, which supports the claims of Berhman (1972).

Studying the agricultural sector is important for developing countries since it is one of the main components that can drive their economic growth. One characteristic that distinguishes this sector from others is a high amount of farm protectionism. This is a controversial topic given that there are two contradictory lines of research that can either support or reject the use of farm protectionism. In such an environment, geography, history, institutions, farm structure, farmer organization, democracy, and the agricultural multi-functionality characteristic (*see e.g.*, Dibden *et al.*, 2009; Swinnen, 2010; Moon & Pino, 2018) are indicated as potential drivers of the different effects of liberalization on the agricultural sector. The aim of this paper is not to support or reject farm protectionism, but to provide information on how it is involved in agricultural production. In fact, we took a different perspective by analyzing the effects of farm protectionism on the use of agricultural inputs. This is useful to better understand the effect that protectionism has on the agricultural sector, especially when studying a country that has experienced an aggressive liberalization in the agricultural sector. For this purpose, we studied the production process of the Chilean agricultural sector by estimating the partial elasticities of substitution among agricultural inputs.

By using annual Chilean data from 1973 to 2010, our robust findings can be summarized as follows: First, farm protectionism decreases the use of labor and increases the use of fixed capital. This implies that protectionism encourages the Chilean agricultural sector to become more capital-intensive. Farm protectionism, then, is a recommended policy if the objective of policy makers is to update production processes in the agricultural sector. Nevertheless, protectionism decreases the use of agricultural labor, which can cause an increase in agricultural unemployment and negatively affect the poorer segments of society. Moreover, protectionism does not have an effect on land and working capital. Second, we identified pairs of inputs that are substitutes and that can evolve differently over time, *i.e.*, fixed capital - labor, land - labor, working capital - land, and working capital - fixed capital. In contrast, working capital and land can evolve similarly over time because they are

complements. In addition, we found evidence that there is no relation between the use of inputs for two of these pairs, *i.e.*, working capital – labor and land – fixed capital. Third, technological changes do not have a significant impact on the use of agricultural inputs. This finding reveals that other sectors of the Chilean economy seem to be benefited by technological changes. Finally, the elasticities of substitution between labor and fixed capital, working capital, and land are less than one. This finding is relevant because it reveals a weakness in the Chilean agricultural sector. Specifically, this result indicates an inability, or poor ability, of the Chilean agricultural sector to confront international shocks. This outcome may be related with the low degree of innovation in the Chilean agricultural sector. For this reason, encouraging the incorporation of new technologies and methods into Chilean agricultural production is recommended in order to avoid negative impacts caused by international shocks.

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[4]This assumes that the mix of future distortions is similar to the one observed in past.

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