Practice Makes Perfect. The Infant Industry Argument for Protection in a Dynamic CGE Model.

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0. Abstract

Learning by own doing on sectoral level is one of the pillars of the infant industry argument. In this paper, the infant industry argument is implemented in a dynamic CGE model through a function that makes total factor productivity (TFP) endogenous to experience, which in turn is measured as the accumulated domestic activity. These learning curves serve for analysis within one technological paradigm and for short to medium time frames.

The implications of differences in marginal returns to experience across sectors are analyzed under two different policy instruments: a production subsidy and an import tariff as the classic infant industry policy. Their suitability as means to increase experience through stimulating domestic activity depends on several characteristics of the economy and the respective sectors, such as elasticities of substitution and transformation of domestic with international products, trade structure and the relative level of productivity of a sector.

Keywords: trade policy, economic development, trade agreements, CGE modelling, infant industry

1. Background

The Infant Industry Argument for Protection (IIA) has been considered the only valid exception for deviating from the free trade principle for a long time. Since the 1980s, however, the IIA has encountered little attention in academia. In parts, because the cases in which protection may be justified are limited to narrowly defined preconditions. In these cases, however, protection can foster technological development

These effects are contrary to foreign spillovers that are widely perceived as the major impact in terms of technology associated with trade liberalization (Diao, Rattsø et al. 2005). In order to provide qualified policy support on the expected net effects of trade policy, it is necessary to consider both mechanisms and if relevant, to quantify and include them in applied trade policy analysis.

An industry can be described as immature if it is theoretically capable of producing at lower costs than it currently does and if the fact that is does not do so is not due to unchangeable conditions. But the immaturity of an industry does not automatically allow to deduct that protection would lead to development. First, the sources of the immaturity must be determined. The most important ones are unrealized economies of scale or lagging behind in terms of education and technology (Mill 1848, Krueger and Tuncer 1982). On the topic of education, the gathering of experience – or learning by doing – is of special relevance (Arrow 1962). However, education can be considered an investment like any other and if it is to pay out it should be in the entrepreneurs' interest to make this investment in a free market framework. So if these investments are profitable but are not undertaken, the reason behind it may be market failure: If knowledge is non-appropriable, entrepreneurs will not be able to reap the profits but may in the contrary suffer: If free-riding firms use this knowledge to produce at lower production costs without having to bear the (full) costs of the initial investment (Baldwin 1969)

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this will lead to lower product prices. In addition, there may be external economies of scale or imperfect information on the commodity market. For neither of the listed types of market failure could a simple industry-wide tariff guarantee the economic development of the sector, as it would not cure the source of the problem. Under certain circumstances, however, a tariff can lead to the generation and acquisition of knowledge and technology: If profit rates are positively linked to the market entry rate and new entrants take on production with state-of-the-art technology[2], this would improve the average productivity of firms and therefore the productivity of the sector. Under these conditions, a tariff can in fact support sectoral growth and realize internal and external economies of scale (Baldwin 1969). Also, an increase in production will quicken the pace at which experience is gathered – more "doing" leads to more "learning by doing". This is part of what Enos describes as the beta stage of learning: It consists of cumulative improvements and adaptations following the large, paradigm changing inventions of the alpha stage. Unlike Schumpeter, Enos deems it possible that the lion share of productivity improvement and decreases in production costs can be attributed to the relatively small innovations of the beta stage and not the ground shaking inventions of the alpha stage (Enos 1962).

2. Inclusion of learning by doing into the dynamic IFPRI Standard Model

The dynamic IFPRI Standard Model

For this paper, the dynamic IFPRI Standard Model was used (Thurlow, 2004). The social accounting matrix (SAM) is based on Thurlow's 2003 South-Africa SAM but was modified strongly to picture a more stylized economy: In the SAM used in this work accounts were aggregated so that there are four activities resp. commodities only, namely agriculture, mining, industry and services. To simplify things, sectors only use intermediate goods from their own production. Export and import values have been adjusted so that trade interventions have a meaningful effect on each sector. There are seven different regions defined as trading partners. The names of the sectors were kept, but due to these and other adjustments they do not relate to the sectors of the original SAM in any way.

There are three labor groups and three household groups. Each labor group is assigned to one and only one household group. The factors were evenly distributed among the sectors, so that each factor group makes up for the same share of total factor payments of all sectors and one sector contributes the same share to income of each factor group.

All labor groups are fully employed and fully mobile, while capital is activity-specific and fully employed. It is assumed that productivity is a characteristic of the sector and that all factors immediately assume the productivity of the sector they are employed in. The consumer price index (CPI) is chosen as numéraire, the exchange rate is flexible and foreign savings are fixed, domestic savings are investment-driven with a uniform change in the rate for the marginal propensity to save for selected institutions. Government savings are flexible while the direct tax rate is fixed. This is to avoid second-round effects, in which e.g. production would increase after consumer demand increased through higher government transfers. The time horizon of the simulations is from 2003 to 2010.

Learning by doing

Learning by doing describes the process in which an increase in experience leads to higher productivity. This paper deals specifically with learning by own doing on sectoral level, which includes learning by own and others' doing on firm level. Experience is defined as the accumulated value of annual domestic

[2] Compared to firms that have been in the market for longer and whose technology may have been state-of-the-art when the firm entered the market but has not been updated or replaced to match the latest technological developments.

production of all previous years over the simulation period. In order to improve comparability across sectors, this sum is set relative to the value of domestic production in the initial year.

$$EXPER_{a,t} = \frac{\sum_t QA_{a,t}}{QA_{a,0}} \quad (1)$$

$EXPER_{a,t}$ – experience; $QA_{a,t}$ – domestic activity

This formulation means that the level of experience increases, even when the annual production quantity decreases. In case of an annual production quantity of zero, the level of experience remains constant.

The impact of experience on productivity is modelled as a learning curve with diminishing returns. In this paper productivity refers to TFP. Both experience and productivity are inherent to the sectors, not the factors.

In the dynamic IFPRI Standard Model TFP is denominated as α_a^a and is a multiplicator in the domestic production function:

$$QA_{a,t} = \boldsymbol{\alpha_{a,t}^{a}} * \left(\delta_a^a * QVA_{a,t}^{-\rho_a^a} + (1-\delta_a^a) * QINTA_{a,t}^{-\rho_a^a} \right)^{-\frac{1}{\rho_a^a}} \qquad a \in ACES \quad (2)$$

$QVA_{a,t}$ – aggregated value-added; $QINTA_{a,t}$– aggregated intermediate input

$\alpha_{a,t}^a$ - CES top level shift parameter; δ_a^a - CES top level share parameter;

ρ_a^a - CES top level function exponent

For the relationship between experience and the TFP parameter a function with diminishing returns and a limit is chosen. The limit (x_a) marks the maximum attainable alpha in the given technological paradigm. It is crucial to determine where on the learning curve the sector in question of the specific country is. The experience gathered before the initial year of the model (y_a) must be accounted for. This results in function (3) for the learning curve that directly links annual domestic production to TFP.

$$\alpha_{a,t+1}^a = x_a - z_a{}^{EXPER_{a,t}+y_a} \quad \text{or} \quad \alpha_{a,t+1}^a = x_a - z_a{}^{\frac{\sum_t QA_{a,t}}{QA_{a,0}}+y_a} \quad (3)$$

x_a – maximum attainable α_a^a, limit of the function, $x_a > 0$

y_a – experience prior to the modelled time frame, $y_a > 0$

z_a – shape-determining parameter, $z_a \in [0; 1]$

Following the formulation of experience, TFP cannot decrease. If annual production falls to zero, the TFP parameter $\alpha_{a,t}^a$ would stay constant for the following year. Hence, there is no “forgetting” of what has been learned in the sector. This approach is a realistic assumption for the short and medium term.

In the model code learning by doing is specified as a multiplicative adjustment factor for the TFP parameter $\alpha_{a,t}^a$ as shown in equation (4). In the initial period it has a value of one.

$$alphaadj_{a,t} = \left(x_a - z_a{}^{\frac{\sum_t QA_{a,t}}{QA_{a,0}}+y_a} \right) * \frac{1}{\alpha_{a,0}^a} \quad (4)$$

This extension of the model serves exclusively for the analysis of the beta stage of learning as described above. Therefore, this model enhancement only serves for a short to medium time frame within one technological paradigm. Attributing major technological break-throughs exclusively to an increase in experience is not perceived as meaningful.

3. Model Results

With this extension, the dynamic effects of an educational tariff have been captured in first model simulations. When comparing a scenario in which no tariff has ever been in place to a scenario in which there has been temporary protection, the difference shows in the higher TFP parameter. With the temporarily increased production quantity in the latter scenario the sector has gathered more experience, leading to a higher TFP and the temporarily protected sector thus produces at a higher productivity level.

The learning curves are implemented in the model in such a way, that agriculture (agri) takes the place of the infant industry with little previous experience within the technological paradigm and furthest away from the maximum attainable α_a^a, whereas the manufacturing sector (ind) has more experience, is nearer to the maximum attainable α_a^a and is thus a more mature sector. The parameter for the limit of the function x_a is set to 1.4 times of the initial total factor productivity $\alpha_{aagri,0}^a$ for the immature agricultural sector, while it is set to 1.2 times of the respective $\alpha_{aind,0}^a$. The parameter y_a for prior experience is set to 10 year equivalents for agriculture and to 20 for industry. These values are chosen arbitrarily. Z_a is calibrated in such a way that $\alpha_{a,0}^a$ is on the learning curve when experience is zero. Z_a must be positive and smaller than one.

For simplicity, mining (min) and services (ser) have flat learning curves so that their total factor productivity remains constant. Without any learning taking place, they can also be considered mature sectors.

Table 1: Total factor productivity and learning curves in the different sectors

	$\alpha_{a,0}^a$	x_a	y_a	$\alpha_{a,t+1}^a$
agri	1.612	$1.4 * \alpha_{agri,0}^a$	10	$\alpha_{agri,t+1}^a = 2.566 - 0.957^{EXPER_{agri,t}+10}$
min	1.900	-	-	$\alpha_{min,t+1}^a = \alpha_{min,0}^a$
ind	1.910	$1.2 * \alpha_{ind,0}^a$	20	$\alpha_{ind,t+1}^a = 2.292 - 0.953^{EXPER_{ind,t}+20}$
ser	2.348	-	-	$\alpha_{ser,t+1}^a = \alpha_{ser,0}^a$

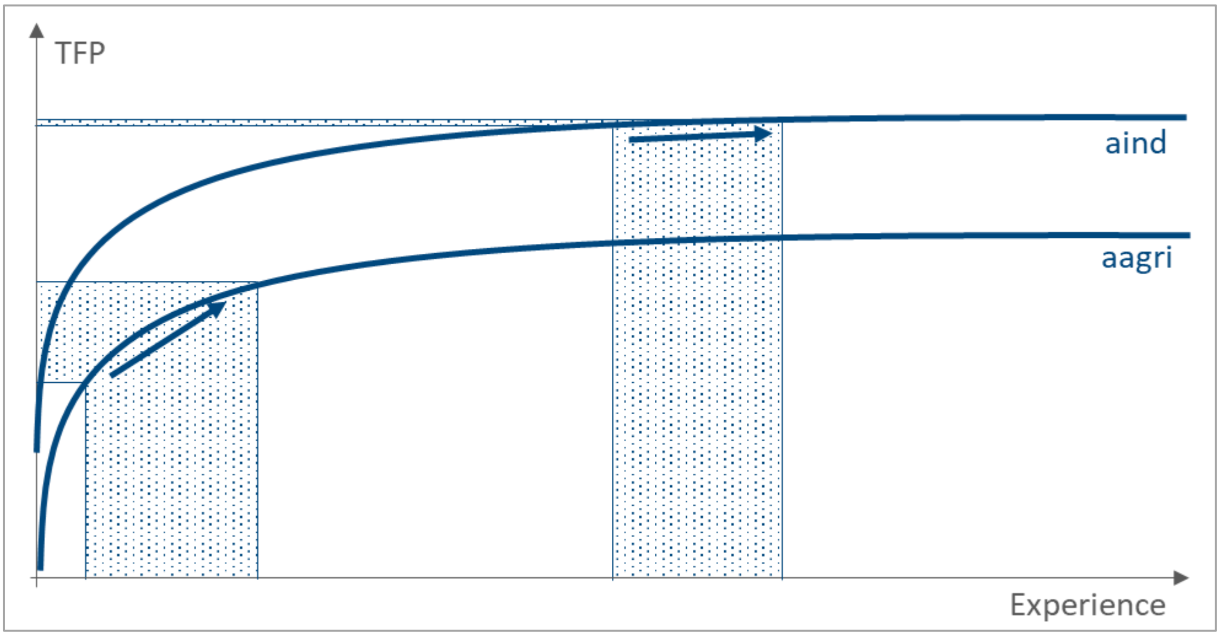
The role of marginal gains to experience

The difference in the learning curves of agriculture and industry and in the positions on the learning curves lead to different marginal returns to experience. The first additional year-equivalent of experience in agriculture leads to an increase of 1.441% in TFP, while the first additional year-equivalent in industry leads only to an increase of 0.940%.

In the model at hand, labor is mobile und fully employed. This means that additional labor can be attracted to work in certain sectors and increase production there, but only at the expense of being drawn away from the sectors of origin. This will decrease domestic production in the latter sectors. Hence, the increases in TFP in one sector come at the expense of TFP increases from learning by doing in other sectors.

Figure 1 illustrates that an increase of TFP in agriculture comes at the expense of a small increase of TFP in industry, while the expense of an increase of TFP in industry comes at the expense of a large increase of TFP in agriculture. If a policy maker decided to support the industrial sector, this would hinder economic development in agriculture as laborers are lacking while it brings only little gain in terms of productivity improvements in industry. Hence, supporting the “wrong” sector can hinder economic development beyond static market distortions.

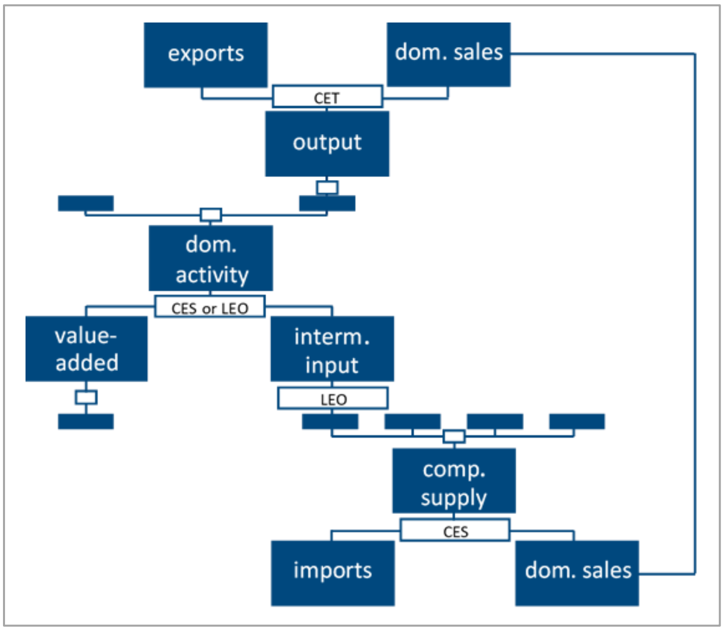
Figure 1: Marginal gains to experience in agriculture and manufacturing. Own depiction



The temporary tariff: impact pathways

The classic infant industry instrument is the import tariff. The expected mechanism here is that an import tariff increases the price of imports, which leads to an increase in the demand for domestic products due to import substitution. For this mechanism to hold, several conditions must be met.

Figure 2: Simplified production nest of the dynamic IFPRI Standard Model. Own depiction.



Import substitution induced by an increased import price will not be strong if the elasticity of substitution is small and/or the import share is small. If the elasticity of substitution is small, domestic users are hesitant to substitute imports by domestic goods. In such a case, an import price increase induced by a tariff mainly results in a decrease in consumption of the composite commodity, but not in a strong increase in consumption of domestic products, potentially even in a decline.

The same applies for a small import share for a given elasticity of substitution. If the import share is small, there is little scope for replacing imports by domestic production, as it is the absolute change in quantities that is relevant. In the same manner a positive and/or large subsistence demand and a low own price elasticity are characteristics that contribute to a high degree of import substitution.

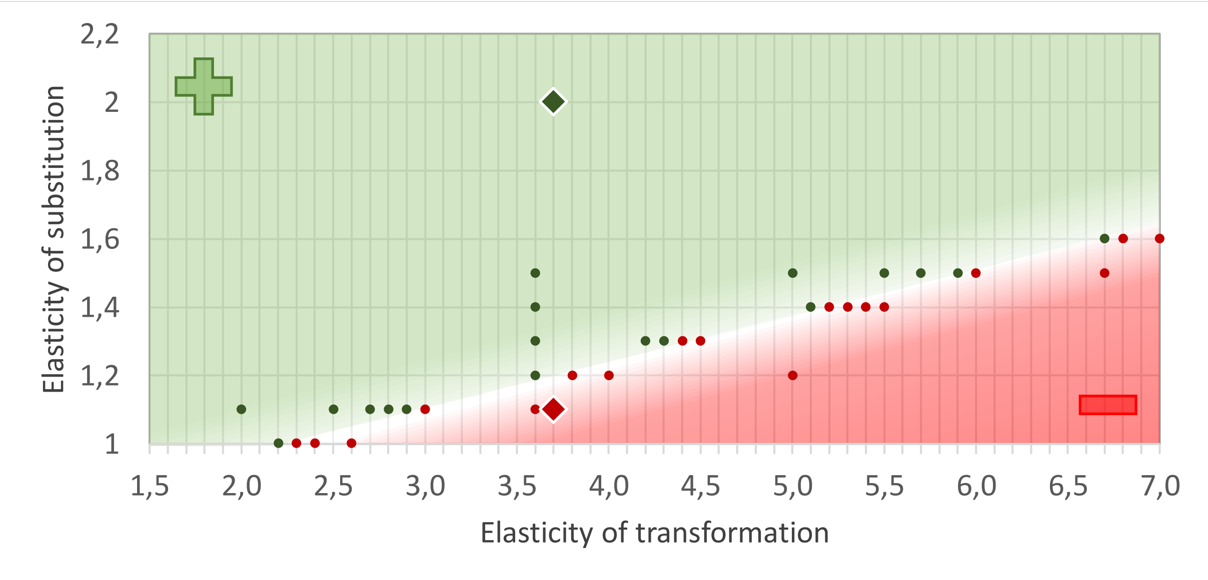
The parameterization on the exporting side of the economy also impacts import substitution: A small elasticity of transformation contributes to a high degree of import substitution. If this elasticity is small, producers do not easily shift their production from exports to the domestic market but must increase domestic production in order to meet an increased domestic demand resulting from higher import prices. A small export share has a similar effect: At a given elasticity of transformation the absolute quantity re-allocated from exports to the domestic market would be small, too, and would leave a gap that still had to be filled by increased domestic production.

The temporary tariff: simulations

Two different scenarios are simulated. In the "BASE" scenario the import tariff stays constant over time. The weighted average import tariff is 0.12% for agricultural goods.[3] In the "TARIFF" scenario the import tariff for agricultural goods is increased to 10% for all regions for the years 2004-2006. In the other years tariff rates are at their original value.

At the given trade structure and per-capita subsistence demand in agriculture[4], this temporary increase in import tariffs only results in increasing experience in agriculture by 2010 if the elasticity of substitution (σ^q) and the elasticity of transformation (σ^t) adhere to the relation depicted in figure 3: Experience in agriculture in 2010 increased through increasing the import tariff for agricultural products for simulations for elasticity combinations depicted with green markers. For elasticity combinations depicted with a red marker, experience in the final year in agriculture was lower than in the "BASE" scenario.

Figure 3: Sign of the effect of a temporary tariff on agricultural goods on experience in agriculture in 2010 depending with different elasticities. Own depiction.



For the two exemplary situations of the elasticity of substitution (σ^q) being at 2 (depicted as the green diamond in figure 3) and alternatively being at 1.1 (depicted as the red diamond in figure 3) and the elasticity of transformation (σ^t) being 3.7 in both cases, domestic production develops as follows:[5]

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[3] The highest tariff for agricultural goods is at 0.21% while the lowest is at 0.08%.

[4] In the model used in this paper, imports account for 66% of the composite domestic supply of agricultural products and the export share is at 23% in the initial year of modelling. The per-capita subsistence demand for agriculture is 23%, 18% and 6% for the respective household groups h1 to h3.

[5] In order to show only the effect of the tariff on domestic activity and not the effect the learning curve would have, TFP is kept constant and exogenous in this case. A model in which the learning curves are included also shows that a high elasticity of substitution leads to higher domestic activity in consequence of temporary

Figure 4: Effect of a temporary tariff on agricultural goods on domestic activity in agriculture with different elasticities of substitution and with fixed TFP. Own depiction.

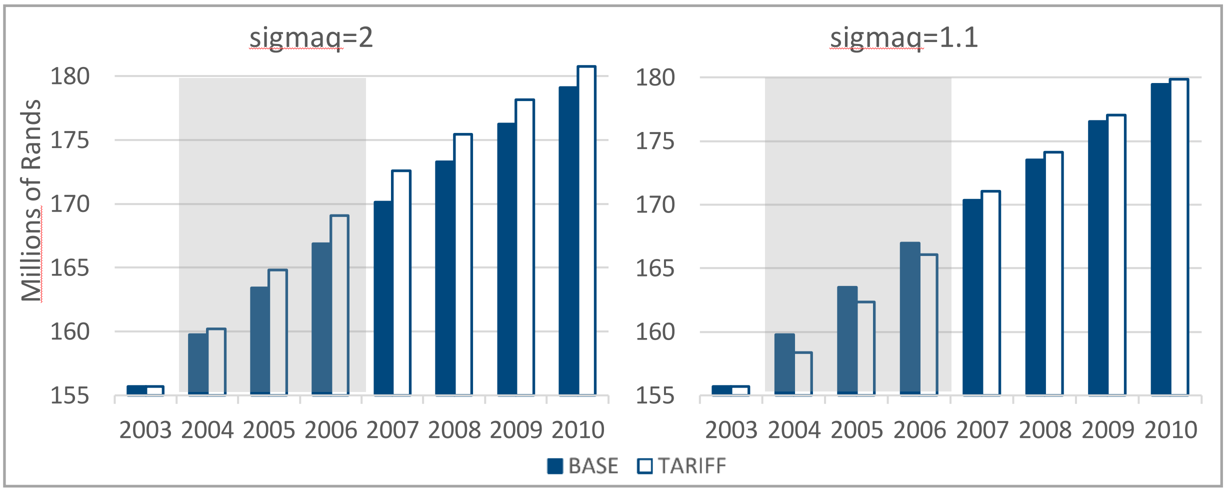


Figure 4 shows that the effect of a temporary tariff on the domestic activity in the protected sector agri depends on the elasticity of substitution. With all other parameters unchanged, a tariff increases domestic activity for the time of protection (shaded area) as well as for the time after it if $\sigma^q = 2$. If $\sigma^q = 1.1$, the activity decreases for the years of protection compared to the baseline scenario and increases slightly after the abolishment of the tariff.[6]

This has important implications for the increase in TFP: TFP depends on experience and experience is the sum of the annual production (i.e. the columns from figure 4) relative to the one in the initial year.

In the case of $\sigma^q = 1.1$, experience is smaller when there has been temporary protection than in the baseline scenario as table 2 shows. Hence, a temporary tariff accelerates learning by doing if $\sigma^q = 2$ but it slows it down if $\sigma^q = 1.1$.

Table 2: Effect of a temporary tariff on agricultural goods on experience in agriculture with different elasticities of substitution and with fixed TFP

	2003	2004	2005	2006	2007	2008	2009	2010
Elasticity of substitution (σ^q) = 2								
BASE	0.00	1.00	2.03	3.08	4.15	5.24	6.35	7.48
TARIFF	0.00	1.00	2.03	3.09	4.17	5.28	6.41	7.55
Elasticity of substitution (σ^q) = 1.1								
BASE	0.00	1.00	2.03	3.08	4.15	5.24	6.36	7.49
TARIFF	0.00	1.00	2.02	3.06	4.13	5.22	6.34	7.48

protection, while temporary protection leads to a decrease in domestic activity compared to the baseline scenario if the elasticity of substitution is low.

[6] The allocation of capital among the sectors depends on the sector's share in aggregate profits and on the relative level of rent for capital paid in the sector. During tariff protection, capital rents decrease for all sectors but least for agriculture. After the abolishment of the tariff, this relation remains. Hence, more capital is drawn into agriculture and agricultural production increases.

The temporary subsidy: impact pathways

A temporary subsidy supports domestic production directly and not only indirectly through import substitution as an import tariff. Therefore, a subsidy always increases the domestically produced quantity and with that the total factor productivity of the supported sector through learning by doing.

The temporary subsidy: simulations

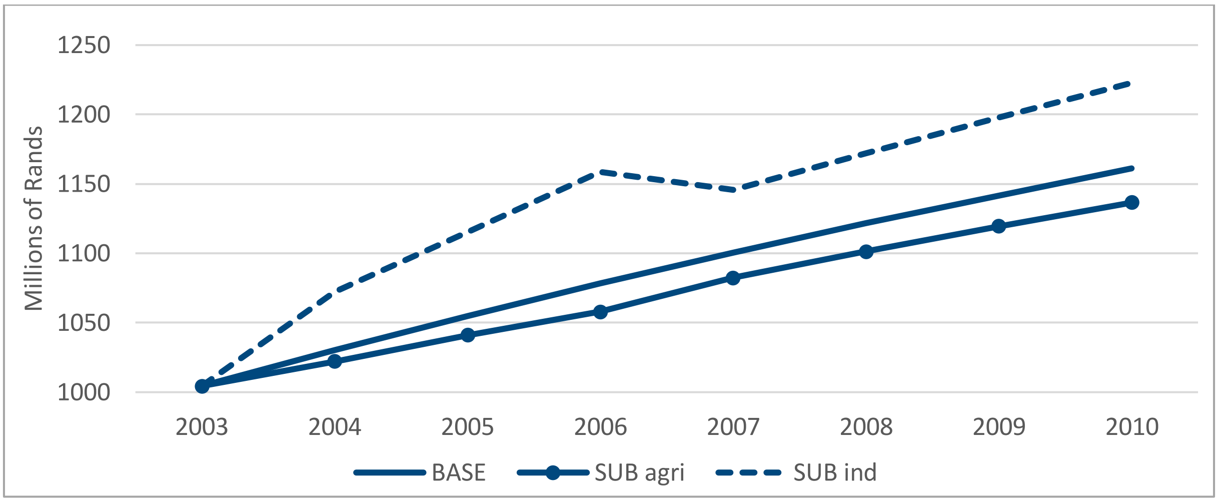
Three simulations were conducted. In the baseline scenario the production subsidy on agriculture is constant at 5% and for the industrial sector, there is a production tax of 3%. In the “SUB agri” scenario, the production subsidy is increased to 20% for the years 2004-2006. For the other years and the other sectors, the tax resp. the subsidy is the same as in the baseline scenario. In the “SUB ind” scenario, there is a production subsidy of 12% for the industrial sectors for the years 2004-2006. Otherwise the scenario is the same as the baseline scenario.

Looking at the aggregate results first, it is found that real GDP in the final simulation year is lower if agriculture receives a producer subsidy. This may seem odd at first: TFP increases significantly in agriculture, increases a little in the industrial sector and remains constant in the remaining two sectors, so as an effect of pure learning by doing, average TFP should increase and with it GDP. It needs to be considered, however, that the model is calibrated in a way that wages are not equal between sectors in equilibrium. Hence, factors are not allocated until marginal productivity is the same across sectors, but that there are high- and low-productivity sectors even in equilibrium. This does not change with the way the learning curves are specified here. As a result, if agriculture is subsidized it attracts production factors which come from higher productivity sectors. These effects counteract the learning by doing effects. Specifically, the TFP parameter in agriculture increases from 1.12 to 1.83.[7] The TFP parameter of the industrial sector however is higher both in the base (2.04) and in the subsidy scenario (2.03). This means that by subsidizing agriculture, labor is drawn from a high- to a low-productivity sector. The economy-wide average TFP will therefore decrease during a subsidy for agriculture if the average is weighted according to the share of total factor supply it employs. Hence, economic development is slowed down during the intervention period and this of course affects production in the remaining years after the reinstatement of the production tax at the original level.

Subsidizing the high-productivity industrial sector on the other hand leads as expected to an increase in GDP both during and after the intervention.

[7] The levels of the subsidy in the subsidy scenarios were selected so that the difference between the production tax/subsidy in the baseline and in the subsidy scenario is equal in percentage points for both subsidy scenarios.

Figure 5: Effects of a temporary subsidy on real GDP



Even though the higher marginal returns to experience in agriculture would have suggested that it is wiser to subsidize agriculture in order to increase productivity within the economy, the relatively low level of TFP in agriculture lets any interventions that draw factors into agriculture result in a decrease in GDP. The only exception of this would be a situation with a very steep learning curve that would lift agricultural productivity above the other sectors and turn it into a high-productivity sector.

4. Political Relevance

A policy maker considering infant industry protection therefore must consider the following questions.

1. Core assumption:
   Does learning by own doing on sectoral level take place? Are the expected effects on productivity higher than benefits from free trade such as technological spillovers?
2. Economic structure:
   Are additional factors available that can be used to increase domestic production in the respective sector? Are the marginal gains of experience high? Is the level of productivity that could be achieved by additional experience high or would the sector remain a low-productivity sector even with additional experience? What are the links of the sectors within the domestic economy and to the global value chain?
3. Choice of instrument:
   When considering a temporary tariff: Is the import share large and the elasticity of substitution high? Is the export share small and the elasticity of transformation low? Is the per-capita subsistence demand large and the own-price elasticity low?
   When considering a temporary subsidy: Does the government have income sources that allow to finance such an instrument?
   General considerations: Does the political environment allow to end the intervention after a certain period? Does the administration have the expertise to determine which sector qualifies for infant industry protection?

5. Outlook and further research

In order to demonstrate the basic mechanisms of implementing learning by doing on sectoral level, several simplifying assumptions were made. The next steps would be to relax these assumptions and make the model more complex and therefore more realistic.

So far it has been assumed that sectors use only intermediate goods from their own production. If intermediate goods from other sector were used, the effects of trade policy would transmit more into other sectors than in the simulations conducted. In a case of successful infant industry protection, this could mean that there is increased production and a higher pace of learning in the infant industry, but in the other industries demanding intermediate goods from the infant industry production costs would rise due to that. This might affect the results regarding overall effect of on GDP and must be considered to give sound policy advice.

Simplifying assumptions were also made regarding production factors. In the simulations so far, labor is fully employed and fully mobile, meaning that any increase in production in one sector is based on labor being drawn away from another sector. But if labor is not mobile but activity-specific (and fully employed), policy interventions cannot lead to an increase in factor use and therefore not to increased production of the supported sector. Hence, it is expected that in this case the mechanism of increased learning by doing would not take off but also production in other sectors would not be decreased.

If, however, labor is not fully employed (but fully mobile) and the additional labor that is drawn into the supported sector comes from unemployment but not from other sectors, it is expected that a positive effect on GDP would be larger compared to the factor market settings used so far: Production expansion in the supported sector would not come at the expense of production in the other sectors and therefore, an increase in productivity in the supported sector would not come at the expense of foregoing potential increases in the remaining sectors. If the other sectors remained unaffected by the policy measures this also means that the relative productivity level of the supported sector is not decisive for the effect on GDP: If the additional labor in the protected industry comes from unemployment, where its productivity is zero, the average TFP will increase due to protection, even if TFP of the protected sector is low compared to the rest of the economy.

Similar implications apply to changing the factor market settings for capital.

Another simplifying assumption was that all sectors demand the different factors in the same proportion, i.e. there is no capital-intensive sector and no sector that demands more high-skilled labor than others. In a more complex model, an uneven distribution of factor demand would link some sectors closer to each other than others in terms of competition for factors. This has relevant implications on the effect of a policy intervention on average TFP and therefore GDP: If the factors drawn into the supported sector come from a sector that has a lower TFP level than the protected one, average TFP is expected to increase, but if they come from a sector in which TFP is higher, the economy-wide TFP would be expected to decrease. Hence, a detailed examination of the sectoral factor demands is necessary.

The whole mechanism shown in this paper relies on the assumption that productivity is a characteristic of the sector. Factors immediately assume the productivity of the sector they are employed in. This is of course an assumption that can be challenged. Focusing on productivity as a characteristic of the factors rather than the industries that employ them would answer to the notion of the “infant economy argument” as discussed in Greenwald and Stiglitz (2006). The mechanism of learning by doing as it is implemented for TFP here could easily be modified to analyze learning by doing increase factor-specific productivity.

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