ELSEVIER

Journal of Development Economics 78 (2005) 22–48

JOURNAL OF Development ECONOMICS

www.elsevier.com/locate/econbase

The big push, industrialization and international trade: The role of exports

Vitor Trindade*

Department of Economics, Maxwell School of Citizenship and Public Affairs, Syracuse University, Syracuse, NY 13244-1090, United States

Received 1 March 2003; accepted 1 August 2004

Abstract

This paper analyzes the "late" industrializations of South Korea and Taiwan, and how they can be produced by an export promotion policy. The paper adopts an open economy version of the well-known big push model. Thus, it recovers neoclassical accounts of industrialization through exports, complementing previous literature, which tends to show the *existence* of the big push, but is scarce on trade *mechanisms* to produce it. The model fits well with some stylized facts of the industrializations in East and Southeast Asia. I also apply it to a comparison of the education policies of East Asia and Latin America.

JEL classification: F12; O14; O24
Keywords: Export promotion; Industrialization; Big push; Coordination failure

1. Introduction

It may be startling, for anyone acquainted only with very recent economic history, to realize that four decades ago South Korea and Taiwan were very poor economies. In 1960, South Korea's GDP per capita was lower than Mozambique's, while Taiwan's stood below most Latin American countries. Of course, in the next three decades the

* Tel.: +1 315 443 3802; fax: +1 315 443 3717.
E-mail address: vmtrinda@maxwell.syr.edu.

0304-3878/$ - see front matter
doi:10.1016/j.jdeveco.2004.08.006

two Asian tigers grew at 8.4% and 7.7%, respectively, in the process creating industrialized economies. Given their success, many have asked what triggered their spectacular industrializations. Certainly, part of the consensus story is the dramatic increases in their investment rates but, to quote Lucas (1993), these "are additions to the list of events to explain, not themselves explanations." This paper attempts a new explanation for such sudden "late" industrializations accompanied with surges in investment, based on export promotion.

It is well known that the industrializations of South Korea and Taiwan coincided with new policies of export promotion. For example, starting in the 1960s, South Korea devalued its currency, introduced a number of export-promotion schemes, and gradually liberalized import controls (Nam, 1990). By 1975, its exchange rate was about 40% of the 1960 value (Edwards, 1992). Exports of manufactures grew from a negligible amount in the 1950s to an average of 22% of GDP in 1973–1975 (Kim and Roemer, 1979), accompanied by a remarkable growth in the manufacturing sector, from 9% of GDP around 1953–1955 to 27% in 1973–1975. Many economists thus posited that the industrializations of both South Korea and Taiwan were due to an "export-oriented industrialization strategy" (Krueger, 1985). Surprisingly, a clear theoretical argument for why *exports* (as opposed to general openness) induce investment and industrialization is lacking. Recently, the role of exports in the industrial take-offs of South Korea and Taiwan has been questioned, most notably by Rodrik (1995, 1999).

To understand a process of rapid industrialization through exports, this paper takes up an open economy version of the "big push" model (see Murphy et al., 1989, for example), with two characteristics. First, there exist complementary industries that may fail to coordinate, inducing multiplicity of equilibria and underdevelopment traps. Second, the country industrializes mostly by imitating foreign goods, not by creating new goods.[1]

As in other big push papers, the model has a final good that is assembled with inputs produced under increasing returns to scale. The intuition for a coordination failure and for the role of exports relies crucially on the forward and backward linkages between inputs and assembly, and can be explained with a simple example. Suppose that "computers" are made with several inputs, and suppose that the South faces a knowledge barrier, such that an investment in know-how is needed before inputs are produced there. Listed in increasing order of their know-how cost, computer inputs are: A, B, C, D, and E (A could be keyboards, B monitors, C chips, and so on). Suppose that inputs are more expensive to transport than computers, and that at an initial stage the "South" is unindustrialized: it only produces input A and does not assemble any computers. I will posit that, just as was the case in South Korea and Taiwan, the South is in a stage of import substitution, with high rates of protection for its importables. Under these circumstances, the South may suffer from a coordination failure, leading to a development trap: higher know-how inputs are

[1] One characteristic of East Asian industrialization is that it is a "late industrialization". In Amsden's (1989) definition, "all late industrializers have in common industrialization on the basis of learning . . . these countries industrialized by borrowing foreign technology rather than by generating new products or processes, the hallmark of earlier industrializing nations." Addis (1999) argues that this implies large-scale industrialization. In other words, it is likely that late industrializers suffer from coordination problems among many different industries, such that when industrialization occurs, many of those industries start up at the same time.

not produced, because there is no internal downstream demand for them (and they are costly to export); and the downstream industry does not locate in the South because most of its suppliers are in the "North." How can the South solve this coordination failure using market incentives, without any distortions such as an industrialization policy?[2]

Let the South adopt an export promotion policy, through the reduction of its import barriers, and the anti-export bias associated with them.[3] This ensures that the policy is non-distortionary. Through it, input B becomes profitable as an export and its production begins, *without* the need to coordinate with other input producers. Let us say that once two inputs are made in the South, computer assemblers find it profitable to move there, as they save on the transport costs of two important inputs. When they do so, the production of Southern inputs becomes more profitable, as there is downstream demand for them, causing inputs C and D to begin production. This is the surge in investment that has been observed in East Asia. In the end, the situation has reversed, with the South producing four inputs and assembling the computers, and the North producing only one input (E).

In the context of international trade, two papers that use coordination failure in inputs to explain underdevelopment traps are Rodrik (1996) and Rodríguez-Clare (1996), in which availability of intermediate inputs determines the extent to which a country is industrialized. However, both papers assume that inputs (the very goods for which there is the potential for coordination failure) are non-tradable, and therefore trade is excluded as a policy instrument. By contrast, trade takes center stage in this paper.

One paper that emphasizes trade in the context of a big push-like model is Bond et al. (2005), in which there are traditional importables and exportables, and a range of modern exportable goods. Just as in here, reducing import restrictions allows the economy, through lower wages, to expand to industrial sectors that would otherwise be unprofitable. With two additional assumptions (there is learning-by-doing in the modern exportable sector, and the knowledge on how to export is public), Bond et al. show that openness can cause faster growth. I focus by contrast on the way that openness can induce a big push. While their South *creates* comparative advantage through learning by doing, my South *explores* a latent comparative advantage to escape an underdeveloped trap. Thus, the two papers have different applications.[4]

An important assumption of the model is that inputs have a higher transport cost to price ratio than final goods. This is the outcome if transport costs are determined by weight, since final goods weigh approximately the same as the inputs that go into them,

---

[2] Industrial policies would be the broad alternatives to the more market driven prescriptions of this paper, and should at best be used with care. Stern et al. (1995) study South Korea's shift in the 1970s from an across the board export promotion to industrial targeting and suggest that the newer policy, abandoned in the 1980s, had mixed results.

[3] The import substitution policy raises factor costs for the exportables. Balassa (1980) offers a colorful example of this: "In Argentina, high tariffs imposed on caustic soda at the request of a would-be producer made formerly thriving soap exports unprofitable". Kim (1985) states on Korea's export policy: "the major incentives served mainly to offset the disincentive effect on exports that the trade regime would otherwise have had."

[4] Wang and Xie (2004) is also a model of industrial take-offs, in which the modern industry has external increasing returns. However, the focus there is on domestic policies. In their section on trade, the authors assume that the modern good cannot be exported. Therefore, in marked contrast with Bond et al. (2005), foreign imports that encroach on the modern sector may actually *reduce* the incentive to invest in it.

but are more expensive. Empirical evidence also suggests it. For example, according to Hummels (2001), the trade-weighted average freight rate as a percentage of US imports of iron and steel (SITC code 67) was 8.4% in 1994, while for road vehicles (SITC 78) it was 2.1% and for transportation equipment (SITC 79) it was 0.9%. Intermediate inputs will also cost more to transport if transport costs have fixed costs, since each input incurs its own fixed cost.[5]

2. Model set-up

Two countries, the South and the North, use labor to produce two final goods. "Food" production requires one unit and $a>1$ units of labor in the North and the South, respectively. The second good, "computers," is competitively assembled with a continuum of inputs:

$$C = \left[\int_0^1 z(i)^\beta \mathrm{d}i \right]^{\frac{1}{\beta}}. \tag{1}$$

Here, C is quantity of computers assembled, $z(i)$ is quantity of input i, and β $(0<\beta<1)$ yields the elasticity of substitution between two inputs: $\sigma=1/(1-\beta)$.[6] I assume that trade in final goods is costless, while transport costs for inputs are dealt with by assuming that only a fraction $g<1$ of an input survives when exported.

Southern firms must spend a "know-how cost" $F(i)$ before they can produce input i,[7] after which they use one unit of labor to make one unit of the input, just as their Northern counterparts. There is at most one producer of each input in either country (the outcome if all *new* input producers in the North also incur the know-how cost). We shall order inputs such that $F(i)$ weakly increases in i, and for simplicity assume that $F(i)$ is *strictly* increasing and continuous in i. Ignoring for now the South's knowledge barrier, note that it has comparative advantage in computers. The big push consists of the South fully exploiting this latent comparative advantage in computers in order to industrialize.[8]

[5] See Anderson and van Wincoop (2004) and literature cited therein for evidence of a fixed component in trade costs. The same paper also documents the importance of trade costs in general. However, more complete evidence for higher trade costs of inputs is remarkably elusive. Yet another way to think about this follows Rodrik (1996): for inputs that are just human capital, "exporting" them involves the large barrier of emigration, compared with the relatively smaller barrier of trade in the final goods.

[6] Although modeled in this simple way, "assembly" here stands for more than a simple putting together of final goods from ready-made kits. Rather, "assembly" denotes the outcome of a country that builds up capabilities in an industrial good (modeled as cheap availability of its inputs), to produce a final package of that good.

[7] For an example of a knowledge barrier to industrialization, see Rhee (1990), who describes how 130 Bangladeshi garment workers were sent to Korea to learn about the industry (the initial investment in know-how). Upon coming back, they opened up most of Bangladesh's garment plants, and were instrumental in the build up of the industry.

[8] We can think of food and computers as targets for first- and second-stage import substitution, respectively. In Balassa's (1980) definition, second stage goods have important economies of scale and an efficient scale of production that is too large for the country, and they are skill-intensive.

Consumers in the North have Cobb-Douglas preferences, with α budget share in food ($0<\alpha<1$). No intuition is lost, and considerable simplification is gained, if Southern consumers have no desire for computers. They only produce them (if at all) to exchange them for food.[9]

The model focuses on a crucial period, at the onset of which the South has not yet industrialized, in the sense that it has not opened its computer industry. It has in place a policy of first-stage import substitution, through a tariff t on food. This policy raises the cost of labor, in effect becoming an indirect tax on Southern exportables (low-end inputs).

The timing of the model is as follows. First, the Southern government decides upon its trade policy, by publicly announcing t for the new period. It may simply keep its historically high tariffs, or it may decide to promote exports by lowering them. Second, Southern input producers (simply "producers") decide independently whether to invest the amounts $F(i)$ in know-how, which are then sunk. Simultaneously, computer assemblers (simply "assemblers") decide in which country to locate.[10] The question is: does the South industrialize by the end of the period?

Perfect competition fixes Northern wages at $w^*=p_F^*=1$, where p_F^* is the price of food in the North, normalized to one. Southern wages are $w=p_F/a=(1+t)/a$, where p_F is the price of food in the South. As mentioned above, t increases labor costs in the South. Southern productivity is assumed sufficiently low to ensure $w<1=w^*$.

Given input prices $p(i)$, the price of computers is:

$$P_C = \left[\int_0^1 p(i)^{1-\sigma} \mathrm{d}i \right]^{\frac{1}{1-\sigma}}, \tag{2}$$

which is simply the unit cost of the CES production function. The demand for each input is:

$$z(i) = \left(\frac{P_C}{p(i)} \right)^{\sigma} C. \tag{3}$$

We will find at most two equilibria, distinguished by the assemblers' location: in the "N-equilibrium" ("S-equilibrium"), assemblers locate in the North (South). The strategy to find the equilibria is as follows. First, I assume that the assemblers locate in the North, and have all other agents optimize. Then I repeat that exercise, assuming that the assemblers locate in the South. Finally, I check under which circumstances the assemblers themselves are optimizing. We will see that they may be optimizing both when they locate in the North and in the South.

[9] This assumption also captures at an extreme the idea of a small market that constrains the opening up of an advanced industry. It may also be the outcome of an explicit policy, as in Export Processing Zones.

[10] Since there are no transport costs for computers, assemblers want to locate in one country only.

3. The two equilibria

3.1. The N-equilibrium

Suppose that the assemblers locate in the North. Southern producer i invests in the know-how cost only if he can avoid a loss, in which case all producers $j<i$ can avoid a loss. Thus the set of all Southern producers that invest is [0, $n(t)$], where $n(t)$ may vary with the tariff level.

Northern producers in ($n(t)$, 1] face demand schedule (3), with constant elasticity of demand σ, and charge the monopoly markup over marginal cost: $p(i)=\mathrm{MC}/(1-1/\sigma)=1/\beta$. Southern producers in [0, $n(t)$] take Northern competition into account and limit price, as illustrated in Fig. 1. The thick solid line is the demand for Southern inputs. It is the same as Eq. (3), except that it is capped at 1, Northern producers' marginal cost. The thick dashed line represents the marginal revenue. Three regimes arise, depending on Southern producers' marginal cost ($\mathrm{MC}=w/g$, which includes the cost of transporting inputs to the North). In the "low-cost" regime ($\mathrm{MC}<\beta$), Southern producers charge the monopoly price, $p(i)=w/g\beta$, since it is less than Northern producers' marginal cost. In the "high-cost" regime ($\beta\leq\mathrm{MC}\leq 1$), Southern producers charge Northern producers' marginal cost: $p(i)=1$. In the "complete specialization" regime ($\mathrm{MC}>1$), Southern producers are not able to compete against Northern producers, and therefore $n(t)=0$.

Substitution of input prices into (2) yields in the first two regimes:

$$\begin{aligned} P_{\mathrm{C}} &= \left[n(t)\left(\frac{\beta g}{w}\right)^{\sigma-1}+(1-n(t))\beta^{\sigma-1}\right]^{-\frac{1}{\sigma-1}} && \text{Low}-\text{cost} \\ P_{\mathrm{C}} &= \left[n(t)+(1-n(t))\beta^{\sigma-1}\right]^{-\frac{1}{\sigma-1}} && \text{High}-\text{cost.} \end{aligned} \tag{4}$$

Free entry in the South implies zero profits for the producer at $n(t)$, if $n(t)$ is neither zero nor one. This can be written:

$$\begin{aligned} &\left(\frac{g}{w}\right)^{\sigma-1}\left(\frac{1}{\beta}-1\right)(\beta P_{\mathrm{C}})^{\sigma}C=F(n(t)) && \text{Low}-\text{cost} \\ &\left(1-\frac{w}{g}\right)P_{\mathrm{C}}^{\sigma}C=F(n(t)) && \text{High}-\text{cost,} \end{aligned} \tag{5}$$

where (3) and the input prices were used to calculate the variable profits on the left.

Northern consumers' budget is $B^*=L^*+(1-n(t))(1/\beta-1)(\beta P_{\mathrm{C}})^{\sigma}C$, where L^* denotes Northern labor endowment. The first term on the right is wages, and the second term is producers' profits. Using the Cobb-Douglas formula $C=(1-\alpha)B^*/P_{\mathrm{C}}$ we obtain:

$$C=\frac{(1-\alpha)L^*}{P_{\mathrm{C}}\left[1-(1-n(t))(1-\alpha)(1-\beta)(\beta P_{\mathrm{C}})^{\sigma-1}\right]}. \tag{6}$$

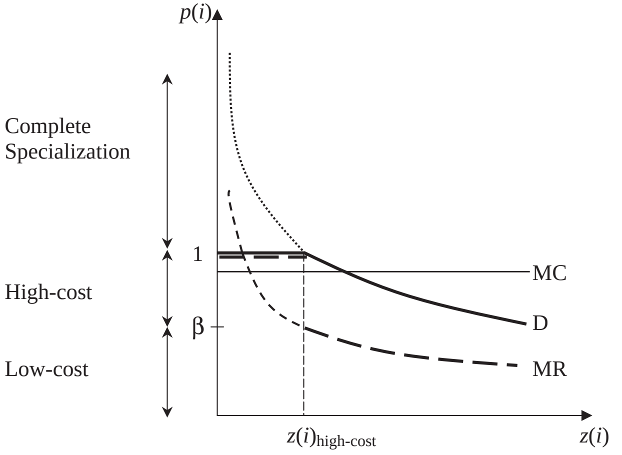


Fig. 1. Limit pricing by Southern input producer i.

The denominator is positive, since from Eq. (4) P_C is at most $1/\beta$. Eqs. (4), (5) and (6) constitute three equations in the three endogenous variables: P_C, C, and $n(t)$. Substitution of (4) and (6) into (5) yields one equation for $n(t)$:

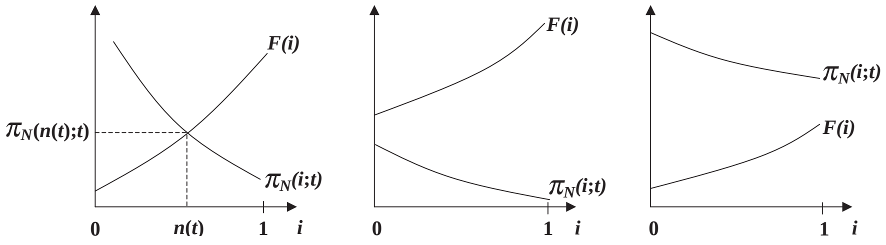
$$\pi_N(n(t);t) \equiv \frac{(1-\alpha)(1-\beta)L^*}{n(t)+[(1-n(t))]\left(\frac{w}{g}\right)^{\sigma-1}[1-(1-\alpha)(1-\beta)]} = F(n(t)) \quad \text{Low}-\text{cost}$$

$$\pi_N(n(t);t) \equiv \frac{\left(1-\frac{w}{g}\right)(1-\alpha)L^*}{n(t)+[(1-n(t))]\beta^{\sigma-1}[1-(1-\alpha)(1-\beta)]} = F(n(t)) \quad \text{High}-\text{cost}. \tag{7N}$$

The first equality defines the function $\pi_N(i;\, t)$. It represents one Southern producer's variable profit, when a mass i of Southern producers produce, the tariff is t, and the assemblers locate in the North. Note that the denominators in (7N) are positive non-zero numbers, for any $n(t)$ and t.

Fig. 2 depicts $\pi_N(i;\, t)$ and $F(i)$, as (continuous) functions of i. $n(t)$ multiplies a positive expression in (7N), therefore $\pi_N(i;\, t)$ decreases with i. To see why, note that producers' price and marginal cost are constants, therefore their variable profits depend only on $z(i)$, thus on $(P_C)^{\sigma}C$. As i goes up, computer prices decrease as seen from Eq. (4), because Southern inputs are less expensive. Whether variable profits decrease hinges on how fast C increases. A sufficient condition for $\pi_N(i;\, t)$ to go down with i is that the elasticity of demand for computers be less than σ, which is certainly true with Cobb-Douglas utility, but is also more general.[11]

[11] In practice, even without any Cobb-Douglas assumption σ will generally increase with the number of inputs, which depresses variable profits (while the same is not necessarily true for elasticity of demand for computers). Even though this is not explicitly modeled, it seems advisable to keep the intuition that input producers' profits fall, as more inputs become available. I am grateful to a referee for raising this issue and suggesting the intuition above.



a) Interior solution b) $n(t) = 0$ c) $n(t) = 1$

Fig. 2. Southern producers invest as long as $\pi_N(i;\, t) > F(i)$.

By construction, $F(i)$ is increasing. If it crosses $\pi_N(i;\, t)$ inside the interval [0,1], then Eq. (7N) has a unique solution (panel *a*). If $\pi_N(i;\, t) < F(i)$ throughout the interval (panel *b*), no Southern producer breaks even, and $n(t)=0$. If $\pi_N(i;\, t) > F(i)$ for all i (panel *c*), every Southern producer invests, therefore $n(t)=1$. Thus, a unique solution for $n(t)$ exists in all cases.

3.2. The S-equilibrium

Assume that the assemblers locate in the South. To avoid repetition, I shall tersely summarize the results. The interval of Southern producers that invest is $[0, s(t)]$. There are low-cost and high-cost regimes, but no complete specialization regime. Fig. 3 traces the Southern wage in the different regimes, dividing the model into four cases.[12]

The analogue to (7N) is:

$$\pi_S(s(t);t) \equiv \frac{(1-\alpha)(1-\beta)L^*}{s(t)+[(1-s(t))](gw)^{\sigma-1}[1-(1-\alpha)(1-\beta)]} = F(s(t)) \quad \text{Low}-\text{cost}$$
$$\pi_S(s(t);t) \equiv \frac{(1-gw)(1-\alpha)L^*}{s(t)+[(1-s(t))]\beta^{\sigma-1}[1-(1-\alpha)(1-\beta)]} = F(s(t)) \quad \text{High}-\text{cost,} \tag{7S}$$

where the leftmost equalities define the function $\pi_S(i;\, t)$, analogous to $\pi_N(i;\, t)$. Note that the only asymmetry between the N- and the S-equilibria lies in the transport costs: from the producers' point of view, the assemblers' location only matters because of transport costs.

Three pieces of the intuition were mentioned in the introduction. First, assemblers' move to the South induces Southern producers to invest, as downstream demand for their inputs rises. Therefore, it should be that $s(t) \geq n(t)$. This is reinforced in the high-cost regime: Northern producers incur transport costs to supply assemblers in the South, raising their marginal costs, and thus the price that Southern producers are able to charge. Second, the tariff on food is an indirect tax on exports. This implies that $n(t)$ and $s(t)$ should decrease with t. Third, industrialization is desirable. That is, the S-equilibrium should Pareto dominate the N-equilibrium. Lemma 1 shows these results (all proofs are relegated to the appendix).

[12] The figure assumes the parameter choice $\beta < g^2$, which is made throughout. Depending on the value of $1/a$, the model will have more or less variation. For example, if $1/a \geq \beta g$, case I (the most interesting one) is eliminated. To keep as many cases in play as possible, I assume that $1/a < \beta g$.

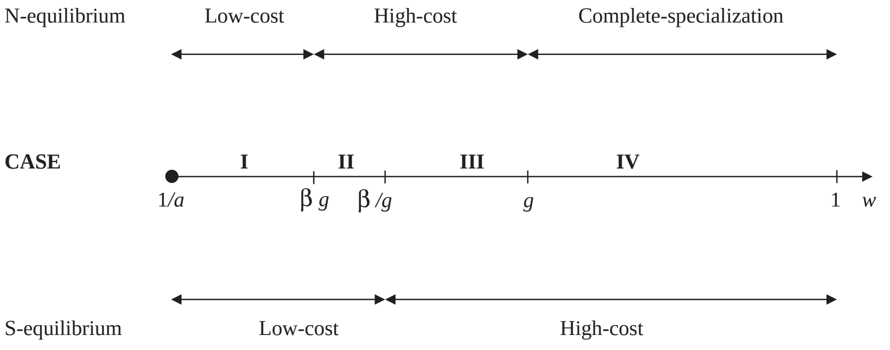


Fig. 3. The different regimes, as w varies from $1/a$ to 1.

Lemma 1. *If the know-how cost function $F(i)$ is strictly increasing and continuous in i, the following three results hold:*

1. *$s(t) \geq n(t)$. The equality sign can hold only when $s(t)=n(t)=1$ or $s(t)=n(t)=0$.*
2. *$s(t)$ and $n(t)$ are non-increasing functions of t. Furthermore, they are strictly decreasing if their values are neither 1 nor 0.*
3. *The S-equilibrium Pareto dominates the N-equilibrium, as long as there is some Southern input production.*

3.3. The assemblers' optimization problem

Finally, we need to verify the optimality of the assemblers' location. Let us fix the tariff t, and define a number $I(t) \in [0,1]$ as follows. Suppose that some mass $i \in (0,1]$ of Southern producers exists, such that if this mass invest in the know-how costs, the assemblers' unit costs are the same in both countries, making assemblers indifferent about where to locate. In that case, we set $I(t)=i$. If no such i can be found, assemblers' costs either are always smaller in the North or the are always smaller in the South, in which case we set $I(t)=1$ and $I(t)=0$, respectively. Suppose that a mass $I(t)$ of Southern producers does invest. The unit costs in the N-equilibrium are readily calculated by substitution of $I(t)$ into (4), and analogously for the S-equilibrium. $I(t)$ is found by equating both costs. Putting N-equilibrium costs on the left, we obtain in the different cases of Fig. 3:

$$\begin{aligned}
&\left[I(t)\left(\frac{g}{w}\right)^{\sigma-1}+(1-I(t))\right]^{-\frac{1}{\sigma-1}}=\left[I(t)\left(\frac{1}{w}\right)^{\sigma-1}+(1-I(t))g^{\sigma-1}\right]^{-\frac{1}{\sigma-1}} && \text{Case I}\\
&\left[I(t)+(1-I(t))\beta^{\sigma-1}\right]^{-\frac{1}{\sigma-1}}=\left[I(t)\left(\frac{\beta}{w}\right)^{\sigma-1}+(1-I(t))(\beta g)^{\sigma-1}\right]^{-\frac{1}{\sigma-1}} && \text{Case II}\\
&\left[I(t)+(1-I(t))\beta^{\sigma-1}\right]^{-\frac{1}{\sigma-1}}=g^{-1}\left[I(t)+(1-I(t))\beta^{\sigma-1}\right]^{-\frac{1}{\sigma-1}} && \text{Case III}\\
&\frac{1}{\beta}=g^{-1}\left[I(t)+(1-I(t))\beta^{\sigma-1}\right]^{-\frac{1}{\sigma-1}} && \text{Case IV.}
\end{aligned} \tag{8}$$

In case IV in the N-equilibrium, the unit cost does not depend on $I(t)$, as Southern producers would not produce inputs, even if they invested. The equation for case III is impossible, since $g<1$ implies that the unit cost in the South is always larger than in the North (therefore, $I(t)=1$). This is because both the N- and the S-equilibria are in the high-cost regime, in which Southern producers match the marginal costs of Northern producers. The latter are higher in the S-equilibrium due to transport costs, causing both Northern and Southern inputs to be more expensive in the South. Case II is also an impossible equation if $w>\beta$ (making $I(t)=1$ again).

Lemma 2 shows two properties of $I(t)$. First, if the mass of Southern producers that invest is higher (lower) than $I(t)$, then the assemblers locate in the South (North). Second, in cases I and II, $I(t)$ is non-decreasing. This is because as the tariff is reduced, Southern inputs become more competitive, and the assemblers lower their threshold to move to the South.

Lemma 2. *If the know-how cost function F(i) is strictly increasing and continuous in i, then:*

1. *For a given level of protection t, if more (less) than a mass I(t) of Southern input producers invest in the know-how cost, then the assemblers locate in the South (North).*
2. *In cases I and II, I(t) is a non-decreasing function of t. In case II with $w>\beta$ and in case III, I(t)= 1. In case IV, I(t) is a constant.*

Taken together, the economic message of Lemmas 1 and 2 is that a decrease in the tariffs makes assemblers more willing to move to the South, and Southern producers more willing to invest. The South can combine these two effects to make the country industrialize.

4. Industrialization through export promotion

4.1. The big push

Fig. 4, the central figure in the paper, recapitulates the results so far, and shows the big push. It graphs $s(t)$, $n(t)$, and $I(t)$ as functions of the policy variable t. The four dashed lines delimit the four cases in Fig. 3. $I(t)$ divides the figure into two regions. The shaded "South" region consists of pairs (t,i) such that if a mass i of Southern producers invest when tariffs are t, then assemblers locate in the South. Conversely, in the unshaded region assemblers locate in the North. Points along curves $s(t)$ and $n(t)$ are all tentative equilibria. However, the assemblers are optimizing only along the portion of $n(t)$ that lies in the "North" region, and the portion of $s(t)$ that lies in the "South" region. Those portions are shown with thicker lines.

Consider the "Normal Big Push" region, where $n(t)<I(t)<s(t)$. There, two equilibria are possible, and therefore so is a big push. Suppose that historical reasons cause the South to be in the N-equilibrium, that is, on the $n(t)$ curve. The South produces relatively few

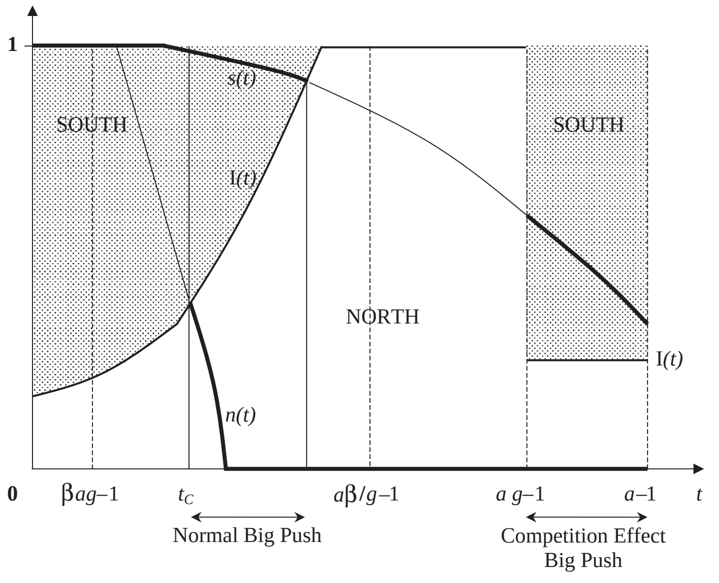


Fig. 4. Lowering the tariff down to t_C induces the big push.

and relatively low know-how inputs, and all computers are assembled in the North. In short, the South is unindustrialized, and faces a classical underdevelopment trap: input producers are reluctant to invest because there is no downstream demand for them; while assembly does not take place because there is no upstream supply. Is there a trade policy to help the South escape this trap?

The answer to that question is the main result of the paper. An export promotion policy, by exploiting forward and backward linkages between input producers and assemblers, may help in *inducing* the big push. To see this, suppose that the Southern government lowers its tariff on food, reducing the anti-export distortion, and moving the economy towards the left in the figure. Southern producers become more competitive through lower labor costs, and some input industries open up for the export market (thus, $n(t)$ increases).[13] At the same time the representative assembler lowers her cutoff to move to the South ($I(t)$ goes down). At a critical tariff, t_C, the number of Southern input producers that invest suffices to induce the assemblers to move South. When they do, investments surge as input producers in the interval ($n(t)$, $s(t)$] rush to invest and open up their industries. At the end, the South has become industrialized. Note that this story conforms well to the stylized fact (Rodrik, 1999) that

[13] Low labor costs seem to have played an important role in East Asia's industrialization. Kim (1985) identifies South Korea's endowment of a "well-motivated, low-wage labor force with a high level of education" as a major factor in Korea's transition to an export promotion policy. In Taiwan, strikes and "excessive" wage demands were in effect made illegal during in the 1960s by ambiguous and stringent requirements (Deyo, 1989). Even the later strengthening of labor unions there took a corporatist nature, and they were not allowed to enter collective bargaining over wages. In South Korea, foreign investors had additional protections from unionization.

a boom in exports and a boom in investments roughly coincided in time in the newly industrialized economies of Asia.[14]

4.2. Existence of the big push

Proposition 1 spells out what countries and industries are likely to have a big push region such that the big push is inducible at sufficiently low t. The key condition is that, given L^*, there are inputs of both sufficiently low and sufficiently high know-how costs.

Proposition 1 (*Existence of the big push*). *If F(i) is strictly increasing and continuous in i, and $1/a<\beta g$, then a normal big push region exists, and the coordination failure is solvable at sufficiently low tariffs if and only if*:

$$F\left(\frac{1}{1+a^{\sigma-1}}\right)\frac{1}{(1+a^{\sigma-1})(1-\alpha)(1-\beta)}\left(1+\frac{1-(1-\alpha)(1-\beta)}{g^{\sigma-1}}\right) < L^* < \frac{F(1)}{(1-\alpha)\left(1-\frac{\beta}{g}\right)}. \tag{9}$$

Furthermore, the leftmost term in (9) *is strictly smaller than the rightmost term. Therefore,* (9) *defines a non-trivial interval for the Northern labor endowment (L^*).*

In Proposition 1, L^* can neither be too large nor too small. If L^* is too large, demand for computers is so large that *all* Southern input producers invest. By contrast, if L^* is too small, there may be a big push region, but demand is insufficient to generate enough investment, even with the most liberal trade policy.

Note that what constitutes a large or a small L^* is linked to the magnitude of $F(i)$. Another way to interpret Proposition 1 is that it places a limit on the magnitude of some know-how costs. If know-how for inputs up to $i=1/(1+a^{\sigma-1})$ is too expensive, the South cannot start up its computer industry. Since $a>1$ and $\sigma>1$, this represents a relatively low mass of inputs ($i<1/2$). Above this mass, know-how costs can be arbitrarily high, and the country is still able to start up the whole industry. On the other hand, know-how costs of the last input ($i=1$) cannot be too low. Thus, some of the inputs must have a substantial knowledge barrier.

4.3. Properties of the big push

The previous section establishes under what circumstances the big push is likely to exist. But when is it "easier" to attain? To make this question concrete, let us equate easiness of the big push with a higher critical tariff. The higher t_C is, the smallest change the South needs in order to achieve industrialization. Proposition 2 deals with this.

[14] Incidentally, there is another region of big push, called "competition effect big push". At these relatively high wages, transport costs make Southern input producers unable to compete at all in the N-equilibrium (thus $n(t)=0$), in which case all Northern producers are monopolists. In the S-equilibrium, Northern producers *can* compete, forcing Southern producers to charge Northern producers' marginal cost. Thus, assemblers may prefer the South.

Proposition 2 (*Properties of the critical tariff*). *Assume that F(i) is strictly increasing and continuous in i. Then the critical tariff* t_C *is weakly increasing with:*

i. A decrease in α *or an increase in* L^**: the market size effect.*
ii. An increase in g: the transport cost effect.
iii. An increase in a: the comparative advantage effect.

Since there are two types of agents, any change affects t_C through two channels: the assemblers' decisions on where to locate; and the producers' decisions on whether to invest. The proposition first identifies a market size effect. As L^* increases (or the Cobb-Douglas weight on food decreases), so does demand for computers. This increases producers' profits while leaving assemblers' behavior unchanged, leading to higher investment at any given t.

A decrease in the transport costs (an increase in g) has more complicated effects. First, it increases the profits of Southern producers that either continue monopoly pricing or continue limit pricing. Second, by decreasing marginal costs, it can switch producers from limit pricing to full monopoly pricing, also increasing their profits. Both of these effects tend to increase $n(t)$. Third, in case I, assemblers' willingness to move to the South is not affected at all when transport costs go down. The assembler in the North saves on Southern inputs, but the assembler in the South saves on Northern inputs. When the assemblers are already indifferent, the savings on transport costs of either manager cancel, therefore $I(t)$ does not change. In case II, decreasing transport costs do induce assemblers to move South. In this case, Southern input producers exporting to the North are limit pricing and therefore do not change their prices at all in response to the change in transport costs, which is not true of Northern producers exporting to the South. Therefore, when transport prices decrease, only the assembler in the South gains. All of this implies a (weak) decrease in $I(t)$, which together with the increase in $n(t)$ increases t_C.

Finally, t_C also increases with a. This is an interesting result that showcases the impact of comparative advantage on the big push. As food productivity decreases (a goes up), the South's comparative advantage in computers becomes more pronounced. All else equal, this facilitates the big push, and again it happens through two channels. First, assemblers are more willing to move to the South and take advantage of cheaper labor (recall that food productivity determines wages). Second, lower wages also make producers' profits higher, and may in addition switch producers from limit pricing to monopoly pricing, again implying an increase in t_C.

5. The stylized story, with examples

5.1. The path to industrialization

This paper envisages a specific path of industrialization through an export promotion policy. The story goes broadly along the following lines:

1. At the outset, the computer industry has not opened up in the South, a country that constitutes a small market for computers. Computers use a large number of inputs,

which incur substantial trade costs, and require a fixed cost in know-how to start up. Abstracting from the fixed cost, the South has comparative advantage in the production of inputs.
2. The South implements an export promotion policy. It does not target specific inputs, and the policy can simply consist of the removal of an anti-export bias.
3. This policy induces a broadening of input production—not just an increase in the scale, but an increase in the number of inputs produced, towards higher-knowledge inputs.
4. Attracted by the wider availability of inputs, computer assemblers move to the South.
5. As a consequence, even more inputs are now produced there, and they tend to be even higher-knowledge inputs. The South has essentially captured the industry from the North, except for the very highest-knowledge inputs.

I proceed now with two illustrative examples of actual industrialization processes, one essentially complete, one that is not.

5.2. Taiwan's computer hardware[15]

As late as 1995, Taiwan's ratio of investment in computers to GDP was 0.80%, which compares to 3.23% for the US, and 1.89% for Japan. Moreover, the number of computers per 1000 people was 98, compared to 365 in the US and 145 in Japan. Taiwan was thus a small market for computers, and the government naturally saw exports as the road to open the industry.

Taiwan's electronics industry was incipient until the late 1950s, but in the 1960s the government began promoting exports, notably through the creation of the world's first Export Processing Zones. During the 1970s, companies such as Philips and IBM began sourcing computer components in Taiwan. By the late 1970s and early 1980s, some Taiwanese firms were assembling Apple clones and IBM-compatible PCs. During the 1980s movement of industry to the region continued as "foreign computer makers invested in production facilities in Taiwan to take advantage of low-cost labor from factory workers to technicians and engineers." Note the last sentence, on Taiwan's comparative advantage in computers.

As a consequence of this movement, a new crop of Taiwanese companies arose as sub-contractors to the MNCs. The founders were often engineers who had worked for the MNCs, and now licensed technology from them, a fact that is consistent with a knowledge barrier. During the 1980s, OEM production concentrated in "low-tech" components, such as cables, keyboards and mice. Gradually, component sourcing climbed the technology chain towards motherboards and monitors. By the 1990s, Taiwan was producing complete PCs and notebooks for IBM and Dell, among others. However, it continued to import components at the top of the technological spectrum, such as DRAMs and microprocessors, from the US and Japan. By 1995, Taiwan had become the

[15] See Dedrick and Kraemer (1998, p. 147–173), from where all quotes and figures are taken, unless otherwise stated.

world's leader in the production of notebook PCs, with a 27% world share. Its world share in desktops PCs was 10%.

All the elements in the story are here: the government's promotion of exports; early investment in components sourcing; the incentive provided by cheap labor; the start up of assembly of final products; local firms' rush to take advantage of subcontracting and OEM opportunities; and the continued reliance on foreign suppliers for the highest-knowledge inputs.[16]

By the 1990s, "Taiwanese companies have developed strong capabilities in design and systems engineering and provide a full range of services to foreign PC makers, from design and manufacturing to distribution and after-sales support".

5.3. Software in India: from 'body shopping' to 'turnkey'?[17]

Starting as early as 1970, Indian authorities were paying attention to the computer industry, and in particular to software. The thrust of their policy, however, was import substitution, which ended largely in failure. An incipient effort of export promotion during the 1970s never really took off, weighed down by regulatory difficulties in the appropriation of export incentives, among other problems.

A major export promotion policy was launched by the administration of Rajiv Gandhi. In November 1984, a Computer Policy was announced, followed in December 1986 by a more specific Computer Software Export, Development and Training Policy. These policies included special low duties for computers, provision of satellite links, and in some cases minimum export obligations. In the early 1990s, the government introduced the Software Technology Parks (STPs), which functioned much like Export Processing Zones for software.[18] Saxenian (2000) emphasizes that the new policies merely removed barriers to growth of the industry, as policy makers' own ignorance about it prevented them from "taking decisive steps to actively promote the software industry." She notes: "The introduction of the STPs coincided with the initiation in 1991 of the economic liberalization process in India. Software producers benefited from general policy changes such as the devaluation of the rupee and the growing openness to foreign direct investment." Thus, the success of the software industry in India must be attributed to general liberalizing policies, not to industrial targeting.

In the wake of these policies, an export boom in software took off. Initially, exports were dominated by "body shopping," the practice of sending programmers to work overseas at the client's site. However, this decreased somewhat in relative value, from 75% of total exports in the late 1980s to about 60% by the early 2000s. Heeks and Nicholson (2002) discern a parallel trend, that of "moving up the value chain from supply of

[16] However, the chronology is more complicated than any model could make justice to. In particular, assemblers' move to the island seems to have happened in at least two "waves": simple assembly during the 1970s, and "complex" assembly with production of final packages by the 1990s. The key is that both types of linkages play a role: forward linkages as local availability of inputs encourages assemblers to locate in the South; and backward linkages as the assemblers appearance in the South causes more inputs to start up there.

[17] The facts in this example are from Subramanian (1992), Saxenian (2000), and Heeks and Nicholson (2002).

[18] The STPs allowed 100% foreign ownership, in return for minimum export obligations.

programming services to addition of design/analysis services to complete turnkey project services". Note the late appearance of "turnkey" products, or final packages. Software exports grew at an average of 40% in the decade prior to 2001, and accounted for 8% of India's total exports in the early 2000s.

How well does this example fit with the premises of our model? First, regarding the size of the domestic market, Heeks and Nicholson (2002) mention evidence that India's small market for software products helped push India's software firms into exports. Second, there can be little doubt that India had, and has still, comparative advantage in software design. In 1994, average wages for computer programmers in the US, Mexico, and India were 47 000, 26 000, and 4000 dollars, respectively. If wages were the whole story, of course, then *all* LDCs would have comparative advantage in computers. But the lower wages of Indian programmers are not likely to be due to their lower skills. Quite the contrary, the Indian government has endeavored to develop the IT skills of its educated population (Heeks and Nicholson, 2002). An accidental factor was also IBM's decision in the late 1970s to abandon India, leaving behind many unemployed programmers familiar with UNIX, who provided inexpensive, but IBM trained, manpower for the nascent industry. As early as 1992, Microsoft was seeking to bring programmers directly from India, surely because it felt that they were internationally competitive. The "reverse brain drain" of Indian expatriates returning to start new companies in India is also a factor in providing the country with Western trained talent.

To think about the costs of trading in inputs, note that one of the most important inputs in software design is the human capital of the software designers themselves. When telecommunications are expensive or unreliable, or when software design at a distance is impractical, the trade costs are those associated with transporting programmers to the customer's site, and are likely to be much higher than the costs of exporting software itself (see footnote 5). The broad time lines of the model also fit well: an export promotion policy; followed by "body shopping"; followed by the production of "turnkey" products; with the starting up of higher value inputs. However, the process of industrialization is certainly not complete. In particular, body shopping still represents a high proportion of the industry. One can therefore use this paper to make the prediction that in the future India should be able to produce more final packages.[19]

6. Application to education policy

If the model sheds light on the process of late industrialization in the South, it is then worthy to ask: is there only one South? Or are there differences among less developed

[19] To quote from one early analysis: "It has been accepted by one and all in the Industry that the software scene in India is still pathetic.... This, after we claimed to have excellent manpower with software development skills. Furthermore, this highly trained manpower is available at a lower cost than anywhere else in the world. And yet we have not seen the emergence of a Microsoft or a Lotus in the country nor packages that [have] swept the imagination of the Indian buyer" (PC World, 1987, cited in Subramanian, 1992, p. 148). Note the emphasis on India's comparative advantage. The lack of final packages is not surprising in the context of the current model, a mere three years after the start of the export policy.

countries, that can help explain why some industrialize and some do not? A case in point is the difference between what I term the South*east* (Korea, Taiwan, and others), and the South*west* (Latin America).

Note that the model is asymmetric between low- and high-knowledge inputs. As the South opens up, the first inputs to start production are those with lower know-how costs. This asymmetry can be used to discuss different approaches to education. As we shall see, two different education policies, broadly similar to those adopted in East Asia and in Latin America, have distinct consequences for industrialization. Assume for concreteness that the know-how cost function has the form $F(i)=(1+\gamma)i^{\gamma}$. The Southeast and the Southwest both have this functional form, with parameter γ_{SE} and γ_{SW}, respectively, where $\gamma_{SE}>\gamma_{SW}>1$. Fig. 5 depicts their know-how schedules as $F_{SE}(i)$ and $F_{SW}(i)$. The two countries have the same average know-how costs, but the Southeast has lower costs in the region of lower i, and higher costs in the region of higher i.

One reason may be that the Southeast provides better elementary and secondary educations, and thus has a better overall workforce, while the Southwest emphasizes its higher education system, and thus has a better specialized workforce. Compare the following education expenditures, circa 1995–1997 (Table 1). One perhaps surprising fact is that Brazil and Mexico actually *led* South Korea in education expenditures as a percentage of GNP. However, the most striking difference is the two Latin American countries' higher emphasis on higher education.

Clearly, the recipe proposed in this paper applies best to the Southeast: begin by opening up your low fixed-cost industries (which in the Southeast are especially low fixed-cost), wait for momentum to build up until assemblers locate in the country, and industrialize as higher-cost industries start. Why would the Southwest, which has a more uniform cost distribution, face a higher hurdle? After all, it compensates for the Southeast's advantage in low-knowledge inputs with its own advantage in high-knowledge inputs. The key here is precisely the larger role that low-knowledge inputs play.

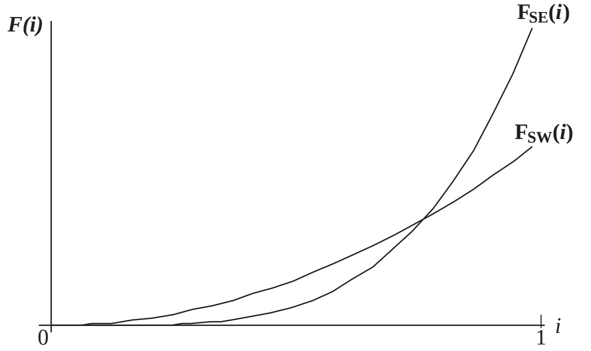


Fig. 5. The Southeast's cost schedule is more skewed.

Table 1
Education expenditures in South Korea, Brazil and Mexico

	Education expenditure, % GNP	Primary education, % total	Secondary education, % total	Tertiary education, % total
South Korea	3.7	45.3	36.6	8.0
Brazil	5.1	53.5	20.3	26.2
Mexico	4.9	50.3	32.5	17.2

Source: United Nations Development Programme, *Human Development Report 2001*.

To show this formally, let us write a closed form solution for the critical tariff, which can be done if it is assumed to lie in case I. Substituting Eq. (A2) (from the appendix) into Eq. (7N), and using $I(t)=n(t)$ and $w=(1+t)/a$, we obtain:

$$1+t_{\mathrm{C}}=a\left[\left(\frac{(1+\gamma)\left(1+\dfrac{1-(1-\alpha)(1-\beta)}{g^{\sigma-1}}\right)}{(1-\alpha)(1-\beta)L^{*}}\right)^{\frac{1}{1+\gamma}}-1\right]^{-\frac{1}{\sigma-1}}. \qquad (10)$$

This t_{C} has all the properties of Proposition 2. The next proposition formalizes the intuition given above, by proving that the Southeast has a higher t_{C} than the Southwest. It also shows that a choice of a single parameter (L^*, as in Proposition 1) is sufficient to ensure that t_{C} lies in case I.

Proposition 3 (*The critical tariffs of the Southeast and the Southwest in case I*). *Suppose that $F(i)=(1+\gamma)i^{\gamma}$ with $\gamma>1$. Furthermore, suppose that and $1/a<\beta g$ (to ensure that case I exists). Then:*

i. The following two inequalities,

$$\frac{1}{\left(1+a^{\sigma-1}\right)^{1+\gamma}}<\frac{(1-\alpha)(1-\beta)L^{*}}{(1+\gamma)\left(1+\dfrac{1-(1-\alpha)(1-\beta)}{g^{\sigma-1}}\right)}<\frac{1}{\left(1+\dfrac{1}{(\beta g)^{\sigma-1}}\right)^{1+\gamma}}, \qquad (11)$$

define a non-trivial interval for L^*. The critical tariff exists and lies in case I if and only if L^* lies in this interval. Furthermore, this interval is included in the interval of Proposition 1.

ii. If the critical tariff lies in case I, it increases with γ.

The message of this proposition is that public investment in primary and secondary education dominates investment in tertiary education, for the purpose of industrialization. This contrasts sharply with endogenous growth models, in which growth is driven by innovation, rather than by complementarities among different industries and imitation.[20]

7. Possible objections and extensions

I address in this section two possible objections about the practical relevance of exports for industrialization. To do so, I use two extensions of the model.

The first objection might be that, in countries such as South Korea and Taiwan, the ratio of exports to GDP in the early sixties was so small that even a large increase in exports could not possibly explain the subsequent growth in the GDP. Consider a country at a protection level just above t_C. Suppose that there is domestic demand for computers (which was not done in the main body of the paper for tractability purposes; but note that the main lines of the story do not change). Then the export promotion policy provides a small increase (from $n(t)$ to $n(t_C)$) of the number of exporting industries. This is however sufficient to induce the big push, which itself causes the mass of input producers to jump from $n(t_C)$ to $s(t_C)$. It is important to note that the resulting increase in production is *larger* than the increase in exports, since some of the additional production is dedicated to domestic consumption. The point here is that there is not a rigid link between the size of the exports boom and the size of the GDP boom. The initial boost in exports plays the role of the first domino to fall in a line, causing all other dominoes to fall as well. The line itself can be as long as desired.

A second possible objection relates to the relative timing between the export and the investment booms. The two booms seem for a wide swath of countries to have occurred more or less at the same time, through a fairly extended period (see Fig. 3.4 in Rodrik, 1999). This is of course not as clear-cut as my story, in which the exports (certainly the incentives to export) precede the investment boom. Suppose however that the computer industry is only one of many industries waiting to open up (while food serves its purpose as the "background" industry, that is, almost the whole economy before the South industrializes). If export incentives are introduced gradually, as happened in practice, then each different "computer" industry takes off at different times. It follows that the simultaneity over an extended period between an export boom and an investment boom is exactly what one would expect.[21]

[20] Ramcharan (2002) analyzes different education policies in a growth framework. Given externalities among skill inputs and fixed costs in education, he finds that multiplicity of equilibria arises, leading to education traps. In his closed economy model, the recommendation is that policymakers invest both in secondary and in tertiary education.

[21] Rodrik (1995) makes the related point that export incentives were in place a few years before the investment boom, the implication being that the investment boom was due to something else. This of course can be explained in the context of my model, even with a single computer industry. Imagine the South gradually moving t to the left of Fig. 4, over a number of years, until the scale finally tips, and the investment boom ensues.

8. Conclusion, and future research

This paper presents a theory of sudden “late” industrialization through export promotion. The basic intuition relies crucially on the fact that a policy of export promotion helps in breaking the vicious circle of an underdevelopment trap, effectively transforming it into a *virtuous* circle. Thus, the export promotion at first encourages production solely for the export market, inducing recalcitrant producers to invest. This later causes a new wave of investment from even more recalcitrant producers, and so on. This naturally coordinating aspect of exports has been absent from the previous literature. The model was further applied to an analysis of educational policies.

It is important to realize, however, that the model applies to a specific class of countries, and to the opening up of specific types of industry. While this facet is certain to limit its applicability, it has the advantage of providing clear indications about the probability of success of an industrialization drive through exports. From the point of view of industrialization as a solution to a coordinating problem, countries that are likely to succeed are endowed with a highly educated, inexpensive, labor force, have low agricultural productivity, and initially constitute small markets for the industries in question. Industries that are likely to have coordination problems are knowledge-intensive, increasing returns to scale industries, such as the high-tech industries examined here.

Nothing in the model rejects a role for the more “internal” policies that have been uncovered in the literature. On the contrary, one further application would be a comparison among policy alternatives that are available to middle income countries seeking to industrialize:[22] the export promotion policy presented here; an investment subsidy or an export subsidy, both of which may or may not be targeted at specific industries; or the government’s direct coordination of private entrepreneurs’ actions. One can use a model of several “computer” industries, as alluded to in the previous section, to compare these different policy alternatives.

In this context, policy makers may have another choice to make: *which* industries to open up? The export promotion policy of this paper simply dismantles the prevalent anti-export bias that is caused by import substitution and, therefore, it does not “choose” industries. An investment policy, on the other hand, can target industries, based on their characteristics (it could, for example, target industries with low elasticity of demand). Preliminary research shows that, under some circumstances, an investment subsidy *and* an export promotion policy both need to be in place for the South to industrialize.

The governments of Taiwan and South Korea have taken more than one approach, and in particular *did* have investment subsidies in place, at the same time that they had the export promotion policy that is the focus of the paper.[23] Thus, the answer to which is the “right approach” to industrialize, even if one restricts attention to middle income countries with sizable investment in education, is likely to be nuanced.

[22] I am grateful to an anonymous referee for suggesting this avenue of research.

[23] For example, Dedrick and Kraemer (1998) report that the Taiwanese government provided low interest loans to computer firms, supplemented them with tax exemptions for investment, allowed accelerated depreciation of fixed assets, and so on.

Acknowledgements

I am grateful to Mary Lovely, Devashish Mitra, Dave Richardson, Stuart Rosenthal, Bin Xu, Susan Zhu, three anonymous referees, and seminar participants in Pittsburgh, Purdue, Syracuse, UCSD, and the Midwest Trade Meetings, for helpful comments. I am especially grateful for all suggestions and encouragement by Jim Rauch (my dissertation advisor).

Appendix A

Proof of Lemma 1. 1. Take for example a level of the tariff t such that case II holds. Then, $\pi_N(i;\, t)$ and $\pi_S(i;\, t)$ are defined by the bottom line of Eq. (7N) and the top line of Eq. (7S), respectively. In this case, both $(1-w/g)\le 1-\beta$ and $\beta \ge gw$ hold. Suppose that both inequalities held with the equality sign. This implies $w/g=wg$, not possible because $w>0$ and $g<1$. Therefore one of the two inequalities above must hold strictly, implying $\pi_N(i;\, t)<\pi_S(i;\, t)$, except if $i=1$ and $w=\beta g$ (a borderline situation that I take into account in case I). If we superimpose Fig. 2 over the corresponding figure for the S-equilibrium, we have the six possible situations in Fig. 6 (ignore for the moment the shaded areas). We can see that $s(t)>n(t)$, except that both functions may be equal, either when they are both 0 or 1. The proof for cases I and III is analogous, except that in the former $\pi_N(1;\, t)=\pi_S(1;\, t)$, implying that when one of $s(t)$ or $n(t)$ equals 1, so must the other. In case IV, $n(t)=0$, which implies the result.

2. Let us prove the result for $n(t)$ only. Suppose that t increases, increasing w. From (7N), $\pi_N(i;\, t)$ decreases, as long as Southern producers stay within the same regime, except when $i=1$ in the low-cost regime, in which case $\pi_N(i;\, t)$ does not change. However, we must also consider the possibility that the increase in t induces a switch from the low- to the high-cost regime, or from the high-cost to the complete specialization regime. In the former case, variable profits go down because, in addition to the increase in w, producers now have to limit price. To prove this formally, we need to show that

$$\frac{(1-\alpha)(1-\beta)L^*}{i+(1-i)\left(\frac{w_L}{g}\right)^{\sigma-1}[1-(1-\alpha)(1-\beta)]} > \frac{\left(1-\frac{w_H}{g}\right)(1-\alpha)L^*}{i+(1-i)\beta^{\sigma-1}[1-(1-\alpha)(1-\beta)]}, \tag{A1}$$

where w_L (w_H) denotes wages before (after) the increase in t, with w_L (w_H) in the low- (high-) cost regime. The inequality in (A1) must hold because $w_L \le \beta g \le w_H$, and one of the latter set of inequalities must be strict, otherwise $w_L=w_H$. If the switch happens from the high-cost from the complete specialization case, then $n(t)$ becomes zero, which immediately implies the result.

Consider all the possibilities in Fig. 6. The point $i=1$ is only relevant when $n(t)=1$, in which case the Lemma is automatically verified because $n(t)$ can only remain at 1 or decrease. For all other cases, imagine a decrease in $\pi_N(i;\, t)$. If $n(t)=0$, then $n(t)$ remains 0. If $n(t)>0$, then $n(t)$ strictly decreases.

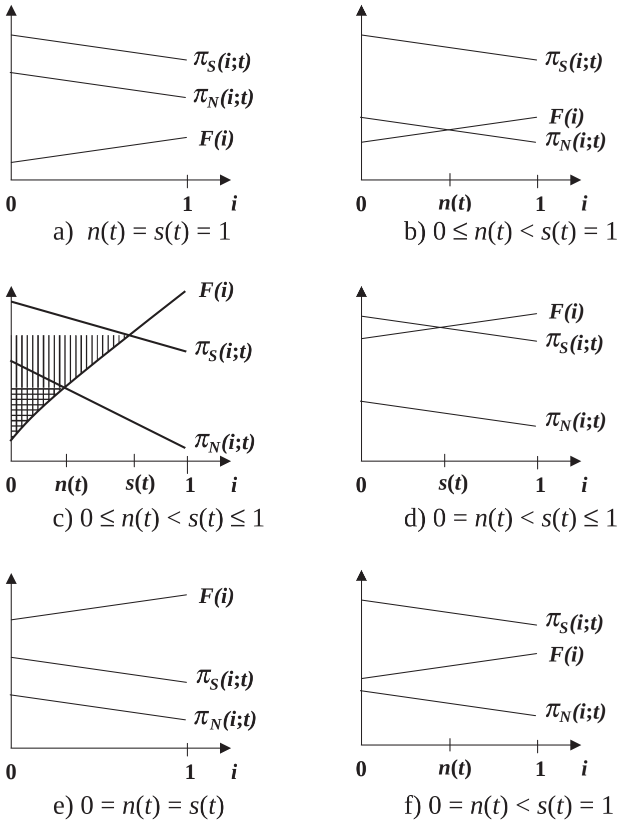


Fig. 6. Proof that $n(t) \leq s(t)$.

Analogous reasoning proves the results for $s(t)$.

3. In panel c, the levels at which $\pi_N(i;\,t)$ or $\pi_S(i;\,t)$ intersect $F(i)$ represent the variable profits for all Southern input producers. Then the shaded areas represent the total Southern profits in the N-equilibrium (the horizontal pattern) and in the S-equilibrium (the vertical pattern, which includes the horizontal pattern). Since real (food) wages are the same in both equilibria by construction, and assemblers make no profits, the S-equilibrium clearly dominates. Inspection of all the panels in Fig. 6 shows that the profits can only be the same in the (trivial) case when $n(t)=s(t)=0$. □

Proof of Lemma 2. 1. Suppose that (8) has a solution (which excludes case III, and case II when $\beta < w \leq \beta/g$). For cases I and II, both square brackets are averages of two numbers, with weights $I(t)$ and $(1-I(t))$. $I(t)$ always multiplies the larger of the two numbers (Southern inputs are always cheaper than Northern inputs). The four different numbers can be ranked, with the result that the numbers on the right are always the two extreme ones. For example, in case I: $\left(\frac{1}{w}\right)^{\sigma-1} > \left(\frac{g}{w}\right)^{\sigma-1} > 1 > g^{\sigma-1}$. When $I(t)$ increases, both square brackets increase, but the one on the right increases more than the one on the left. This can be shown by noting that $\mathrm{d}[IA+(1-I)B] = \mathrm{d}I(A-B)$, where A and B represent two numbers that do not depend on $I(t)$, and that A–B is larger on the right (South). Starting from equality, we can conclude that when $I(t)$ increases, unit costs of assembly become lower in both countries, but more so in the South. This proves the result for cases I and II. Case IV is trivial to check.

2. Eq. (8) can be solved for the interesting cases:

$$\begin{aligned} I(t) &= \frac{1}{1+\left(\frac{a}{1+t}\right)^{\sigma-1}} && \text{Case I} \\ I(t) &= \frac{1}{1+\frac{\left(\frac{a}{1+t}\right)^{\sigma-1}-\frac{1}{\beta^{\sigma-1}}}{1-g^{\sigma-1}}} && \text{Case II,}\ t\leq a\beta-1 \\ I(t) &= \frac{g^{-(\sigma-1)}-1}{\beta^{-(\sigma-1)}-1} && \text{Case IV,} \end{aligned} \tag{A2}$$

where $w=(1+t)/a$ has been substituted. Inspection of this equation immediately shows that $I(t)$ increases with t in the first two cases, and is a constant in the last. □

Proof of Proposition 1. The proof is broken down into the following easy steps.

(i) To begin, note that for t sufficiently high, $n(t)=0$. Simply take t large enough that $w=g$, the border between cases III and IV (see Fig. 3). If we consider this to be case III, then the N-equilibrium is in the high-cost regime, and we can see from (7N) that $\pi_N(i; t=ag-1)=0$ for all i, which in turn implies $n(t)=0$. This is of course also true if we consider this to be case IV.

(ii) Next, let us prove that $n(t)$ is a continuous function of t. If the N-equilibrium is either in the low- or in the high-cost regime (that is, if $w\leq g$), then $n(t)$ is the solution to Eq. (7N). $\pi_N(i; t)$, taken within each of the two regimes, is not only a continuous function of i, but it is also a continuous function of t. This is essentially because its denominator is a simple polynomial of either i or t that cannot be zero. However, we also need to investigate the continuity of $\pi_N(i; t)$ in the transition between the two regimes. At $w=\beta g$, $\pi_N(i;t)$ is the same across the two lines in Eq. (7N). Let us also note that $\pi_N(i; t)$ is *strictly* decreasing with i, and $F(i)$ is *strictly* increasing with i, the latter by assumption. These results, together with continuity of $F(i)$, imply continuity in $n(t)$ within and across the low- and high-cost regimes. Using the discussion in step (i) above, $n(t)$ is continuous throughout.

(iii) $I(t)$ is also a continuous function of t, for $t\leq a\beta-1$. In that region, $I(t)$ is defined by Eq. (A2), and it is continuous by inspection within each case. At the transition between the cases I and II, when $(1+t)/a=\beta g$, the two top lines of (A2) are the same, making $I(t)$ continuous. When $t=a\beta-1$, it is easy to see that $I(t)=1$. Therefore, the normal big push region can only be in the region $t\leq a\beta-1$, and the remainder of this proof is restricted to that region.

(iv) The coordination failure is solvable at sufficiently low tariffs if $I(0)<n(0)$ (see Fig. 4). The assumption $1/a<\beta g$ implies that at $t=0$ the model is in case I. Then $I(0)=1/(1+a^{\sigma-1})$, which is a number strictly between 0 and 1. Part (ii) already showed that $\pi_N(n(0); 0)$ is a *strictly* decreasing and continuous function of $n(0)$. Considering the different panels of Fig. 2, this implies: for $I(0)<n(0)$ to hold, a necessary and sufficient condition is that $F(I(0))<\pi_N(I(0);0)$. Eq. (7N) in the low-cost regime then yields the first inequality in the proposition (Eq. (9)).

(v) We already noted that for t sufficiently high, $I(t)=1$. In particular, $I(t=a\beta-1)=1$. Note that this value is reached within case II.

(vi) With results (i)–(v) in place, the functions $I(t)$ and $n(t)$ must cross once, and they do so at $t>0$. However we must show that $I(t)$ crosses $n(t)$ where $n(t)<1$. If they crossed where $n(t)=1$, $s(t)=1$ as well, and there is no big push. In contrast, if they cross where $n(t)<1$, then $s(t)>n(t)$, and there must be a big push region.

$I(t)$ becomes 1 at $w=\beta$ or $t=a\beta-1$. A necessary and sufficient condition for $n(t=a\beta-1)<1$ is that $\pi_N(1;\, t=a\beta-1)<F(1)$, which from (7N) in the high-cost regime leads to the second inequality of Eq. (9). If this inequality applies, $I(t)$ cannot cross $n(t)$ when $n(t)=1$.

(vii) Finally we need to show that the leftmost term in Eq. (9) must be strictly smaller than the rightmost term. Because $F(i)$ is increasing, and $1/(1-\beta)<1/(1-\beta/g)$, a sufficient condition is that $1-(1-\alpha)\,(1-\beta)<(ag)^{\sigma-1}$, which must be true because $ag>1/\beta>1>1-(1-\alpha)\,(1-\beta)$ and $\sigma>1$. This completes the proof. □

Proof of Proposition 2. (i) Suppose that either L^* or $1-\alpha$ increases. It is immediate to see from (A2) that $I(t)$ does not change. Neither do the boundaries between the different cases of Fig. 4 (see Fig. 3). Inspection of Eq. (7N) reveals that $\pi_N(i;\,t)$ increases, for any i and t. Then Fig. 2 implies that $n(t)$ increases or remains constant for a fixed t. This in turn implies that t_C is non-decreasing.

(ii) Suppose that g increases. From (A2), $I(t)$ remains unchanged in case I and decreases in case II. However, the boundary between case I and case II in Fig. 4 shifts to the right. Take a t that is in case II before g goes up, and in case I after. We must make sure that $I(t)$ for such a t also decreases. From (A2), this is equivalent to proving that:

$$\frac{1}{1+\left(\dfrac{a}{1+t}\right)^{\sigma-1}}<\frac{1}{1+\dfrac{\left(\dfrac{a}{1+t}\right)^{\sigma-1}-\dfrac{1}{\beta^{\sigma-1}}}{1-g^{\sigma-1}}}, \tag{A3}$$

where g is the initial value before it increases. Simplifying, (A3) yields $((1+t)/a)>\beta g$, which is true in case II.

Let us now see what happens to $\pi_N(i;\,t)$ (with fixed i and t) when g increases. It is easily seen from (7N) that it must increase, within each case. However, suppose again that t switches from case II to case I when g increases from g_L to g_H. Thus: $\beta g_L \le w \le \beta g_H$ (at least one strict inequality must hold). For such t, each producer goes from a limit price to a full monopoly price, thus his profits should go up. To prove this formally we need to check that:

$$\frac{(1-\alpha)(1-\beta)L^*}{i+(1-i)\left(\dfrac{w}{g_H}\right)^{\sigma-1}[1-(1-\alpha)(1-\beta)]}>\frac{\left(1-\dfrac{w}{g_L}\right)(1-\alpha)L^*}{i+(1-i)\beta^{\sigma-1}[1-(1-\alpha)(1-\beta)]},$$

where (7N) was used for the definition of $\pi_N(i;\, t)$. This strict inequality follows from the inequalities for w above. Again, this implies that $n(t)$ increases or remains constant for each t. This, together with the previous paragraph, implies that t_C increases or remains constant.

(iii) Suppose now that a goes up. Since the proof essentially retraces the proof for part (ii), a terse account should suffice. Again, it is easy to see from (A2) that $I(t)$ goes down in either case I or case II. Furthermore, even for a t that switches from case II to case I (A3) (where the initial a is used) is now a *sufficient* condition for $I(t)$ to go down.

It easy to see that $\pi_N(i;\, t)$ goes up, as w goes down (recall that $w=(1+t)/a$) in both lines of Eq. (7N). For a t that switches from case II to case I, all we need to show is essentially the same as Eq. (A1), except that w_L (w_H) is now reinterpreted as the wage after (before) the increase in a. Again, the inequality holds because that $w_L \le \beta g \le w_H$, with one of the latter set of inequalities necessarily strict.

When we put all of these together, the implication that t_C must increase or remain constant as a increases follows. □

Proof of Proposition 3. (i) First, the interval defined by the two extreme terms in the inequality chain exists and is non-trivial. This is because $a^{\sigma-1} > 1/(\beta g)^{\sigma-1}$, by assumption. Second, let us prove that this interval is included in the interval defined in Proposition 1. The first inequality is the same as Eq. (9), while it can easily be shown that

$$\frac{(1+\gamma)\left(1+\dfrac{1-(1-\alpha)(1-\beta)}{g^{\sigma-1}}\right)}{(1-\alpha)(1-\beta)\left(1+\dfrac{1}{(\beta g)^{\sigma-1}}\right)^{1+\gamma}} < \frac{1+\gamma}{(1-\alpha)\left(1-\dfrac{\beta}{g}\right)}, \text{ since } \beta<\beta/g \text{ and}$$
$$1-(1-\alpha)(1-\beta)<1/\beta^{\sigma-1}.$$

Thus, the interval for L^* defined by Eq. (11) is smaller than, and is included in, the interval defined by Eq. (9).

(Necessary condition). Now assume that the critical tariff exists and falls under case I. We already used this assumption in the derivation of Eq. (10). Furthermore, the assumption implies that $0<t_C<\beta a g-1$, where t_C is taken from (10). With some rearrangement, this is equivalent to inequalities (11).

(Sufficient condition). Assume that (11) holds. Since we already proved that the interval defined by (11) lies inside the interval of Proposition 1, t_C exists. We can still solve the top lines of Eqs. (7N) and (A2) to calculate "t_C" as in Eq. (10). We still do not know that it falls under case I. However, (11) tells that "t_C" thus calculated *is* within case I, which vindicates using Eqs. (7N) and (A2) to calculate it. Here we can use uniqueness of t_C, itself clear from Fig. 4, and the underlying assumptions. If we found *one* t_C by crossing $I(t)$ with $n(t)$, and its case is consistent with the case of those equations that we picked, then it must be *the* critical tariff.

(ii) As just proved, if t_C lies in case I, then (10) holds true. All we have to do is to prove that it increases with γ. Rewrite (10) as $1+t_C = a\left[((1+\gamma)A)^{\frac{1}{1+\gamma}}-1\right]^{-\frac{1}{\sigma-1}}$, where A does not depend on γ. We need to prove that $f(\gamma) \equiv \ln\left[((1+\gamma)A)^{\frac{1}{1+\gamma}}\right]$ decreases with γ. Taking derivatives, we get $\frac{\partial f}{\partial \gamma} = \frac{1}{(1+\gamma)^2}(1 - Ln[(1+\gamma)A])$. For this to be negative, we need $(1+\gamma)A > e$. (11) implies:

$$(1+\gamma)A = \frac{(1+\gamma)\left(1+\frac{1-(1-\alpha)(1-\beta)}{g^{\sigma-1}}\right)}{(1-\alpha)(1-\beta)L^*} > \left(1+\frac{1}{(\beta g)^{\sigma-1}}\right)^{1+\gamma} > (1+1)^{1+\gamma} > 2^2 > e,$$

which completes the proof. □

References

Addis, C., 1999. Taking the Wheel: Auto Parts Firms and the Political Economy of Industrialization in Brazil. Pennsylvania State University Press, University Park, PA.

Amsden, A.H., 1989. Asia's Next Giant: South Korea and Late Industrialization. Oxford University Press, New York.

Anderson, J., van Wincoop, E., 2004. Trade Costs. Journal of Economic Literature 42, 691–751.

Balassa, B., 1980. The process of industrial development and alternative development strategies. Princeton Essays in International Finance 141.

Bond, E.W., Jones, R.W., Wang, P., 2005. Economic Takeoffs in a Dynamic Process of Globalization. Review of International Economics 13, 1–19.

Dedrick, J., Kraemer, K.L., 1998. Asia's Computer Challenge: Threat or Opportunity for the United States and the World? Oxford University Press, New York.

Deyo, F.C., 1989. Beneath the Miracle: Labor Subordination in the New Asian Industrialism. University of California Press, Berkeley, Los Angeles.

Edwards, C., 1992. Industrialization in South Korea. In: Hewitt, T., Johnson, H., Wield, D. (Eds.), Industrialization and Development. Oxford University Press, New York.

Heeks, R., Nicholson, B., 2002. Software Export Success Factors and Strategies in Developing and Transitional Economies. Development Informatics Working Paper no. 12, Institute for Development Policy and Management, University of Manchester.

Hummels, D., 2001. Toward a Geography of Trade Costs. Purdue University manuscript.

Kim, K.S., 1985. Lessons from South Korea's experience with industrialization. In: Corbo, V., Krueger, A.O., Ossa, F. (Eds.), Export Oriented Development Strategies: The Success of Five Newly Industrialized Countries. Westview Press, Boulder, CO, pp. 57–78.

Kim, K.S., Roemer, M., 1979. Growth and Structural Transformation. Harvard University Press (Studies in the Modernization of the Republic of Korea 1945–1975), Cambridge, MA.

Krueger, A.O., 1985. The experiences and lessons of Asia's super exporters. In: Corbo, V., Krueger, A.O., Ossa, F. (Eds.), Export Oriented Development Strategies: The Success of Five Newly Industrialized Countries. Westview Press, Boulder, CO, pp. 187–212.

Lucas Jr., R.E., 1993. Making a miracle. Econometrica 61, 251–272.

Murphy, K., Shleifer, A., Vishny, R., 1989. Industrialization and the big push. Journal of Political Economy 97, 1003–1026.

Nam, C.H., 1990. Export promotion strategy and economic development in South Korea. In: Milner, C. (Ed.), Export Promotion Strategies: Theory and Evidence from Developing Countries. New York University Press, New York, pp. 165–183.

Ramcharan, R., 2002. Columbia or High School? Understanding the Roles of Education in Development. IMF Working Paper 02/36.

Rhee, Y.W., 1990. The catalyst model of development: lessons from Bangladesh's success with garment exports. World Development 18, 333–346.

Rodríguez-Clare, A., 1996. The division of labor and economic development. Journal of Development Economics 49, 3–32.

Rodrik, D., 1995. Getting interventions right: how South Korea and Taiwan grew rich. Economic Policy 20, 55–107.

Rodrik, D., 1996. Coordination failures and government policy: a model with applications to East Asia and Eastern Europe. Journal of International Economics 40, 1–22.

Rodrik, D., 1999. The New Global Economy and Developing Countries: Making Openness Work. Overseas Development Council, Washington.

Saxenian, A., 2000. Bangalore: The Silicon Valley of Asia? Center for Research on Economic Development and Policy Reform, Stanford University.

Stern, J.J., Kim, J.H., Perkins, D.H., Yoo, J.H., 1995. Industrialization and the State: The Korean Heavy and Chemical Industry Drive. Harvard University Press, Cambridge, MA.

Subramanian, C.R., 1992. India and the Computer: A Study of Planned Development. Oxford University Press, New Delhi.

Wang, P., Xie, D., 2004. Activation of a modern industry. Journal of Development Economics 74, 393–410.