Trade Liberalization, Democratization and Technology Adoption*

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Abstract

We study the role of trade liberalization, democratization and their interaction for technology adoption. A general equilibrium theory with heterogeneous skills predicts a complementarity between trade and democracy in creating demand for superior technologies and political incentives to facilitate their adoption. This is the case because unbalanced regime changes may lead to vested interests of the decisive political actors represented by the rentier elites in autocracies and workers in democracies. We use panel data on technology adoption, at a disaggregated level, for the period 1980-2000. We exploit within country variation over time and the heterogeneous timing of trade liberalization and democratization. The results suggest the existence of a positive interaction between trade openness and democratization for technology adoption. The result that transitions to open democracies are beneficial for the technological dynamics is robust to a large set of checks.

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1 Introduction

Trade liberalization and democratization will bring economic prosperity. Technological improvements are, in particular, natural outcomes of greater openness to trade and more political freedom. Although this view has found large support in the last decades, the consequences of these regime changes for technological improvement are not straightforward theoretically and have not been systematically explored empirically. This paper presents a theoretical and empirical investigation of the role of trade liberalization, democratization, and their interaction for technology adoption.

Existing theoretical literature has predicted that openness and democracy increase productivity, but mainly through indirect channels (see the related literature in Section 2). Trade leads to more efficient use of available resources, reducing the scope for inefficient rent-seeking made possible by economic protectionism. Democracy reduces the ability of rent-seeking oligarchic elites to protect their vested interests, allowing the population to reap the benefits of their economic efforts. Opening to trade may therefore restrict the economic power of the elites while democratizing erodes their political power. The starting point of our analysis is the idea that, in a positive perspective, improving institutions in one dimension, but not in the other, may create an unbalanced shift in economic and political power that materializes in vested interests and political resistance to technology adoption. A natural implication of this view is the existence of a complementarity between trade liberalization and democratization for incentives to adopt new technologies.

We study a general equilibrium occupational choice framework where the population is composed of a rentier elite and a majority of workers endowed with heterogenous skill levels. The model derives predictions on the impact of a shift to free trade or democracy on the demand for skilled biased technology adoption by different groups. Production takes place in two sectors: one traditional sector using manual labor and natural resources, the rents of which are extracted by the minority elite, and a modern manufacturing sector using skilled labor. Workers with heterogeneous skills optimally relocate between the two sectors with endogenously determined wages. The framework is used to characterize the preferences of the ruling political group regarding technology adoption in each trade and political regime.

The theory predicts that, starting from a closed autocracy, the elites may not benefit from the adoption of new technologies in the transition to an open economy as it reduces the rents they can extract. In turn, a process of democratization in autarky may trigger the emergence of vested interests against technological improvements by part of the newly politically enfranchised population since technology adoption in the modern sector results in a reduction in unskilled wages. Consequently, the model predicts that trade liberalization or democratization alone do not necessarily lead to an increase in the demand for technological improvements. A transition to an open democracy leads to an unambiguous increase in the demand for better technologies by part of all workers (skilled and unskilled) that are assumed to be politically pivotal in democracies. The model therefore predicts the existence of a positive complementarity between the trade and the political regime in creating demand for more productive technologies.

The role of the interaction between the trade and political regimes for the adoption of better technologies has not been empirically explored. The theoretical predictions are tested in reduced form using disaggregate measures of adoption at the level of single technologies using the CHAT database for 83 technologies in 104 countries over the period 1980-2000. As benchmark, we exploit within-country variation in panel regressions with country and time fixed effects, and add technology or technology×time fixed effects to deal with the highly unbalanced nature of the dataset. The baseline specification therefore investigates the effects of both regime changes separately and jointly by exploiting a difference-in-difference design. The explanatory variables of main interest are the timing of trade liberalization and the timing of democratization. This methodology essentially compares a country that liberalized (or democratized) in a certain year to countries that did not experience institutional changes in that year.

The results provide support to the widespread perception that trade openness and democracy both have positive effects on the level of technology when exploiting cross-country variation. When exploiting within country variation over time, the average (treatment) effect of either trade liberalization or democratization is generally statistically insignificant. Once the empirical specification is extended to the consideration of the predicted non-linear effects, the results reveal a large positive and highly statistically significant interaction between trade liberalization and democratization both across countries and within countries over time. In particular, countries going through both transitions experience significant improvements in productivity and technology adoption. The positive effect of a joint regime transition is persistent over time. The findings therefore reveal that the average effects of trade liberalization or democratization hide relevant heterogeneity and suggest that studying their role in linear regressions frameworks can be misleading.

Two main concerns have been raised in the literature on the effects of trade liberalization and democratization on macroeconomic outcomes at the country level (see Section 2). We follow the literature and address the issue of omitted variable bias by restricting attention to within country variation over time rather than cross-country variation. Period specific effects (e.g. technological waves), technology specific effects (differential patterns of adoption in different technologies) and period-technology specific effects (e.g. trends of adoption and dismissal in some specific technologies) are controlled for by including fixed effects on each of these dimensions. Another, generally more serious, concern is a potential reverse causality problem running from regime changes (trade liberalization or democratization) to aggregate economic conditions (e.g. income growth). These concerns have been addressed by running event studies analysis that exploit the randomness of the timing of the regime changes (rather than the randomness of the regime changes *per se*) in difference-in-difference designs and/or by exploiting the panel structure of the data. In our application, reverse causality should be less of a concern for two main reasons. First, the analysis investigates the changes in technology adoption at a highly disaggregated level (and not the change of a dependent variable at the country level like income levels), which also allows to account for specific period-technology dynamics. As argued in the literature, this limits by construction the likelihood of problems of reverse causality running from technology adoption in each single technology to the timing of regime changes at the country level. Second, a main empirical result of the paper is the existence of heterogeneous effects in the non-linear specifications. Reverse causality is unlikely to be the driving factor behind the heterogeneous effects of regime changes since there is no obvious reason why the statistical bias should vary across different samples of countries (that have already undergone a shift in the other regime).

To assess the robustness of the results, and to investigate the empirical relevance of some side predictions, we perform an extensive set of checks. The results are robust to controlling for relevant covariates such as income per capita and population, consistently emerge in different samples using annual data and 5-year intervals, and are robust with other (for instance continuous) measures of our independent variables. The results are qualitatively and quantitatively very stable when including initial conditions in each technology (thereby allowing for the convergence effect at the technology level). In addition, we measure technology adoption at the extensive margin to account for the introduction of different technologies in each country at different points of time, which also allows us to account for technology$\times$country fixed effect while retaining within country variation in the timing of adoption. Finally, we show in the Supplementary Material that the findings are not driven by a specific technology sector, and qualitatively hold when using manufacturing value added per worker as an alternative measure of technology adoption, when using leads as counterfactuals, or restricting attention to countries that only change one regime thereby iteratively ruling out reverse causality by construction in trade and political transitions.

The paper is organized as follows. Section 2 discusses the related theoretical and empirical literature. Section 3 presents the theoretical framework. Section 4 introduces the data, the estimation strategy and the empirical results while Section 5 concludes. The proofs and information on data sources are relegated to the Appendix. The full list of countries with the timing of regime changes, the summary statistics, the robustness checks and the further results are collected in the Supplementary Material.

2 Background Literature

The theoretical role of trade liberalization and democratization on the dynamics of technological change (and workers' productivity) have been studied, mainly independently, by trade and political economists. Wood (1995) was among the first to highlight the possible effects of trade openness on the "incentives" for (defensive) technology adoption. Thoenig and Verdier (2003) pointed out that firms that may have had little incentive to adopt prior to trade liberalization undertake skill-biased innovations or adopt existing technologies to face a more intense competition from international markets. Acemoglu (2003) argues that trade liberalization also increases the possibility to adopt superior technologies. He notices, however, that not all countries appear to have equally profited from this opportunity and highlights the need to investigate the incentives for endogenous technology adoption.

The role of political institutions, public policies and implementation of informal arrangements for technology adoption has been largely discussed both in political science and economic history. Olson (1982) and, in particular, Mokyr (1998) provide extensive discussions on how policies implemented by political rulers can be strategically designed to facilitate, or slow down, technological dynamics through non-competitive arrangements, transparency and efficiency of the bureaucracy, or the cost of market entry. Acemoglu, Aghion and Zilibotti (2006) endogenously relate the existence of barriers and alternative strategies that affect technology adoption to the distance to the technological frontier.

Following Melitz (2003) and Melitz and Ottaviano (2008), a number of recent contributions in international trade predict that aggregate industry productivity grows with trade liberalization through a selection effect, produced by the reallocation of resources towards more productive firms. This self-selection mechanism, which is supported by a large and increasing empirical evidence, can contribute to explain part of the losses faced by the autocratic elites should they concentrate their interests in relatively less efficient firms (or sectors of production).[1] In terms of differential role of political regimes, it has been argued that

[1] See also Melitz and Redding (2012) for a comprehensive overview. Aidt and Gassebner (2010) provide evidence that oligarchic rulers are more free to extract resources in countries protected by trade barriers by, e.g. exploiting trade taxes.

oligarchies raise more significant entry barriers against new entrepreneurs, whereas more diffused political power in democracies tends to dismantle such barriers making it easier for the population at large to take advantage of new technologies, see Acemoglu (2006).

We contribute to the theoretical literature by providing an investigation of the preferences of the group in power on policies that facilitate or block the adoption of new technologies under different trade regimes. To this end we set up a theoretical framework where workers with heterogeneous productivity self-select into different sectors. The theory builds on Yeaple (2005), and extends it to two sectors, a skill-intensive (modern) and an unskilled (traditional) sector, to study wage differentials in general equilibrium. Along the lines of Galor and Moav (2000) we consider ability-biased technological progress that generates different changes in wage inequality both within and between the skilled and unskilled workers.

Technology adoption depends on the interaction between trade and political regimes. The paper contributes to recent literature that highlights the crucial role of political institutions in determining the impact of trade openness on aggregate outcomes in terms of *economic institutions*. The theoretical argument parallels, and complements, the one proposed by Falkinger and Grossman (2005) on public investment in education. Other works, like Segura-Cayuela (2006), Do and Levchenko (2009) and Stefanadis (2010) have investigated the role of interactions between trade and political regimes for redistributive policies, contract enforcement and property rights protection, respectively.

When exploiting cross-crounty variation in trade or political regimes the typical finding is a positive effect of these institutional changes on income (or income growth).[2] Acemoglu et al. (2008) note that the results may be driven by omitted country specific characteristics and show that the cross-country correlation between income and democracy completely disappears once country (and time) fixed effects are included. Subsequent work by Murtin and Wacziarg (2014) and Cervellati et al. (2014) qualify their findings, however, showing that the effect depends on the time horizon of the analysis and sample composition. Two further problems are related to the conceptualization and measurement of trade openness and democracy and the lack of exogenous (worldwide) variation in these regime changes. The problems have been recently addressed by a careful coding of the regime changes that have been used to identify the effects of trade liberalization and democratization by exploiting the heterogeneous timing of the transitions in difference-in-difference frameworks. Most notable, Rodrik and Wacziarg (2005), Papaioannou and Siouraounis (2008), and Persson

[2]There is a vast literature studying the determinants of income growth at the cross-country level. Przeworksi and Limongi (1993), Barro (1996), Tavares and Wacziarg (2001) and Persson (2004) study the effect of democracy, while Greenaway, Morgan, and Wright (2002), Dollar and Kraay (2003), Edwards (2008) focus on the effect of trade liberalization.

and Tabellini (2009) demonstrate a positive and significant causal effect of democratization on income growth, while Slaughter (2001) shows a positive effect of trade liberalization on per capita income convergence across countries.[3] Giavazzi and Tabellini (2005) extend the scope of the analysis to explore the dynamic feedbacks between economic and political liberalization for investment and income growth. Their findings suggest that studying the effects of each reform separately can be misleading.

The existence of an interaction between trade liberalization and democratization for technology adoption at a disaggregate level has not been investigated in the empirical literature.[4] Limited data availability has until recently prevented the possibility of addressing this empirical question. Comin and Hobijn (2004) collected data for the pre and post WWII era across 25 major technologies in 23 countries over a period of 200 years and document that openness to trade increases the speed at which countries adopt technologies.[5] The cross-country panel data on technology adoption at a disaggregate level that has recently been made available (in the CHAT database) by Comin and Hobijn (2009a) for over one hundred technologies in more than 150 countries is best suited for our purposes.[6] The interaction between changes in trade and political regimes are investigated, accounting for country specific unobserved heterogeneity and waves of technological change using a difference-in-difference framework with country and time fixed effects.[7] As benchmark we use the data on trade openness from Wacziarg and Welch (2008) and the data on democratization from the Polity IV database. The empirical strategy exploits variation over time within the different technologies by accounting for country specific unobserved heterogeneity and common time effects.

[3]Aghion, Alesina and Trebbi (2008) show that democracy fosters value added per worker in the more advanced sectors of an economy by reducing the protection of vested interests and granting freedom of entry into markets.

[4]To the best of our knowledge, the view of an unconditionally positive role of openness and democracy across countries was not documented (using for instance data on technology adoption), but was rather indirectly inferred from the fact that, everything else equal, open economies and democratic countries tend to be richer than closed economies and autocracies.

[5]Comin and Hobijn (2009b) and Comin, Dmitriev and Rossi-Hansberg (2012) also highlight the role of political economy and trade on technology adoption by showing how lobbies and geographical distance slow down technology diffusion.

[6]Comin and Mestieri (2010) explore the intensive margin of technology adoption further by filtering out the effect of aggregate demand on technology adoption.

[7]The panel structure also allows to perform counterfactual exercises using the leads and lags of the changes. Some of the works discussed above have also applied GMM estimators to identify the role of institutional changes exploiting long periods of time with low frequency data (e.g. at 5, 10 or 25 years intervals). We also use System GMM estimates as a robustness check with the panel data on manufacturing productivity, where the balanced nature of the data allows the use of the technique.

3 Theoretical Analysis

3.1 Set-Up

Preferences and Production. Consider an economy, where individuals have preferences over a manufacturing good X and a traditional good Z,

$$u = x^{\beta} z^{1-\beta}, \tag{1}$$

where x and z are the individual consumption of goods X and Z. We set the price of good Z to unity as numeraire and denote by p the (relative) price of the manufacturing good.

There are two factors of production: Labor, denoted by L and a fix factor of production, N, that stands for, e.g., land or natural resources. The population is divided into two groups: a unit mass of workers, who are endowed with a skill level θ distributed according to a cumulative distribution function $G(\theta)$ with density $g(\theta)$ where $\theta \in [1, \infty]$, and a smaller (minority) group of size $\sigma < 1$ referred to as the "elite" who do not supply labor, but are the residual claimants of the income produced in the economy net of the remuneration of workers.[8] As discussed below, we assume that only the elite have political power to enforce policies in autocracies, whereas policy choices reflect the preferences of the majority of the population (composed by workers) in democracies. In the context of technology adoption, this implies assuming that related policy decisions in the two regimes are made by the elite and by workers, respectively.

Production of the two goods takes place in two perfectly competitive sectors: (i) a resource-based traditional sector, which uses manual labor, L, and N to produce good Z; (ii) a productivity-based manufacturing (modern) sector, which uses skilled labor to produce good X. Workers can freely supply their labor to any of the two sectors.

The good Z is produced using an aggregate production function with constant return to scale,

$$Z(L, N) = L^{\eta} N^{1-\eta}. \tag{2}$$

The effective labor supplied by any individual working in the Z sector is independent from his skill level θ and is normalized to 1. On the contrary, the amount of effective labor supplied in sector X depends on the skill level θ and is equal to $l(\theta, A) = \theta^{A}$, where $A \in [1, \overline{A}]$ represents the productivity of available technologies and $1 < \overline{A} < \infty$ is an exogenously given world technology frontier. Production in sector X is given by the total number of goods produced

[8]That the elite do not supply labor is only for simplicity. The results only require that these individuals are able to extract resources on top of the returns from supplying labor.

by all workers employed in that sector,

$$X\left(G\left(\theta\right),A\right)=\int_{\theta}l\left(\theta,A\right)dG\left(\theta\right), \tag{3}$$

and depends both on the amount of workers in the sector and on their productivity.[9]

Factor Income. Denote by y the individual factor income. For a given price of the manufacturing good p, an individual supplying $l\left(\theta,A\right)$ units of effective labor to the X sector earns,

$$y_X=\theta^A p. \tag{4}$$

The wage earned by a worker in the Z sector equals his marginal productivity and is independent from his skill level, as no skills are used in the production of the traditional good. The individual factor income of a worker in the traditional sector is therefore given by,[10]

$$y_Z=w\left(L,N\right)=\frac{\partial Z\left(L,N\right)}{\partial L}. \tag{5}$$

The elite are the residual claimants of the production in the traditional sector, that is, they appropriate (and distribute evenly among their group of size σ) all income produced in that sector net of the wages paid to workers,

$$y_E=[Z(L,N)-w(L,N)L](1/\sigma). \tag{6}$$

Notice that since the production function (2) is constant returns to scale, this is equivalent to assuming that the elite control all rents accruing to the natural resources N. For our purposes we do not need to specify the means by which the (oligarchic) elite extract resources in the traditional sector. Empirically, the economic and political ruling groups in developing economies extract rents by various means including the control and ownership of natural resources (like oil or land) which are priced on regulated markets, by controlling the state apparatus (which involves public patronage, corruption, fiscal transfers and directed benefits), or by controlling the state monopolies, to name some.[11]

Two main features of the model drive the theoretical predictions. The first is that more advanced sectors of production are skill (or human capital) intensive and better able to absorb technological improvements, while traditional sectors rely more on the use of less skilled labor. The second is that the economic interests of the (oligarchic) elites in terms of extractable rents predominantly rely on the returns produced with a relative higher intensity

[9] This modeling of the production function of the manufacturing sector essentially follows Yeaple (2005).
[10] Recall that the price of the Z good is normalized to one.
[11] See Acemoglu (2006) for an extensive discussion of these issues.

of low skills and natural resources rather than human capital. This set-up aims at modeling these two features in the simplest way.[12]

Trade and Political Regimes. We consider a dichotomous representation of the trade regime. The economy can either be closed (in autarky) with no possibility to trade, or open, where all goods can be traded at zero cost.[13] In autarky the entire demand must be covered through internal production and the relative price, p, may differ from the one prevailing in international markets, p^*. In an open economy the internal demand is unrelated to internal production and domestic relative price coincides with the world relative price: $p = p^*$.

We consider two extreme political regimes. In an autocracy, the elite control the state and extract all rents (net of wages) produced in the traditional sector. Only the elite are politically represented since they are the only ones allowed, *de jure*, to vote (due to the existence of constraints on the political franchise) or can *de facto* control public policies by influencing or controlling elections and thereby setting policies in their own self-interest. In a democratic regime all individuals can vote and policies mirror the preferences of the majority of the population which, by assumption, is made up by workers.[14] The key assumption is that a process of democratization reduces the ability of the elite to defend their economic interest by exploiting their political power.

3.2 Equilibrium

Labor market equilibrium. Individuals face the choice between working in the Z sector supplying one unit of (unskilled) labor, or in the X sector supplying their individual skill that amounts to θ.

Workers take earnings, prices of goods and the technology of production as given when making optimal choices, which essentially amounts to comparing the expected income that can be earned in each sector, (4) and (5), given their individual skill level θ. A worker with

[12]For instance, the assumption that an increase in A only affects the production of good X is only to simplify illustration. The results only require that productivity in the modern sector is relatively more elastic to technological improvements than in the traditional sector.

[13]This representation is in line with the use of dichotomous measures of openness that, following the empirical literature, is exploited in the empirical Section 4.

[14]As discussed in the Section 4, in line with literature the empirical coding of the political regime is also dichotomous and makes use of information on the extension of the political franchise (whether it is restricted or universal), the presence of free and contested elections, and by considering the extent of substantive political and civil liberties (which are measured by the Freedom House and the Polity Projects).

productivity $\underline{\theta}$ is indifferent between working in either sector if, and only if,

$$\underline{\theta}^A p = w\left(L, N\right). \tag{7}$$

Alternatively, any worker with strictly higher skills, $\theta > \underline{\theta}$, optimally chooses to work in the X sector because from (7) we have,

$$\theta^A p = (\theta/\underline{\theta})^A w(L, N) > w(L, N),$$

where $(\theta/\underline{\theta})^A$ is the wage premium enjoyed by a worker with skills θ given A. Any worker with $\theta < \underline{\theta}$ optimally chooses to work in the traditional sector and earns $w(L, N)$.

The equilibrium in an open economy only requires that the labor market is in equilibrium because the prices of goods are unaffected by the allocation of labor across sectors (as free trade implies convergence of relative prices to the international levels) and total consumption of each good does not need to be equal to its total production. Hence, we have,

Lemma 1 [Equilibrium in an Open Economy] *For any $\{A, G\left(\theta\right), N\}$, in an open economy there exists a unique threshold level of skills, which is denoted by $\underline{\theta}^o(A)$ and characterized by (7) evaluated at $p = p^*$, for which the economy is in equilibrium.*[15]

Product market equilibrium. In a closed economy, the production of each good must equal its total demand. The characterization of the macroeconomic equilibrium therefore requires that both the labor and the product markets clear.

Given the utility function (1), the demand (in terms of aggregate expenditure) of each good is proportional to nominal income. Since in a closed economy the aggregate demand of each good must equal its total production we have that product market clears if, and only if,

$$(1 - \beta) p X(G(\theta), A) = \beta Z(L, N). \tag{8}$$

The economy is in equilibrium if the product and the labor markets both clear, that is, when (7) and (8) jointly hold. Given the production functions (2) and (3), this is the case if, and only if,

$$\beta G(\underline{\theta}) \underline{\theta}^A = \eta (1 - \beta) \int_{\underline{\theta}}^{\infty} \theta^A dG(\theta). \tag{9}$$

We therefore have,

[15] The analysis and the results can be extended to a set up with multiple manufacturing sectors, as in Yeaple (2005), each characterized by a different A. In particular, it would remain true that the most productive workers will employ the most productive technologies with the only difference that the equilibrium would involve multiple (and not a unique) thresholds for θ.

Lemma 2 [Equilibrium in a Closed Economy] *For any $\{A, G(\theta), N\}$, in a closed economy there exists a unique threshold level of skills denoted by $\underline{\theta}^c(A)$ for which (9) holds so that both the product and the labor markets are in equilibrium.*

Proof: See Appendix.

3.3 The Effects of Technological Improvements

To characterize the conflict of interests regarding technological improvements across different groups, consider the possibility of a costless increase in the productivity of (skilled) labor in the modern sector, A. This can be interpreted, for instance, to be a consequence of the adoption of a new technology that allows a country to advance towards the world technological frontier. It can also come from a policy aimed at attracting better technologies through FDI, investing in R&D, or the reduction of barriers to entry in modern business through better property rights protection, etc. The assumption that technological improvement is costless allows to focus on the conflicts of interest regarding its economic consequences by abstracting from redistributive issues related to the financing of these policies.[16]

Let us consider first the effect of a rise in productivity, A, in a closed economy:

Lemma 3 [Technological Improvements in a Closed Economy] *In a closed economy, a marginal increase in A increases the equilibrium threshold skill level of the indifferent worker, denoted by $\underline{\theta}^c(A)$ (thereby decreasing the share of workers in sector X). The total production of both sectors X and Z increases, the relative price of the manufacturing goods, p, decreases and*

(i) wages in the traditional sector, w, decrease,

(ii) the skill premium of workers in the manufacturing sector, $(\theta/\underline{\theta}^c)^A$, increases only for workers with $\theta > \overline{\theta}(A) > \underline{\theta}^c(A)$ so that in the X sector only workers with a high enough skill level can experience an increase in nominal earnings, $w(L(\underline{\theta}^c), N)(\theta/\underline{\theta}^c)^A$.

Proof: See Appendix.

[16] Empirically one can only explore the sign, or equivalently the direction, of changes in technology adoption in response to regime changes and not an optimal level of technology. To simplify the derivation of the prediction on the direction of the change we have limited our analysis to the consideration of a costless (marginal) change in A. As discussed in the proofs of Lemmas 3 and 4 in the Appendix, the impact of A on the rents of the elite and unskilled wages is nevertheless monotonic in the current framework which naturally leads to corner solutions in adoption at the intensive margin. The characterization of optimal interior values of A would therefore require extending the model to the explicit consideration of positive, and increasing, costs of adoption.

In a closed economy, improvements in productivity in the X sector lead to a shift of workers away from this sector. The seemingly counter-intuitive effect is due to the fact that in a closed economy the internal demand and supply of each good must equalize in general equilibrium. A higher A expands the economy's production possibility frontier thereby increasing total income, so that the equilibrium demand and the production of all goods increase. Since the larger demand can only be satisfied by domestic production, it requires more workers in the traditional sector (that does not experience an increase in productivity). The larger demand for X is satisfied by an increase in production using fewer, but more productive, workers. Notice that this is not influenced by the shape of the utility function and continue to hold under a CES utility with elasticity greater than one.

As labor becomes more abundant, the equilibrium wage in the traditional sector, w, is reduced. An increase in the threshold $\underline{\theta}^c$ also reduces the skill premium of the least skilled workers in the manufacturing sector.[17] Only workers with sufficiently high skills $\theta > \overline{\theta}(A)$ can experience a strict net gain in their skill premium from technology adoption. These predictions are along the lines of Galor and Moav (2000), who show that ability-biased technological transition leads to an increase in wage inequality both within the skilled and between the skilled and unskilled workers. More productive technologies therefore increase competition between workers in a closed economy and force the less skilled worker to accept a reduction in their baseline wage. As a result, rents extracted by the elite from the traditional sector increase at the expense of the lower wages of the less skilled workers.

Next, let us summarize the effect of increasing productivity in an open economy:

Lemma 4 [Technology Adoption in an Open Economy] *In an open economy, a marginal increase in A decreases the equilibrium threshold skill level of the indifferent worker, $\underline{\theta}^o(A)$ (thereby increasing the share of workers in sector X). The production of X increases, while that of Z decreases. Prices remain unchanged at $p = p^*$ and*
(i) wages in the traditional sector, w, increase,
(ii) the skill premium of all workers in the manufacturing sector, $(\theta/\underline{\theta}^o)^A$, and hence their nominal earnings, $w(L(\underline{\theta}^o), N)(\theta/\underline{\theta}^o)^A$, increase.

Proof: See Appendix.

In an open economy, an improvement in the productivity of the modern sector attracts more workers thereby increasing the production of X. Local production of the traditional good decreases and the larger demand is met by imports. In the traditional sector, where labor gets more scarce and marginally more productive, the indifference wage required by

[17] A higher $\underline{\theta}(A)$ implies that the indifferent worker in X is more skilled than the indifferent worker prior to technology adoption, yet accepts a strictly lower wage in equilibrium.

workers increases. Once the economy has liberalized to trade, a rise in productivity, A, therefore increases the skill premium both directly (for any skill level) and by reducing the minimum skill level $\underline{\theta}^o$ required to work in that sector. Consequently, in an open economy the adoption of a better technology reduces the rents that the elite can extract.

3.4 The Effect of Trade Liberalization and/or Democratization on the incentives for Technology Adoption.

The ultimate goal of the analysis is to study the change in incentives for technological improvements (an increase in A) in response to a change in the trade and/or the political regime. To this end, we next characterize who gains and who looses from the adoption of a new technology that results in a higher A under each trade regime. We then relate the adoption decision to the preferences of the group in power under each political regime.

In this set-up with homothetic preferences, the equilibrium individual levels of consumption for each good, denoted by $x(A)$ and $z(A)$, are proportional to individual income. This implies that, as derived in the Appendix, the indirect utility of each individual is given by,

$$u(x(A), z(A)) = \widetilde{\beta} \frac{y(A)}{p(A)^{\beta}}, \tag{10}$$

where $\widetilde{\beta} \equiv \beta^{\beta} (1-\beta)^{1-\beta}$ and $y(A)$ and $p(A)$ denote the equilibrium individual income and relative price for any given A. The individual indirect utility (10) therefore increases with the nominal income and decreases with the price, $p(A)$. The effects of increasing productivity A on the income of different individuals and prices in closed and open economies are studied in Lemmas 3 and 4.

Consider an economy initially characterized by an autarkic trade regime and ruled by the autocratic elite, that is, a closed autocracy. As discussed in more details in Section 4, empirically no country has experienced a contemporaneous change in both trade and political regime during the observation period 1980-2000. The historical transitions from closed autocracies to open democracies has therefore always involved as intermediate step: either a transition to an open autocracy or a transition to a closed democracy. Accordingly, we investigate the change in the incentives for technology adoption after trade liberalization, after democratization, and after a (long-run) transition that involves both.

Let us first study how the incentives of the ruling autocratic elites towards technological improvements change in the face of opening to trade. From Lemma 3, in a closed economy a larger A leads to a reduction in the price p, which increases the indirect utility of all individuals in the economy by making manufacturing goods cheaper. The oligarchic elites, who are the residual claimants of the production in the traditional sector, gain from the reduction in baseline wages, w, which is associated with a higher skill premium in the manufacturing sector and tougher competition facing the less skilled workers. Both effects unambiguously increase the real income and, therefore, the indirect utility of the autocratic elites. In an open economy, technology adoption does not deliver advantages in terms of relative prices (since they are set in international markets). Also from Lemma 4, the autocratic elites face a reduction in their ability to reap the benefits of more productive technologies in an open economy since wages increase following the shift of workers towards the manufacturing sector. They are therefore worse off if productivity A increases.

Opening the economy increases the vested interests of the autocratic elites. Said the other way around, a process of trade liberalization alone is therefore expected to reduce the incentives for technological improvements by part of the ruling oligarchic elites.

Proposition 1 [Trade Liberalization] *For any $\{A, G(\theta), N\}$, in a closed autocracy the incentives of the ruling elite for fostering technological improvements are reduced after opening to trade.*

Proof: See Appendix.

Consider now the effect of a process of democratization of a closed autocracy. By assumption the political power to implement (technology adoption) policies shifts from the elite to workers. A rise in the political representation of workers reduces the political ability of the (former) autocratic elites to defend their economic interests. However, in view of Lemma 3 technology adoption can have different effects on the well-being of different workers. Although for different reasons than those for the (former) oligarchic elites, the more skilled workers of the manufacturing sector unambiguously gain from higher productivity (their wage increases and they enjoy lower prices). A transition to democracy should therefore leave incentives for technological improvements essentially unchanged if these workers become political pivotal (if they are, for instance, the new median voter). In turn, the workers in the traditional sector and the less skilled in the manufacturing sector enjoy a net gain only if the reduction in equilibrium prices more than offsets the reduction in their wages. If this is not the case and the less skilled workers outnumber the highly skilled workers then the process of democratization may even lead to a reduction in the demand for adoption of new technologies and, accordingly, for the incentives to facilitate improvements in this dimension.[18]

[18] This appears the most likely scenario in less developed countries, where the low income workers tend to be politically pivotal, see Tavares (2008).

Depending on the actual gains or losses of workers with lower skills in terms of their real wages and their political power in democracy, we should therefore expect a process of democratization in a closed economy to either have no effect or a negative effect on the incentives to promote technological improvements.[19]

Proposition 2 [Democratization] *Consider a closed autocracy. For any* $\{A, G(\theta), N\}$*, transferring political power from the elite to workers, e.g. a process of democratization, either leaves incentives for fostering technological improvements unchanged or reduces them.*

Proof: See Appendix.

Finally, from Lemma 4, technological improvements unambiguously benefit all workers in an open economy. Experiencing a transition to an open democracy raises incentives to adopt new technologies. In view of Proposition 2, the increase in such incentives is smaller (or absent) if trade liberalization takes place in a country that has already experienced a transition to a democracy, where the highly skilled workers benefitting from a larger A are politically pivotal.

Proposition 3 [Trade Liberalization and Democratization] *Consider a transition to an open democracy. For any* $\{A, G(\theta), N\}$*, the incentives of the ruling political group for fostering technological improvements*
i) strictly increase after democratization of an open autocracy,
ii) increase, or are left unchanged, after trade liberalization in a closed democracy.

Proof: See Appendix.

The joint consideration of Propositions 1, 2 and 3 also implies that the total effect of moving from a closed autocracy to an open democracy is theoretically ambiguous as it also depends on the potential slowdown in technology adoption during the first transition. Recall that there are two phases to the transition. From Propositions 1 and 2 that the first step of the transition (towards openness or democracy) either leaves unchanged or negatively affects the incentives for technology adoption. From Proposition 3, the second phase of the transition is positively related to technology adoption.

Before turning to the empirical evidence some remarks are in order. To derive testable implications for the interaction between regimes and technological dynamics, the theory studied the effect of technology adoption on the utility of the different individuals. As discussed also in Section 2 above, the literature has studied several public policies and

[19] If technological progress is not skill-biased, it always leads to higher real wages for all workers and democratization would always leave the incentives (by the people) to foster technology improvements unchanged.

interventions used by the political rulers to defend their interests and, in particular, affect technology adoption. To the extent to which technological dynamics are endogenous to individual and political choices, the previous Propositions characterize the incentives for the different individuals, and for group in power (the autocratic elite in an oligarchy and the workers in a democracy) to facilitate or slow down the dynamics of technology adoption conditional on the trade-regime.

The predictions were derived considering exogenous changes in either the political and/or the trade-regime, which may also be subject to deliberate shifts. However, it is important to notice that the theoretical prediction of the differential incentives for technology adoption holds irrespective of the actual reasons behind the change in the political and trade regimes. The primary goal of the empirical analysis is therefore to explore the novel predictions of a significant complementarity between changes in political and trade regimes for technology adoption. Although the proposed theory does not allow clear-cut conclusions for endogenous regime changes that may follow (or aim at) technology adoption, the question on the role of technological dynamics for endogenous democratization and opening to trade remains interesting and empirically relevant.[20] Accordingly, to address this question we will perform specific tests that can be used to investigate whether the emerging heterogeneous effect is likely to be imputed to reverse causality running from technology adoption to a joint process of democratization and trade liberalization.

4 Empirical Evidence

The theoretical framework delivers several testable predictions. Propositions 1, 2 and 3 characterize changes in the demand and incentives for the adoption of new technologies after trade liberalization or/and democratization. The theory predicts, in particular, a complementarity between trade and political regimes. In the model, and in the data, the joint transition in both regimes therefore represents the long-run situation resulting from two consecutive transitions over time.

In this section, we investigate the empirical relevance of the theoretical insights and conduct a series of sensitivity exercises to explore the robustness of the baseline findings. To devise an estimation strategy let us recall that the theory does not deliver any prediction on the level of technology in closed and open countries or in autocracies and democracies, but

[20] In view of the model presented above we should not expect technological dynamics to be a main driver of either regime change. The autocrats are not enticed to extend the franchise, which would at any rate not affect (or even dissuade) technology adoption on part of the new ruler, and do not have any long run gains from opening to trade since this would impair their incentives for technology adoption.

on the changed incentives for technology adoption in response to changes in regimes. A test of the predictions therefore requires exploiting variation in regimes and technology *within* countries over time rather than across countries at each point of time.

4.1 Data

We investigate the effect of trade liberalization and democratization for technology adoption in the period 1980 to 2000, which encompasses most of the third wave of democratization and many episodes of trade liberalization. The baseline indicator for trade liberalization is from Wacziarg and Welch (2008), which update the Sachs and Warner (1995) openness indicators and trade liberalization dates. The liberalization date is the year after which the Sachs and Warner's openness indicators are met.[21] It takes the value of one at the starting date indicated by Wacziarg and Welch (2008), and zero otherwise. This coding involves permanent trade regime changes. As baseline information for democratization we use data on political regimes from the Polity IV database. As benchmark, we use the coding of democratization by Papaioannou and Siourounis (2008), which further imposes a stability conditions thereby restricting attention to the subset of permanent democratic transitions.[22]

In line with the theory, and following the empirical literature discussed in Section 2, we consider a dichotomic representation of the trade and the political regimes as baseline.[23] The use of a binary coding also allows to implement some empirical specifications as difference-in-difference(-in-difference) and to limit the typical problems associated with the use of slow moving variables in panel regressions with country and time fixed effects. For robustness, we also use continuous measures of both democracy and trade openness. The full list of the countries in the sample including the dates of change of their trade and political regimes and the list of countries in the different bins of trade and political regimes are reported in the Supplementary Material.

In the absence of direct measures, the early empirical literature has focused on the Solow residual as proxy for factor productivity. A main limitation of this strategy is that this mea-

[21] According to Sachs and Warner, a country is defined as being opened if none of the following criteria is met: (i) average tariffs exceed 40 percent, (ii) non-tariff barriers cover more than 40 percent of trade (iii) it has a socialist economic system (iv) the black market premium on the exchange rate exceeds 20 percent, or (v) there is a state monopoly on major exports. The trade liberalization variable is dichotomous.

[22] The polity variable measures the quality of democratic institution and varies from +10 (strongly democratic) to -10 (strongly autocratic). To check the robustness of the results we also alternative coding of political regimes, such as Golder (2005).

[23] The conceptualization of trade openness and democracy as dichotomic follows a large empirical literature, see Munck and Verkuilen (2002), Przeworski et al. (2000), and Wacziarg and Welch (2008).

sure captures (by construction) also the effect of all other factors beyond technology adoption such as, e.g., the variation of capacity utilization, labor hoarding, and the inefficiencies of the economy related to formal and informal institutions. The best available information on technological dynamics within countries overtime is the level of adoption at the level of single technologies that is available from the Cross-Country Historical Adoption of Technology, CHAT, dataset, assembled by Comin and Hobijn (2009a). For the period 1980-2000, we exploit a baseline sample that contains data on the adoption of 83 technologies for 104 developed and developing countries. The data provides information on the number of units of capital embodying a given technology or goods produced using it present in a given economy, and it is available for a wide range of technologies, countries and years.[24]

4.2 Empirical Specification

Testing the predictions requires estimating the effect of changes in either the trade or the political regime, or both. The baseline explanatory variables of interest are $Open_{jt}$, a dummy variable that takes the value of one in the years after opening to trade and zero otherwise, and $Demo_{jt}$, which takes the value of one once the country has democratized and zero otherwise. To study how the possible complementarities between the trade and the political regimes affect adoption, we consider the interaction between the two variables, $Open_{jt} \times Demo_{jt}$.

The empirical strategy exploits information on changes in trade and political regimes within countries overtime (rather than the mere status of openness and democracy at each point of time). We use information on technology adoption at the disaggregate level from the CHAT database and estimate the model,

$$\begin{aligned} ln\left(TechA_{ijt}\right) &= \beta_0 + \beta_1 Open_{jt_{-1}} + \beta_2 Demo_{jt_{-1}} + \beta_3 \left(Open_{jt_{-1}} \times Demo_{jt_{-1}}\right) \\ &+ \beta_4 X_{jt} + \Phi_{ijt} + \varepsilon_{ijt}. \end{aligned} \tag{11}$$

where X_{jt} denotes time varying country-level covariates and ε_{ijt} is a technology, country and time specific error term. The standard errors allow for clustering at the country-level to account for heteroskedasticity and non-independence across the repeated observations within countries.[25]

The empirical model (11), encompasses (and will be specialized to investigate) different panel data specifications. The vector Φ_{ijt} generically indicates the possible inclusion of

[24] For robustness checks we also use information on country level labor productivity from Mayer, Paillacar and Zignago (2008) that still offers only an indirect measure of technology adoption at country level.

[25] This level of clustering is chosen as benchmark since the information on trade and political regimes is at the country level. For robustness we have nonetheless also considered clustering of the errors at the technology-country level and at the technology level.

different types of fixed effects at the level of technology i, country j and time t (and possibly their interactions). As baseline we consider dichotomous codings of both openness and democracy (and their interaction) with two ways fixed effects, $\Phi_{ijt} = \phi_j + \phi_t$. The inclusion of country fixed effects, ϕ_j, accounts for time invariant country specific characteristics that may jointly affect both the technology level, the trade and the political regime, and omitted variables such as geography or social norms that may differently affect technology adoption in different countries. The inclusion of common time fixed effects, ϕ_t allows to account for global waves in technological adoption. This specification is the typical difference-in-difference model, henceforth d-i-d, used in the literature discussed above.

The CHAT database is highly unbalanced in nature and the different technologies are measured in different units. To account for these features, an extended specification also includes technology fixed effects ϕ_i so that $\Phi_{ijt} = \phi_i + \phi_j + \phi_t$. Following Comin and Hobjin (2009b), we also use technology×time fixed effects denoted by ϕ_{it} (rather than technology and time fixed effects separately) to account more flexibly for the possibility that different technologies follow different adoption paths over time, so that $\Phi_{ijt} = \phi_j + \phi_{it}$.[26] Finally, we explore a specification that includes technology×country fixed effects, ϕ_{ij} to account for country specificities that can favor/disfavor the adoption of specific technologies so that: $\Phi_{ijt} = \phi_{ij} + \phi_t$.[27]

4.3 Baseline Results

Preliminaries. As preliminary analysis we explore the role of different trade and political regimes, rather than their changes, for the levels of technology in Pooled OLS regressions. The results are presented in Table 1.

Column (1) documents a larger level of technology adoption in open economies than in closed economies while Column (2) shows a similar differential between democracies as compared to autocracies. These patterns are in line with the common wisdom that more open or more democratic economies, taken alone, are characterized with higher technology adoption. Column (3) confirms these findings by including information on both trade and political regimes. The empirical specification is extended, in column (4), to the inclusion of

[26]For many technologies the data reports information on the number of capital goods per capita (like, e.g. the number of computers per capita). For some technologies the information refers to the output produced (e.g. the amount of steel produced in electric arc furnaces), while for some the information is about the technology level of diffusion (e.g. the number of credit and debit card transactions per capita). We refer to Comin and Hobjin (2009a) for an exhaustive description of the data.

[27]This specification is highly demanding and requires a balanced panel. To this end we will explore technological dynamics in a fully balanced panel.

Table 1: Preliminaries - Pooled OLS (Dependent variable, $\ln(TechA_{ijt})$)

Dep. Variable	Technology Adoption - CHAT Data			
	(1)	(2)	(3)	(4)
Openness	1.247^a		0.781^a	0.533
	(5.447)		(3.352)	(1.545)
Democracy		1.322^a	0.890^a	0.727^b
		(5.944)	(3.914)	(2.320)
Open×Demo				0.388
				(0.863)
Country FE	No	No	No	No
Year FE	No	No	No	No
Observations	56,959	56,959	56,959	56,959
Countries	129	129	129	129
Adjusted R^2	0.0114	0.0122	0.0153	0.0155

Dependent variable, $\ln(TechA_{ijt})$, is the adoption of technology i in country j in year t. OLS estimates with robust standard errors adjusted for clustering by country. Student ts are in parentheses. ^{a}, ^{b} , ^{c} significantly different from 0 at 1%, 5% and 10% level, respectively.

the interaction between the trade and the political regimes to check whether there is any significant interplay between these regimes and technology.

To interpret the results recall that the base category is the set of closed autocracies. This implies that, for instance, the estimate of the variable 'democracy' in column (4) compares the level of available (adopted) technology between closed autocracies and closed democracies, while the coefficient of the variable 'openness' reflect the difference between closed and open autocracies. The results suggest that the technology in open autocracies does not significantly differ from closed autocracies. Closed democracies are technologically more advanced than closed autocracies and open democracies are the countries with the highest level of technology.[28]

Technology Adoption Within Countries Overtime (Yearly Frequencies). The results of the pooled OLS regressions do not represent, strictly speaking, a test of the hypothesis. The theoretical model provides testable predictions on the effect of *changes* in the trade and/or the political regime on the incentives to adopt new technologies rather than on different levels of technology under different regimes. We next investigate the role of changes in regimes within countries over time estimating the empirical model (11) at yearly frequencies.

The results of the within estimates need to be interpreted with reference to the omitted

[28] Adding the three coefficients we find that the level of technology is 165% larger in open democracies as compared to closed autocracies (significant at 1%).

category that (as in a standard difference-in-difference framework) is the set of countries that do not change the respective (trade or/and political) regime at each point in time. To isolate the role of regime changes, like for instance the effect of a *transition* to democracy, the d-i-d literature typically evaluated the effect with respect to all countries that do not democratize at each point in time including both those that remain autocracies and those that are already (and always) democracies. Similarly, the mere effect of opening to trade can be studied using a reference group including both countries that do not open to trade and countries that are already open.

Estimating the effect of a transition from autocracy to democracy, rather than the effect of democratization in itself, requires dropping from the reference (omitted category) all countries that are already democracies at the beginning of the observation period. Similarly countries that are always open must be excluded from the omitted category if one wants to estimate the effect of a transition from closed to open economies (rather than the effect of opening up to trade *per se*). As baseline we therefore focus the analysis on the sub-samples of countries either start closed or autocratic, or both. This allows to explore the effect of each regime change and the predicted complementarity between regimes and to interpret the effect of passing from each (trade-political) regime bin to another and of the magnitude of the total effect (of moving from a close-autocracy to an open-democracy).[29]

The descriptive statistics and the correlation tables of the baseline sample are presented in the Appendix. The within correlations between democracy and openness is about 0.05, between democracy and the interaction is 0.36 and between openness and the interaction, is around 0.7.[30]

Table 2 reports the results. Columns (1) and (2) present the d-i-d effects of opening to trade and democratization. The effect of each regime change on technology adoption is, respectively, positive and negative but generally statistically insignificant at conventional

[29] This amounts at excluding from the omitted category the countries that are open-democracies since the beginning of the sample period. Compared to the full sample of 129 countries this involves restricting attention to 104 countries. We have replicated all the analysis in the full sample (thereby including also open-democracies in the reference category). The qualitative results, and in particular the existence of complementarity between trade and political regimes, consistently emerge but the interpretation of the effect of each single transition and the evaluation of the total effect is more difficult to interpret in that case.

[30] The Appendix also reports to the variance inflation factor of the baseline within specifications, VIF, calculated for each variable by doing a linear regression of that variable on all the other variables, and then obtaining the R^2 from that regression (the VIF is computed as $1/(1-R^2)$). A VIF exceeding 10, which usually happens when R^2 exceeds 0.90, it is typically taken as a sign of severe multi-collinearity. For the baseline model the VIF test yields a value of 1.93 that is suggestive that multi-collinearity is unlikely to be a concern (Hill and Adkins, 2007).

levels. Column (3) confirms the patterns when accounting for both transitions. According to the theory, however, the average effect of each transition should be expected to conceal important heterogenous effects and, in particular, a complementarity between both regimes. To test this prediction, Column (4) includes the interaction effect between the two regimes by estimating empirical model (11) that nests the specifications of columns (1) to (3) as special cases. The results reject the null hypothesis of an insignificant interaction $\beta_3 = 0$ in the empirical model (11), and document the existence of a positive, large and highly significant effect of the interaction between openness and democracy.

Table 2: Trade Openness and Democracy: Technology Adoption - Yearly Data

Dep. Variable	Technology Adoption - Disaggregate Level CHAT Data					
	(1)	(2)	(3)	(4)	(5)	(6)
Openness	0.072		0.075	-0.129	-0.142^b	-0.134^b
	(0.790)		(0.810)	(-0.950)	(-2.374)	(-2.444)
Democracy		-0.016	-0.024	-0.110	-0.014	-0.022
		(-0.188)	(-0.274)	(-1.213)	(-0.337)	(-0.538)
Open×Demo				0.302^b	0.210^a	0.227^a
				(2.022)	(3.272)	(3.786)
Population (log)	No	No	No	No	Yes	Yes
GDP per Capita (log)	No	No	No	No	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	No
Technology FE	No	No	No	No	Yes	No
Tech×Years FE	No	No	No	No	No	Yes
Observations	38,735	38,735	38,735	38,735	36,222	36,107
Countries	104	104	104	104	97	97
Adjusted R^2	0.0673	0.0673	0.0673	0.0673	0.951	0.954

Dependent variable, $\ln(TechA_{ijt})$, is the adoption of technology i in country j in year t. OLS estimates with robust standard errors adjusted for clustering by country. Student ts are in parentheses. ^{a}, ^{b} , ^{c} significantly different from 0 at 1%, 5% and 10% level, respectively.

Columns (5) and (6) extend the specification by including further covariates, in particular population and GDP per capita that are relevant drivers of technology adoption within countries overtime. These specifications respectively include technology and technology×year fixed effects in order to flexibly (non linearly) control for the specificities in the diffusion paths of different technologies (see Comin and Hobjin, 2009b, p. 235).[31] Compared to the baseline, these are not standard difference-in-difference specifications since the estimates are based on the variability that is left in the data after netting out technology specific time

[31]For space reasons we directly report the most extensive specifications in columns (5) and (6). The results are similar when controlling for the covariates in the d-i-d framework and when excluding them in the specifications with alternative technology and time fixed effects.

trends that are assumed to be common across countries.

Across the different specifications the joint transition to open-democracies involves a sizable acceleration in technology adoption, in the order of at least 20%, and passing from a close-autocracy to an open-democracy leads to an increase in technology adoption that, depending on the specifications, ranges from 15% for the d-i-d to 7% in the most extensive specification controlling for population, GDP and for time varying technology specific diffusion patterns.

Discussion. The baseline findings at yearly frequencies are robust to several checks including the use of alternative coding of democratization, and are not driven by specific set of countries, in particular those belonging to the former Soviet block that went through a transition to market economies in the 1990s.[32] A potentially more serious concern involves the existence of biases due to reverse causality. As the literature points out, the estimates of the effect of political or trade regimes can be affected by reverse causality if the variable of interest, for instance income growth or the level of foreign direct investments, consistently affects the probability that a country undergoes trade liberalization or a transition to democracy.[33] In line with the arguments proposed in the literature, reverse causality should bias the estimates of the effect of either trade liberalization or democratization upwards delivering 'false' positive effects if improvements in technology adoption facilitate opening to trade and/or democratization. It is not obvious, however, which type of reverse causality could deliver consistently opposite statistical biases when opening to trade in different political regimes or samples.[34] Also the variable of interest is not, as is typical in the literature, at the level of countries (like e.g. GDP) but is at the level of single technologies whose dynamics appear unlikely to affect trade openness or democratization at the country level. Furthermore, the difference-in-difference empirical specification essentially exploits the differential timing of the regime transitions across countries (rather then the regime change *per se*). The identification of the causal effect of the regime changes therefore requires that the timing of the transitions are not consistently affected by the change in technology adoption. Nevertheless, we have performed a set of tests that allows to explore the possible role of reverse causality and that are informative on some side predictions.

The patterns emerge when restricting attention to the subset of countries that only

[32] Results are available upon request.

[33] See Bertrand *et al.* (2004) and Giavazzi and Tabellini (2005) for extensive discussions of this issue.

[34] For instance there are about 60 transitions to trade openness (the full list of trade and political regimes and transitions years that is reported in the Supplementary Material). About 40 percent of these transitions take place in autocracies and 60 percent take place in democracies.

switch one regime thereby iteratively ruling out reverse causality by construction. The analysis has been replicated in the sub-samples obtained by dropping iteratively each sector of technologies. The patterns are very similar also when including three and five years leads as counterfactual. We also replicated the analysis using manufacturing productivity from Mayer, Paillacar and Zignago (2008) as an alternative, indirect, proxy for technology adoption. The measure is at country level, which makes it more prone to reverse causality, but the more balanced panel allows to replicate the analysis using GMM estimates. All these robustness checks that confirm the baseline findings at yearly frequencies are reported and discussed in the Supplementary Material.

4.4 Robustness and Further Results

The baseline results in Table 2 illustrate the patterns of the effect of trade liberalization, democratization and their interaction that typically emerge from different panel specifications. Before concluding we present results obtained by: exploiting five years panel frequencies; non dichotomous measures of technology adoption; controlling for country and technology initial conditions and different lags of regime changes; looking at the extensive margin of technology adoption in a balanced panel at yearly frequencies.

Five Years Frequencies. A first check involves exploring panel specifications at 5-year rather than yearly frequencies. In spite of a shorter time dimension (involving 5 time series observations) and a substantially reduced sample, the resulting panel is more balanced. A five year time horizon also allows to study the effect of regime changes in technology adoption by implicitly accounting for the existence of some delays in the effect of regime changes.[35]

The results are reported in Table 3. At five years frequencies the effect of openness alone in column (1) is positive and (marginally) significant while no significant effect of democratization can be detected in column (2). Columns (4) to (6) confirm the baseline findings at yearly frequencies with similar size, both in terms of the interaction and total effect, and statistical significance.

Non Dichotomous Measures of Trade and Political Regimes. As a further robustness check it is useful to investigate the effect of openness and democratization in terms of non-dichotomous measures. Implementing this strategy is subject to some caveats that have

[35] The within correlations of the panel with five-year intervals are 0.03 between demo and openness, 0.36 between democracy and the interaction, and around 0.65 between openness and the interaction with a VIF value of 1.82.

Table 3: Technology Adoption - 5 Years Frequencies

Dep. Variable	Technology Adoption - 5 Years Frequencies					
	(1)	(2)	(3)	(4)	(5)	(6)
Openness	0.206^c		0.221^c	-0.142	-0.164^b	-0.152^b
	(1.669)		(1.783)	(-0.804)	(-2.094)	(-2.156)
Democracy		-0.111	-0.131	-0.277^b	-0.051	-0.050
		(-1.016)	(-1.150)	(-2.293)	(-1.083)	(-1.083)
Open × Demo				0.540^a	0.239^a	0.253^a
				(2.833)	(2.833)	(3.220)
Population (log)	No	No	No	No	Yes	Yes
GDP per Capita (log)	No	No	No	No	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	No
Technology FE	No	No	No	No	Yes	No
Tech.×Years FE	No	No	No	No	No	Yes
Observations	9,115	9,115	9,115	9,115	8,434	8,397
Countries	104	104	104	104	97	97
Adjusted R^2	0.059	0.059	0.059	0.059	0.950	0.954

Dependent variable, $\ln(TechA_{ijt})$, is the adoption of technology i in country j in year t. OLS estimates with robust standard errors adjusted for clustering by country. Student ts are in parentheses. ^{a}, ^{b} , ^{c} significantly different from 0 at 1%, 5% and 10% level, respectively.

been raised in the literature on democratization. The interpretation of the results cannot be made along the lines of a standard difference-in-difference set up and the time variation in non dichotomous measures should be interpreted with caution as they are potentially more noisy compared to dichotomous ones. An additional complication for trade openness is that no standard non-dichotomous measures are available for trade reforms over this observation period.[36] We use five years panel data on the ”freedom to trade internationally index” from the Fraser Institute and the polity IV continuous index to explore their role of technological dynamics.[37] The results, reported in Table 4, confirm the patterns obtained with the difference-in-difference estimators at five years frequencies even if the coefficients are slightly less precisely estimated.

Initial Technological Levels and Timing of the Effects. The highly unbalanced

[36]Measures of trade openness often used in the literature, such as the total imports and exports over GDP, cannot be used for our purposes since they inform on the actual trade-flows and not on the trade regime changes (or trade reforms). These measures are also typically regarded as likely endogenous to technological dynamics.

[37]With non-dichotomous measures the within correlation between openness and democracy, openness and the interaction, and democracy and the interaction are around 0.14, -0.21 and -0.42, respectively with a VIF of 1.17.

Table 4: Non Dichotomous Measures of Trade and Political Regimes

Dep. Variable	Technology Adoption - 5 Years Frequencies					
	(1)	(2)	(3)	(4)	(5)	(6)
Openness Score	0.010		0.014	0.026	-0.017	-0.003
	(0.282)		(0.373)	(0.697)	(-0.877)	(-0.147)
Democracy Score		-0.105	-0.113	0.062	0.008	0.060
		(-0.612)	(-0.647)	(0.310)	(0.100)	(0.725)
Open Sc.× Demo. Sc.				0.172^b	0.079^b	0.077^b
				(2.222)	(2.304)	(2.348)
Population (log)	No	No	No	No	Yes	Yes
GDP per Capita (log)	No	No	No	No	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	No
Technology FE	No	No	No	No	Yes	No
Tech×Years FE	No	No	No	No	No	Yes
Observations	11,871	11,871	11,871	11,871	11,538	11,537
Countries	105	105	105	105	101	101
Adj. R^2	0.0611	0.0611	0.0610	0.0610	0.950	0.954

Dependent variable, $\ln(TechA_{ijt})$, is the adoption of technology i in country j in period t. Openness and democracy scores are continuous indexes normalized to range from 0 to 1. The alternative continuous openness measure is taken from the Fraser Institute and is the index of "Freedom to Trade Internationally". The democratization index is taken from the Polity IV database. OLS estimates with robust standard errors adjusted for clustering by country. Student ts are in parentheses. Panel data at 5-years frequencies. ^{a}, ^{b} , ^{c} significantly different from 0 at 1%, 5% and 10% level, respectively.

nature of the CHAT database is not suited to perform dynamic panel estimates. The availability of data from different technologies within each country nevertheless allows to control for initial conditions in the form of the initial level of technology.[38] Column (2) of Table 5 extends the baseline results, replicated for comparability in Column (1), to the consideration of the initial level of each technology. The results reveal that the heterogeneous effects of regime changes are not imputed to the omission of, country and technology, specific initial conditions.[39]

The results of Tables 3 and 4 suggest that the effect of the joint transitions can be detected also on a five year horizon. The remaining columns of Table 5 further extend the yearly analysis considering three and five years lags of the change in trade openness and democ-

[38]The inclusion of country fixed effect would preclude the possibility to control for initial conditions if the variable of interest is at the country level as for the measures of aggregate productivity. The inclusion of technology×year fixed effects can help account for technology specific trends over time. Controlling for the initial level of each technology in each country nonetheless appears a natural, although quite demanding, robustness check.

[39]In spite of the different techniques and dependent variable, the findings confirm the insights obtained GMM results that account for the role of lag changes of Manufacturing productivity discussed above.

racy (on top of the initial conditions in technology adoption). This allows to investigate the longer term effect of these regime changes on the intensive margin of technology adoption more explicitly. The results uncover very similar patterns but suggest more persistent effects of the positive complementarity between trade liberalization and democratization. On the contrary, the effect of a switch in each of the single regimes is temporary and fades out as time goes by, being insignificant after five years.

Table 5: Initial Conditions and Lagged Effects - Yearly Frequencies

Dep. Variable	Technology Adoption - Intensive Margin					
	One Year Lag		Three Years Lag		Five Years Lag	
	(1)	(2)	(3)	(4)	(5)	(6)
Openness	-0.134^b	-0.088^b	-0.106^b	-0.067	-0.075	-0.038
	(-2.444)	(-2.159)	(-2.191)	(-1.571)	(-1.507)	(-0.848)
Democracy	-0.022	0.012	-0.028	-0.001	-0.019	-0.004
	(-0.538)	(0.411)	(-0.713)	(-0.045)	(-0.553)	(-0.130)
Open×Demo	0.227^a	0.084^c	0.249^a	0.098^b	0.267^a	0.106^b
	(3.786)	(1.980)	(4.178)	(2.027)	(4.271)	(2.073)
Population (log)	Yes	Yes	Yes	Yes	Yes	Yes
GDP per Capita (log)	Yes	Yes	Yes	Yes	Yes	Yes
Tech.×Years FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Tech. Initial Conditions	No	Yes	No	Yes	No	Yes
Observations	36,107	36,107	36,107	36,107	36,107	36,107
Number of Countries	97	97	97	97	97	97
Adjusted R^2	0.954	0.986	0.954	0.986	0.954	0.986

Dependent variable, $\ln(TechA_{ijt})$, is the adoption of technology i in country j in year t. OLS estimates with robust standard errors adjusted for clustering by country. Student ts are in parentheses. ^{a}, ^{b} , ^{c} significantly different from 0 at 1%, 5% and 10% level, respectively. Columns (1) and (2) consider the effect of regime changes with one year lag (baseline). Columns (3) and (4) consider the effect of regime changes lagged by three years while columns (5) and (6) consider regime changes lagged five years. Columns (2), (4) and (6) include the initial level of technology in the respective sector and country.

Extensive Margin of Technology Adoption. A specific feature of the CHAT technology adoption data is that it is highly unbalanced with different technologies entering the database with different delays. As alternative dependent variable we consider a dummy taking the value one once a given technology is adopted in a country for the first time and zero otherwise. The resulting empirical specification essentially exploits variation in the timing of the introduction of each technology within each country.[40] Relying on information on tech-

[40]Comin and Hobjin (2010) study adoption lags using cross-sectional information on the delay in adoption of each technology in each country so that the unit of observation is at the level of technology-country. In our analysis we exploit variation within countries over time where the unit of observation is instead at the

nology adoption at the extensive margin also allows to exploit a balanced panel database, and to include technology×country fixed effect while retaining within country variation in the timing of adoption. The results are reported in Table 6.[41] Trade openness alone tends to increase technology adoption at the extensive margin, democratization is not significant.

Table 6: Extensive Margin of Technology Adoption - Yearly Frequencies

Dep. Variable	Technology Adoption - Extensive Margin						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Openness	0.017^a		0.018^a	0.001	0.003	0.004	0.003
	(4.067)		(4.254)	(0.222)	(0.554)	(0.751)	(0.554)
Democracy		-0.005	-0.006	-0.013^b	-0.014^b	-0.015^a	-0.014^b
		(-0.920)	(-1.227)	(-2.540)	(-2.445)	(-2.649)	(-2.445)
Open × Demo				0.025^a	0.021^a	0.019^b	0.021^a
				(3.173)	(2.733)	(2.505)	(2.734)
Population (log)	No	No	No	No	Yes	Yes	Yes
GDP per Capita (log)	No	No	No	No	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	No	Yes
Techology FE	No	No	No	No	Yes	No	No
Techology×Years FE	No	No	No	No	No	Yes	No
Techology×Country FE	No	No	No	No	No	No	Yes
Observations	135,698	135,698	135,698	135,698	122,376	122,363	122,376
Countries	104	104	104	104	97	97	97
Adj. R^2	0.0309	0.0308	0.0309	0.0311	0.759	0.804	0.874

Dependent variable is a dummy variable for the presence of any given technology j in a country i and year t, $TechA_{ijt}$. OLS estimates with robust standard errors adjusted for clustering by country. Student ts are in parentheses. ^{a}, ^{b} , ^{c} significantly different from 0 at 1%, 5% and 10% level, respectively.

5 Concluding Remarks

This paper provides a theoretical and empirical analysis of the interplay between trade liberalization and democratization for the dynamics of productivity and technology adoption. A theoretical model is set up to study the incentives of different social groups to favor, or oppose, technological change. The theory predicts the existence of a complementary between trade liberalization and democratization for the dynamics of productivity. The predictions are tested exploiting within country variation over time in trade openness, democracy and their interaction for the evolution of technology adoption over time for a large set of countries.

level of technology-country-year.

[41] The within correlation between openness and democracy, openness and the interaction, and democracy and the interaction are around 0.05, 0.65 and 0.40, respectively with a VIF of 1.85.

The findings document the existence of a positive and significant interaction between trade openness and democratization for technological dynamics. The results, that prove robust to a large set of checks, qualify the common wisdom and have relevant policy implications.

The theoretical predictions on the role of changes in trade and political regimes are tested in reduced form by exploiting cross-country panel data. The theory predicts differential effects of technology adoption on the rents of the elites, on unskilled wages and on the skill premia in the different regimes. The channel proposed in the theory therefore relates to the demand for technology adoption, or the existence of vested interests, by part of the politically decisive groups conditional on the trade regime. Lack of data on rent extraction, employment and wages at the sector level for a large enough panel of countries currently prevents a deeper investigation of the possible channels behind the documented heterogeneous effects. Extending the analysis of the effects of trade liberalization and democratization to the considerations of further effects beyond technology adoption appears to be a fruitful direction for further analysis.

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6 Appendix

6.1 Analytical Derivations and Proofs

Proof of Lemma 2. The assumption that individual preferences (1) are homothetic implies the standard result that the individual optimal total expenditure in each type of good is a fixed proportion of his total expenditure (and therefore income). This also implies that the aggregate demand for each good is given by,

$$pX = \beta E \text{ and } Z = (1-\beta)E, \tag{12}$$

where E denotes the total expenditure in the economy (that equals total income produced and distributed to owners of factors of production in the economy).

In a closed economy the total demand for each good, implicitly characterized in (12), must be covered by internal production. Given the production function for each sector (2) and (3), and for allocation of workers in the two sectors, summarized by the productivity of the indifferent worker $\underline{\theta}$ the previous conditions can be expressed as,

$$p\int_{\underline{\theta}}^{\infty} \theta^A dG(\theta) = \beta E, \tag{13}$$

and

$$Z(L(\underline{\theta}), N) = (1-\beta)\, E, \tag{14}$$

The product market clears when (13) and (14) jointly hold that is if, and only if,

$$p = \frac{\beta}{1-\beta}\frac{Z(L(\underline{\theta}), N)}{\int_{\underline{\theta}}^{\infty} \theta^A dG(\theta)}. \tag{15}$$

Recall that the labor market is in equilibrium at $\underline{\theta}$ if (5) and (4) jointly hold which implies

$$p = \frac{w(L\left(\underline{\theta}\right), N)}{\underline{\theta}^A}. \tag{16}$$

The product and the labor markets therefore clear at $\underline{\theta}$ if, and only if, (15) and (16) hold simultaneously which implies

$$Y(L_Y\left(\underline{\theta}\right)) = \frac{1-\beta}{\beta}\frac{w(L_Y\left(\underline{\theta}\right))}{\underline{\theta}^A}\int_{\underline{\theta}}^{\infty} \theta^A dG(\theta). \tag{17}$$

Recall that, for any given $\underline{\theta}$, the share of workers in the traditional sector is

$$L\left(\underline{\theta}, N\right) = \int_1^{\underline{\theta}} g(\theta)d\theta = G(\underline{\theta}). \tag{18}$$

The production function (2) is constant returns to scale. Assuming a Cobb-Douglas functional form we have that the total income distributed to the workers in the traditional sector is a fixed proportion of total production in that sector so that,

$$w(L(\underline{\theta}), N)L(\underline{\theta}) = \eta Y(L(\underline{\theta}), N). \tag{19}$$

Using (18) and (19), the equilibrium condition (17) can be finally expressed as,

$$G(\underline{\theta})\underline{\theta}^A = \eta\frac{1-\beta}{\beta}\int_{\underline{\theta}}^{\infty}\theta^A dG(\theta). \tag{20}$$

The equilibrium in a closed economy is unique since the left hand side of (20) is strictly increasing in $\underline{\theta}$ while the right hand side is strictly decreasing in $\underline{\theta}$.

Proof of Lemma 3. Denoting by $\underline{\theta}^c$ the equilibrium threshold in a closed economy and rewriting the equilibrium condition (20), define

$$F(\underline{\theta}^c, A) = G(\underline{\theta}^c)k - \frac{\int_{\theta^c}^{\infty}\theta^A dG(\theta)}{\underline{\theta}^{cA}} = 0 \tag{21}$$

where $k = \frac{1}{\eta}\frac{\beta}{1-\beta}$. To see the effect of an increase in A on $\underline{\theta}^c$ we use the implicit function theorem to get

$$\frac{\partial\underline{\theta}^c(A)}{\partial A} = -\frac{\delta F(.)/\delta A}{\delta F(.)/\delta\underline{\theta}^c} = -\frac{-\int_{\theta^c}^{\infty}\theta^A\left(\ln\theta - \ln\underline{\theta}^c\right)dG(\theta)/\underline{\theta}^{cA}}{G'(\theta^c)k - \frac{\underline{\theta}^{cA}\left(-\underline{\theta}^{cA}\right) - A\underline{\theta}^{cA-1}\int_{\theta^c}^{\infty}\theta^A dG(\theta)}{[\underline{\theta}^{cA}]^2}} > 0. \tag{22}$$

since by Leibniz rule

$$\frac{\partial\int_{\theta^c}^{\infty}\theta^A dG(\theta)}{\partial\underline{\theta}^c} = -\underline{\theta}^{cA} < 0$$

and since $\partial L\left(\underline{\theta}^c\right)/\partial\underline{\theta}^c > 0$.

Although for the purposes of this paper we are only concerned with marginal changes in A, it is easy to also see that the impact of A here is monotonic. Consider condition (21). It can easily be shown using proof by contradiction that increasing A cannot be followed by a fall in $\underline{\theta}^c$ because in this case the first term always falls, whereas a lower $\underline{\theta}^c$ would necessarily imply a larger second term.

The observation above also directly implies a reduction in the wage w in the traditional sector following an increase in A. The effect of an increase in A on the skill premium is given by

$$\frac{\partial\left(\theta^A/\underline{\theta}^c(A)^A\right)}{\partial A} = \left(\theta^A/\underline{\theta}^c(A)^A\right)[\ln\theta - \ln\underline{\theta}^c(A)\frac{\partial\underline{\theta}^c(A)}{\partial A}] \tag{23}$$

From (22) $\partial\underline{\theta}^c(A)/\partial A > 0$ and since $\ln\theta$ is strictly monotonic in θ there exists a unique $\overline{\theta}(A)$ such that (23) equal zero.

The increase in the labor occupied in the traditional sector, Z implies an increase in the total production in that sector. In principle the equilibrium production in the X sector may increase (due to A) or decrease (due to higher $\underline{\theta}^c$) depending on the sign of $d\left(\int_{\theta^c}^{\infty}\theta^A dG(\theta)\right)/dA$. But the equilibrium condition requires that the positive direct effect of a better technology A dominates and always increases total output also in the X sector. This can be seen by considering again the condition for the equilibrium in a closed economy,

$$G(\underline{\theta}^c)\underline{\theta}^{cA} = \eta\frac{1-\beta}{\beta}\int_{\theta^c}^{\infty}\theta^A dG(\theta). \tag{24}$$

As shown above, a higher A increases $\underline{\theta}^c$, so the left hand side of (24) is increasing in A so that also the right hand side must increase which requires an increase in total production in the X sector: $d\left(\int_{\theta^c}^{\infty}\theta^A dG(\theta)\right)/dA > 0$. Finally, notice from (16) that the reduction in equilibrium wages w and the increase in the threshold level of skill $\underline{\theta}^c$ implies a reduction in p.

One can conclude the effect of an increase in A monotonically increases the utility of the elites and increases the proportion of workers who would suffer from technology adoption after the movement of workers from the X to the Z sector. This reinforces the possibility of a negative effect of democratization on technology adoption as in the extreme case of a very high A only the minority of the population who still work in the manufacturing sector (the most skilled) necessarily benefit from technology adoption.

Proof of Lemma 4. The equilibrium in an open economy is implicitly characterized by (16) evaluated at the international prices $p = p^*$. That $\frac{\partial\underline{\theta}^o(A)}{\partial A} < 0$ and, therefore, that the labor supply L and total production in Z decrease can be directly verified by applying the implicit function theorem to (16). All the remaining results directly follow as in the proof of Lemma 3.

Again, one could show here that the argument regarding marginal changes in A can be extended to show the monotonic effect of a larger A. Looking back at (16), we can prove by contradiction that the effect of an increase A is also monotonic here. As p is fixed in this case, a higher A cannot be followed by an increase in $\underline{\theta}$ because this would make the denominator on the RHS increase further while it would necessarily decrease $w(L(\underline{\theta}), N)$ in the numerator, which would violate the equality. Also here one can conclude that the effect of an increase in A monotonically decreases the utility of the elites and increases that of all workers.

Characterization of indirect utility. As discussed above, individual maximization of utility requires that total expenditure in each good to be a fixed proportion of total individual expenditure,

$$x^i p = \beta y^i \text{ and } z^i = (1-\beta)y^i, \tag{25}$$

where x^i and z^i denote the optimal demand of each good by part of an individual with income y^i. The indirect utility of each individual i, which is given by,

$$v^i = \left(z^i\right)^{1-\beta}\left(x^i\right)^{\beta}. \tag{26}$$

can be rewritten using (25) as

$$v^i = \widetilde{\beta}\frac{y^i}{p^{\beta}}, \tag{27}$$

where $\widetilde{\beta} \equiv \beta^{\beta}(1-\beta)^{1-\beta}$. Since total expenditure of each agent equals his total income, equation (27) essentially states that the indirect utility of each individual is proportional to his real income, which is given by his nominal revenues divided by price index p^{β}. Condition (27) can also be simply interpreted by saying that an individual is better off (after the improvement of technology A) if and only if his real income increases.

Proof of Proposition 1. We need to characterize the change in attitude towards technological improvements by part of the political rulers in an autocracy following a process of openness to trade. The total income of the elite, which is residual claimant of the income produced in the Z sector, is given by $Y^E = (1-\eta)Z$ and by dividing it by the size of Elite, denoted by σ, one gets the per-capita income of each member of the elite. From (27) each member of the elite strictly gains from an increase in the productivity A if, and only if, their real income increases. From Lemma 3 in a closed economy an increase in A increases the indirect utility of the elite since it increases Z and reduces the price p. From Lemma 4, however, Z decreases in response to higher A in an open economy (while $p = p^*$). A process of trade openness therefore reduces (respectively increases) the incentives of the elite to favor (respectively block) technology adoption.

Proof of Proposition 2. From Lemma 3 the earning of a worker in the traditional sector, $w(L, N)$, decreases with a higher A in a closed economy. In an autarky, the traditional workers can gain from technological improvements if, and only if, the reduction of price p more than compensate the reduction in their nominal income. In turn, from (4), the earnings of an individual with skill θ working in the modern sector are given by the base wage times the skill premium, $w(L, N)\left(\theta/\underline{\theta}\right)^A$ that from Lemma 3 can be increasing only for the highly skill workers for which the increase in skill premium $\left(\theta/\underline{\theta}\right)^A$ more than compensate the reduction in the base wage, w. Therefore, compared to a closed autocracy the process of democratization strictly reduces the incentives for technology adoption if the new political ruler (the new pivotal voter) is a worker that looses from technology adoption (e.g. a less skilled worker) and is unchanged if the new political ruler gains from technology adoption (e.g. a highly skilled worker).

Proof of Proposition 3. Compared to an open autocracy the emergence of an open democracy strictly increases the incentives to increase A since, from Lemma 4, in an open economy all workers (the new political rulers) gain from higher A while the elite loose. Compared to a close democracy, openness to trade (weakly) increases the incentives for technology adoption since (again from Lemma 4) all workers gain from higher A while (from Lemma 3) in a closed democracy (only) the highly skilled workers are (more) likely to gain from higher A.

6.2 Summary Statistics and Partial Correlations

We report the summary statistics and the within correlations and Variance Inflation Factors (VIFs) for the baseline samples of Technology Adoption (CHAT data).

Table 7: Summary statistics

Variable	**Observations**	**Mean**	**Std. Dev.**	**Observations**	**Mean**	**Std. Dev.**
	Baseline			5 years Frequencies		
Technologie Adoption	38735	7.685	5.871	9115	7.413	5.978
Openness	38735	0.371	0.483	9115	0.361	0.480
Democracy	38735	0.463	0.499	9115	0.461	0.499
Open×Demo	38735	0.253	0.435	9115	0.246	0.430
Population (log)	36222	9.591	1.443	8434	9.588	1.440
GDP per Capita (log)	36222	0.956	0.907	8434	0.952	0.899
	Non Dichotomous*			Extensive Margin		
Technologie Adoption	7506	7.610	5.980	135698	0.156	0.362
Openness	7506	5.626	1.566	135698	0.344	0.475
Democracy	7506	0.713	6.936	135698	0.440	0.496
Open×Demo	7506	0.210	0.490	135698	0.222	0.416
Population (log)	7188	9.738	1.438	122376	9.369	1.395
GDP per Capita (log)	7188	1.024	0.898	122376	0.822	0.910

*The non dichotomous index of openness and democracy have been normalized to range from 0 to 1 and centered around their mean in the econometric exercises. We present the summary statistics of the interaction between the centered variables.

Table 8: Within Correlation Matrices and VIFs: Different Samples

Samples:	Baseline		5 years Frequencies		Non Dichotomous		Extensive Margin	
	Open.	Demo.	Open.	Demo.	Open.	Demo.	Open.	Demo.
Openness	1		1		1		1	
Democracy	0.0541	1	0.0256	1	0.1419	1	0.0544	1
Open × Demo	0.6955	0.3580	0.6601	0.3593	-0.2122	-0.4155	0.6565	0.4016
Mean VIF	1.93		1.82		1.17		1.85	

The within correlation are calculated using country and time demeaned variables.