Appendix. Evidence and Alternative Explanations: A Bayesian Approach to Process Tracing

While there are many different approaches to understanding process tracing, there is a growing consensus that the logic of inference draws on Bayesian probability (Bennett 2015, Humphreys and Jacobs 2015, Fairfield and Charman 2017). Following Fairfield and Charman (2017), this appendix briefly overviews the logic of Bayesian probability and illustrates how it implicitly underpins the inferences drawn in our case study narratives. We use concrete examples that showcase evidence presented in the narratives, as well as supplemental evidence that could not be included in the main text due to space constraints.

Rather than undertaking a fully formalized analysis of our case studies with quantified probabilities and mathematical application of Bayes’ rule (Fairfield and Charman 2017), this appendix aims to provide a basic introduction to the thought process that underpins intuitive reasoning in qualitative process tracing. We focus on assessing the likelihood of the evidence under alternative hypotheses, which in turn allows us to update the odds we place on a working hypothesis vs. a rival hypothesis as the correct explanation for an outcome of interest.

Readers without prior exposure to conditional probability and Bayesian process tracing may find it helpful to read Bennett (2015) before proceeding; those with some familiarity may wish to consult Fairfield and Charman (2017) for a more extensive treatment of Bayesian probability as the logic of process tracing. It should be noted that while Bennett (2015) and Humphreys and Jacobs (2015) closely link Bayesian analysis to Van Evera’s (1997) well-known process-tracing tests (e.g. hoop, smoking gun), Fairfield and Charman (2017) advocate simply asking how much the evidence increases or reduces our confidence in a given explanation relative to a rival explanation. This appendix follows the latter approach.

Bayes’ Rule

In conducting qualitative case research, we identify plausible explanations, drawing on existing studies and own experience. As we gather evidence, we reevaluate which of these hypotheses provides the best explanation for the case. Bayesian probability and Bayes’ rule provide a mathematical framework for how we should revise our degrees of belief in a hypothesis, given our relevant prior knowledge and the evidence we discover during our research.
Bayes’ rule, expressed in terms of conditional probabilities, states that:

$$P(H_1 | E \ I) = \frac{P(H_1 | I) \ P(E | H_1 \ I)}{P(E | I)}$$ \hspace{1cm} (1)

The term on the left is the *posterior probability* that we should place on hypothesis $H_1$, given a body of evidence $E$ as well as the salient background information, denoted $I$, that we bring to bear on the problem. The first term on the right is the *prior probability* of the hypothesis given our background information alone. The second term on the right is the *likelihood* of the evidence: if we take $H_1$ and $I$ to be true, what is the probability of the evidence? The term in the denominator is the unconditional likelihood of the evidence, which will not play a central role in our case applications.

When comparing two rival hypotheses, Bayes’ rule can be written as an *odds ratio*:

$$\frac{P(H_1 | E \ I)}{P(H_2 | E \ I)} = \frac{P(H_1 | I)}{P(H_2 | I)} \times \frac{P(E | H_1 \ I)}{P(E | H_2 \ I)}$$ \hspace{1cm} (2)

The term on the left is the *posterior odds* on hypothesis $H_1$ vs. hypothesis $H_2$. This ratio represents our relative degree of confidence regarding which hypothesis is correct, after we have analyzed the evidence. The first term on the right is the *prior odds* on $H_1$ vs. $H_2$, which represents our relative degrees of belief in the hypotheses before we analyze evidence $E$. The second factor on the right is the *likelihood ratio*. We can think of the likelihood ratio as the probability of observing the evidence $E$ if we imagine living in a hypothetical world where $H_1$ is true, relative to the probability of observing $E$ if we imagine living in an alternative hypothetical world in which $H_2$ is true (Fairfield and Charman 2017). The likelihood ratio is the critical term that tells us how to update our odds on the hypotheses—does the evidence increase our confidence in $H_1$ or does it increase our confidence in $H_2$?

Fairfield and Charman (2017: §3.1.1) emphasize that assessing likelihoods, $P(E | H_1 \ I)$, entails *assuming that $H_1$ is correct*—we are interested in the probability of the evidence conditional on the truth of the hypothesis. We therefore need to place ourselves in “the world of the hypothesis” and ask how surprised we would be by the evidence. If the evidence seems expected, the likelihood will be high; if the evidence seems surprising, the likelihood will be low. When evaluating likelihood ratios, we need to judge whether one rival hypothesis or the other makes the evidence more plausible; Bayes’ rule tells us that we should gain confidence in the hypothesis that makes the evidence more likely.
It is worth emphasizing from the outset that “conclusive process tracing is good, but not all good process tracing is conclusive” (Bennett and Checkel 2015:30). Bayesian analysis entails making the best inferences possible given the evidence we are able to attain, but in many cases it may not be possible to establish the truth of a hypothesis beyond all reasonable doubt.

**Example 1. Tax policy in Chile: social mobilization vs. technocrats**

In our analysis of Chile, we argue that social mobilization drove social policy expansion and progressive tax increases after 2011, once the student movement was able to stage sustained and massive protests. We will denote this explanation as $H_{SM}$. Consider a rival hypothesis, $H_T$, that technocrats are critical in driving progressive reforms because their expertise gives them autonomy and power to promote their own agenda (e.g. Ewig 2016).

A priori, we view $H_T$ as less plausible than $H_{SM}$. While technocrats can play an important role in designing and proposing policies, what matters is whether those policies are politically viable, and technical expertise in itself does not necessarily provide a political advantage. For any policy, there are almost always both advocates and opponents who can claim technical expertise; which side prevails generally depends on other sources of power and reform strategies. Below, however, we will set priors aside and simply focus on how we should update the relative odds on these two hypotheses given our case evidence.

We will assume for simplicity that $H_{SM}$ and $H_T$ are mutually exclusive, such that either social mobilization plays the primary role in driving progressive reforms, or technocrats play the primary role in driving progressive reforms.¹ Let us compare $H_T$ with $H_{SM}$ as explanations for the 2012 Chilean tax reform in light of the following evidence:

$E = $ An executive-branch advisor (2012) explained in an interview with T. Fairfield that Piñera’s Finance Minister resisted the 2012 corporate tax increase: “Felipe Larraín was never convinced of the need to do it, but the president’s view ultimately prevailed. ...The Finance Minister was very resistant to the idea of doing a tax reform; he was the main opponent of the tax increase, because of the effect it could have on growth, especially give an international scenario of high volatility. The president was the one who definitively promoted the design and the decision... This president makes decisions very autonomously, especially on these issues.”

While this evidence does not clearly illustrate the causal mechanism behind $H_{SM}$, it is consistent with that hypothesis. In this world, we expect incumbent politicians to pursue progressive

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¹ This assumption is included in the background information that defines the hypothesis space we wish to consider. See Fairfield and Charman (2017: Section 3.1).
reforms, and according to the informant, Pres. Piñera behaved in just this manner despite the Finance Minister’s objections. In contrast, if we imagine an alternative world in which \( H_T \) holds, this information would be quite surprising. In that world, we would expect key technocrats like the Finance Minister, who was closely involved in the reform process, to have played a central role in proposing, designing, and advocating this progressive tax reform, and we would anticipate that politicians including the president would defer to their expertise. Instead, the Finance Minister resisted the reform, and the President ignored his advice. The likelihood of this evidence under \( H_T \) is therefore very low. In sum, this piece of evidence is much more probable under \( H_{SM} \) relative to \( H_T \), significantly increasing the odds in favor of our explanation relative to the rival.\(^2\)

Instead of directly pitting the role of technocrats against social mobilization, we could begin with a more complex set of mutually exclusive hypotheses that includes the possibility of both social mobilization and technocratic expertise contributing to reform. For example: \( H_{SM} = \) “Social mobilization was the primary factor driving reform;” \( H_T = \) “Technocrats played the primary role in driving reform;” and \( H_{SMT} = \) “Social mobilization and technocrats contributed in relatively equal measure to driving reform.” However, the evidence above weighs against \( H_{SMT} \) relative to \( H_{SM} \) just as it weighs against \( H_T \) relative to \( H_{SM} \).

While we do not have evidence that weighs as strongly against \( H_T \) for the other cases included in this paper, we find little to suggest that technocrats made any significant independent contribution to the policy outcomes. In the Mexican health care reform, for example, there is no evidence that Fox’s technical advisor, Julio Frenk, operated “autonomously” to promote a more progressive agenda than that espoused by the PAN. Frenk agreed with the PAN’s critiques of the existing health care system, and it was clear from the outset that he would design a reform that ensured a subsidiary role for the state and increased private provision of services. Therefore, if we consider including technical expertise along with the causal factors we highlight, we would create a more complex theory that does not provide any clear additional explanatory power. This more complex theory would necessarily be penalized in Bayesian analysis with a lower prior probability relative to our theory.\(^3\)

\(^2\) Similar evidence for the 2010 tax increase strongly favors our electoral competition argument over the technocrat argument.

\(^3\) See Charman and Fairfield (2017: Section 3.1) on logical Bayesianism and priors.
Example 2. Social policy in Mexico: electoral competition vs. resource abundance

For our second example, consider social policy expansion in Mexico. Let us compare our electoral-competition explanation, $H_{EC}$, against a mutually-exclusive rival hypothesis, $H_{RA}$, that identifies resource abundance as the primary causal factor: During times of economic bonanza, right-wing governments expand social policy benefits, because of a cross-partisan, international consensus in favor of anti-poverty measures that create minimal budgetary pressures.\(^4\) We find this hypothesis rather implausible on its face—there are many other budgetary items that right-wing governments could be expected to prioritize during times of economic bonanza, including income tax cuts, investment incentives, or crime control. However, we will again set priors aside and focus instead on how the relative odds on the two hypotheses should be updated in light of the evidence.

We will take as background information that Mexico during the second half of Fox’s term experienced both intense electoral competition for low-income voters (as discussed at the beginning of Section 4) and good economic growth (growth rates around 4\%). We now evaluate three pieces of evidence in turn:

\[ E_1 = \text{Significant social policy expansion did not occur until 2001, after the Fox administration took office, even though Mexico experienced even higher growth rates (4–7\%) from 1996–2000. Moreover, Fox’s first social policy innovations coincided with a year of negative growth (2001).} \]

This information about the timing of reform is neither expected nor surprising under $H_{EC}$—our electoral competition argument does not make strong predictions about prevailing economic conditions. By comparison, this evidence has a low likelihood under $H_{RA}$—in a hypothetical world where that hypothesis is correct, we would expect to see significant social policy expansion beginning in the late 1990s. We would also be surprised to find reforms initiated in 2001 during a time of economic downturn. The evidence therefore weighs strongly in favor of the electoral competition argument.

\[ E_2 = \text{Regarding the political importance of pension expansion, a PRD social policy advisor (interview, 2007 with C. Garay) said: “Every senior is at the peak of a pyramid with a large base. If you assist all the seniors then everyone is happy because everybody has a parent, a grandparent. ...The increase in popularity [López-Obrador] attained with this program was impressive. Why wouldn’t I vote for this candidate who did so much for my grandpa?”} \]

\(^4\) We thank an anonymous reviewer for suggesting this hypothesis.
This evidence does not contradict the resource-abundance hypothesis, but we are much more likely to hear politicians making this type of observation if the electoral-competition hypothesis is correct. Notice that $E_2$ does not provide direct evidence in favor of our explanation, since the informant is not affiliated with the incumbent government but rather the left-wing opposition party. However, this evidence provides indirect support precisely because the likelihood of hearing politicians identify social policy as important for winning votes is higher under our electoral competition explanation relative to a resource-abundance explanation, which makes no predictions about the electoral potential of social-policy expansion.

$E_3 = \text{Despite initially discrediting PRD candidate Lopez-Obrador’s call for non-contributory pensions as populist, Fox launched a pension program for senior members of households enrolled in \textit{Oportunidades} a few months before the 2006 election.}$

In a world where $H_{EC}$ holds, the likelihood of the type of political dynamic described in $E_3$ is high. The timing of the right’s endorsement of pension reforms suggests that the PAN (a) viewed social policy expansion as an effective means to win voters away from the PRD and (b) would not have initiated this pension program had the issue not become electorally salient. In a world where $H_{RA}$ holds, we would not be surprised to find the PAN proposing pension expansion, given that growth had resumed healthy rates by 2004, but again this hypothesis does not speak to the precise timing of social policy expansion—in particular, why the reform was not proposed a year or two earlier or later. The likelihood of this evidence, which highlights the important context of the presidential campaign, is therefore higher under $H_{EC}$ relative to $H_{RA}$.

In sum, while none of the three pieces of evidence above contradicts the resource abundance hypothesis, each weighs more strongly in favor of the electoral competition hypothesis. In other words, the evidence increases the plausibility of $H_{EC}$ relative to $H_{RA}$.

**Example 3. Education reform in Chile: social mobilization vs. resource abundance**

For our final example, consider the Piñera’s administration’s 2011 education reforms. We argue that social movement mobilization, in the form of massive protests, was the primary causal factor driving these reforms—as before, we denote this explanation as $H_{SM}$. As a rival explanation, we will again consider the resource abundance hypothesis, $H_{RA}$, which identifies economic expansion as the primary causal factor driving increased spending on education. We will take the fact that Chile experienced strong growth (around 6%) in 2010 and 2011 and the fact that student protests intensified toward the end of 2010 and reached a massive scale by
spring 2011 as part of our background information. In other words, the causal factors central to the two respective rival hypotheses are both present in the case. Let us now evaluate two key pieces of evidence:

\[ E_1 = \text{Piñera proposed the Great National Agreement for Education (GANE), which deviated significantly from his original policy agenda, after waves of massive protest and with the clear intention of restoring social peace—as illustrated for example in the following excerpt from a major national newspaper: “The president made an appeal to ‘end the takeovers and protests and resume a path of dialogue and agreements’ via this initiative, ‘whose main objectives are to improve the quality, access to, and financing of higher education...” (Tercera, July 5, 2011: Presidente Sebastián Piñera propuso un “Gran Acuerdo Nacional por la Educación”)} \]

The likelihood of this evidence is higher under \( H_{SM} \) compared to \( H_{RA} \) because both the timing of the proposal relative to protest and the concern over restoring social peace are expected under our social mobilization explanation—the evidence provides glimpses of the hypothesized causal mechanisms—whereas \( H_{RA} \) makes no specific predictions about timing, given that both this year and the previous year, as well as the following two years, experienced strong growth.

\[ E_2 = \text{According to one of Piñera’s advisors, concern over the fiscal cost of the education reforms, in conjunction with budgetary pressures created by social policy commitments made during Piñera’s previous year in office, motivated the President’s decision to initiate the 2012 tax reform (interview: Executive-advisor 2012, with T. Fairfield), despite earlier promises that the 2010 corporate tax increase would be temporary.} \]

In a world where \( H_{RA} \) is true, we would be surprised to observe \( E_2 \). Under \( H_{RA} \), we would expect the government to be less concerned with fiscal discipline, given the context of economic expansion and high copper prices, or we might expect the government to tap into the copper reserve fund, or to temporarily increase the copper royalty as was done in 2010. Permanently raising broad-based corporate taxes runs against the resource abundance hypothesis, which anticipates reforms that do not create significant budgetary pressures of the sort that could motivate a government to increase taxes on its core constituency. In contrast, the likelihood of \( E_2 \) under \( H_{SM} \) is high—our argument predicts that social mobilization will push governments to initiate reforms they would not otherwise embrace, including progressive taxation, when addressing social demands creates budgetary pressures.

\[ E_3 = \text{The text of the government’s 2012 tax reform proposal alluded to the 2011 student protests—“We are aware that 2011 will be remembered as the year in which our society forcibly posed its desire for unmet needs to be addressed in the area of education”—and} \]
identified spending on education as the motivation for the tax increase: “Our government has made the decision to step up efforts throughout the country to improve the quality and coverage of education at all levels, and thereby meet the demands of society. ...This bill proposes measures to increase public resources in order to finance new commitments in education that primarily benefit vulnerable sectors and the middle class.” (Proyecto de Ley que Perfecciona la Legislación Tributaria y Financia la Reforma Educacional, 4/30/2012)

As with $E_2$, this evidence illustrates key aspects of the causal mechanism posited in $H_{SM}$, including government responsiveness to social-movement demands and associated revenue pressures motivating progressive tax increases. The likelihood of $E_3$ under $H_{RA}$ is far lower, because that hypothesis makes no predictions about the role of social mobilization in triggering reform, nor does that hypothesis anticipate any need for progressive tax increases to finance education reform.

The other pieces of evidence presented in the case narrative also favor $H_{SM}$ over $H_{RA}$, following the same logic of inference. The causal mechanisms that we trace are both (a) highly consistent with the social mobilization argument and (b) much less likely to occur in a hypothetical world where resource abundance plays the central role in spurring reform.

References