Bayesian representation of a prolonged archaeological debate[§]

Abstract

This article examines the effect of material evidence upon historiographic hypotheses. Through a series of successive Bayesian conditionalizations, I analyze the extended competition among several hypotheses that offered different accounts of the transition between the Bronze Age and the Iron Age in Palestine and in particular to the "emergence of Israel". The model reconstructs, with low sensitivity to initial assumptions, the actual outcomes including a complete alteration of the scientific consensus. Several known issues of Bayesian confirmation, including the problem of old evidence, the introduction and confirmation of novel theories and the sensitivity of convergence to uncertain and disputed evidence are discussed in relation to the model's result and the actual historical process. The most important result is that convergence of probabilities and of scientific opinion is indeed possible when advocates of rival hypotheses hold similar judgment about the factual content of evidence, even if they differ sharply in their historiographic interpretation. This

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speaks against the contention that understanding of present remains is so irrevocably biased by theoretical and cultural presumptions as to make an objective assessment impossible.

Keywords: Bayesianism, Archaeology, Bronze-Iron transition, Historical knowledge, Biblical interpretation.

1. Introduction

Using a case study, this article examines our ability to gain epistemic knowledge about the distant human past and in particular the relation between evidence and historiographic interpretation.

Several scholars (Salmon 1976, 1982; Wylie 1988; Tucker 2004; Carrier 2012, 2014) have advocated the use of Bayesian logic for evaluation of historiographic hypotheses. This opinion is, however, not universally shared. Disputing views can be divided into two major categories: general reservations about Bayesian formalism (Glymour 1980; Talbott 2015: 9-12), and, more fundamentally, claims that the unavoidable theory-ladenness and values-ladenness of observation undermine Bayesian methodology. Objections of the second kind are often directed particularly against the human sciences, for example:

> "…people who start out with very different assessments of whether a given theory is probable will generally be unable to agree about the description and interpretation of almost any piece of evidence that is brought forth in support of the theory. The human sciences, understood to be dealing in an essential way with the interpretation of artifacts as products of human intentions, can thus be seen as ultimately concerned not with rationality or irrationality but with hermeneutics (Ullmann-Margalit 2006:78)."

Or, more specifically, against the ability to gain any objective knowledge about the human past:

> "Just as in the experience of art we are concerned with truths that go essentially beyond the range of methodical knowledge, so the same thing is true of the whole of the human sciences… Fundamentally, the experience of

> historical tradition reaches far beyond those aspects of it that can be objectively investigated (Gadamer 1975)."

Even stronger relativistic convictions have been evinced by some archeologists, for example (Hodder 1997:19) "relativism, which we follow, holds that knowledge is rooted in a particular time and culture. Knowledge does not mimic things. Facts and objectivity are constructed." Shanks and Tilley sharpen the point:

> Individuals, interest groups, and societies all have different perspectives on the past. There is and can be no monolithic undifferentiated PAST. Rather there are multiple and competing pasts made in accordance with ethnic cultural and gender political expectations (1987: 11).

Other philosophers of history and archaeology have, however, rejected these relativistic views. Kosso (1989) offers a characterization for the objectivity of evidence: Objective evidence is one that is verified independently of what it is evidence for. He points out that problems in the epistemology of the past have analogies in the natural sciences, so that

> … we can say that knowledge of the human past can support a correspondence model of truth…. Coherence is a necessary requirement of justification, but by itself it is not enough to separate good fiction from the truth. Add to it the need to encounter a steady supply of evidence, to acknowledge at least some of it as reliable and relevant, and to fit it into the existing coherent system … and we reduce the threat of circular, self-serving, rigged testing (Kosso 2001 181-12).

Wylie (2002:209) likewise stresses the importance of independence, both of evidence and of background theories, and maintains that: (2007:97)

> although archaeological evidence is thoroughly laden with theory – although it is unavoidably a construct, open to question and revision – it can nevertheless impose decisive limitations on what can be claimed about past cultural systems, their internal dynamics, and their trajectories of development and transformation.

Recent works have expanded these ideas into general theories about the epistemology of the past, specifically endorsing a Bayesian perspective of historiography. Tucker (2004) argues that "consensus on historiographic beliefs in uncoerced, heterogeneous, and sufficiently large groups of historians is indicative of knowledge of history" and

> Once we understand the hierarchy that gives precedence to consensus generating cognitive values over other values that divide the historiographic community, it becomes clear that value-laden historiographic interpretation is inevitable, but hierarchically inferior to its scientific core according to cognitive values.

Carrier (2012) presents a detailed argument for the relevance of Bayesian method to historiography and goes on (2014) to demonstrate how this methodology can be applied to settle a particular historiographic dispute, concerning the historicity of Jesus. Almost literarily negating Ullmann-Margalit's assertion above, he says (2012: 89):

> Imagine a situation where all observers start with different estimates and then acquire exactly the same total knowledge; ... if they only employ valid arguments, working from exactly the same information, then they would have to agree. ... So if they still came to a different conclusion, we would have to identify irrationality as the culprit.

In what follows I examine a prolonged scholarly rivalry among several hypotheses that sought to account for what happened during the passage from the Late Bronze to the early Iron Age in Palestine, and in particular the demographic and historical underpinnings of the appearance of the "Israelite" ethnos and the establishment of the territorial kingdoms of Israel and Judah several centuries later.

The debate lasted for most of the 20th century. Initially two incompatible hypotheses were offered, then a third, and finally a fourth. By the 1990s, the dominant hypothesis was all but completely abandoned, its main rival still held as a minority view. Most scholars supported variations of a hypothesis that had not even been considered initially and would presumably have been rejected as widely improbable if it had.

I construct the interplay between historiographic hypotheses and archaeological evidence in a simplified Bayesian model of successive conditionalization[1]. Under the model's fairly moderate assumptions, the actual two-generation process that led to a profound change in the beliefs of a disciplinary community can be reconstructed.

[1] Such construction, incidentally, counters another objection to the application of Bayesianism to historiography – that the Bayesian approach is too formalized, requiring precise and inaccessible data, etc. (Cf. Carrier 2012:62-65)

On the basis of this case study I argue that the relativist opinions are unwarranted. I demonstrate, in particular, that posterior probabilities of historiographic hypotheses can converge even if they start from deep and entrenched discord about prior assumptions. This discussion will also enable me to shed light upon several known issues in Bayesian formalism: the problem of old evidence, the introduction and testing of new theories, the possibility of eliminative inference, and the import of uncertain or disputed evidence.

The following section is a minimal introduction to Bayesian formalism, confined mainly to features that are relevant to this paper. Section 3 delineates both the hypotheses about the Bronze/Iron Age transition in Palestine that were advanced in the 20th century and the relevant archaeological findings from the same period. Section 4 describes the methodology employed in the model. Section 5 comprises three Bayesian simulations, each one a "contest" between pairs of hypotheses, together with sensitivity checks to the model's assumptions. Section 6 discusses the results of these simulations and Section 7 concludes with some general remarks.

2. Bayesian confirmation[2]

One way of formulating the principle of Bayesian conditionalization is to state that upon learning the truth of evidence *E* that bears upon a hypothesis *H* a rational person would update her estimate of the plausibility of *H* (or degree of belief in *H*), by assigning it the posterior probability, $P_f(H)$ such that:

1) $P_f(H) = P(H|E\&K) = P(E|H\&K)* P_i(H|K)/P(E|K)$

where *Pi(H)* is the prior probability of the hypothesis, *P(H|E)* its probability given the evidence *E*, *P(E|H)* is the likelihood of *E* if *H* is true, *P(E)* is the probability of the evidence *E* (before it was actually found to be true), and *K* stands for the background knowledge. Sometimes *K* is assumed to be implicit in the probabilities (Strevens 2006; Talbott 2015), enabling the formula to be simplified to:

1a) $P_f(H) = P(H|E) = P(E|H)* P_i(H)/P(E)$

This shorthand is used throughout the paper, but a point about its applicability is made in Section 6c.

[2] This section is a minimal exposition of the notions and topics that are relevant to what follows, and does not attempt to represent the immense subject of Bayesian confirmation theory. From the vast literature on this subject, see e.g. (Earman 1992), (Strevens 2012).

2.1 **Comparison between competing hypotheses**: Often in science, a hypothesis is not evaluated alone but in conjunction with other hypotheses that purport to explain the same phenomena. Equation (1a) then can be generalized to:

1b) $P_f(Hn) = P(E|Hn)*P_i(Hn)/P(E) = P(E|Hn)*P_i(Hn)/ [\sum_k P(E|Hk) * Pi(Hk)]$

For equation (1b) to be valid, hypotheses H_k must be mutually exclusive ─ each must differ from the others in at least one prediction about an observable event ─ and the set $\{H_k\}$ of hypotheses must be exhaustive. While the first stipulation can be easily fulfilled, the second rarely ever is since it requires knowledge of all possible hypotheses that say something about *E*, including those that have not yet been thought of. The cases discussed here, like many others in the history of science, demonstrate that this assumption of omniscience (Earman's (1992) LO2) is not realistic.

An oft-mentioned resolution of this conundrum suggested by Shimony (1970) is to include in $\{H_k\}$ a "catchall hypothesis" and to "shave off" from it probabilities for new hypotheses as they arise. However, this "trick" has no principled methodology within the Bayesian formalism.

Another issue related to the application of either (1a) or (1b) is that they both include prior probabilities, *Pi(H).* Bayesians differ in their understanding of the probabilities in the Bayesian formalism. "Subjectivists" or "Personalists" (e.g., Howson, Strevens) maintain that they can only represent a researcher's degree of belief; it is tacitly assumed (or hoped) that given sufficient evidence, posterior probabilities converge ("get washed out") to the "real" ones. "Objectivists" (e.g., Salmon) state that priors should reflect real-world probabilities, pointing out that convergence under a finite series of evidence is not assured if scientists are allowed to assign wildly arbitrary priors. It is, however, difficult to see how the objective probability of (for example) string theory being true should be determined, let alone that of complex non-quantitative hypotheses discussed here. I shall therefore adopt an unabashed subjectivist stance.

W. Salmon (1990), following Kuhn points out that we normally evaluate several alternatives and attempt to choose from among them. For a comparison of two hypotheses, *H1* and *H2*, the ratio of their posterior probabilities becomes:

2) $P_f(H1)/P_f(H2) = [P(E|H1)*P_i(H1)] / [P(E|H2)*P_i(H2)]$

which can be rearranged as:

2a) $[P_f(H1)/P_f(H2)]/ [P_i(H1)/P_i(H2)] = P(E|H1)/P(E|H2)$

Equation (2a) has the favorable outcome of getting rid of *P(E)* – the probability of the evidence, something that we rarely know how to estimate – and also of the obscure "catchall hypothesis". It enables a systematic evaluation of the influence of the evidence on the relative plausibility of competing hypotheses. If more than two hypotheses are to be evaluated, the pairwise comparison can be repeated.

The mechanism implied by (2a) is frequently used in actual statistical testing of hypotheses. The ratio of likelihoods *P(E|H1)/P(E|H2)* is often called "Bayes' factor" and representative values for it are given in the literature, for example in Jeffreys (1961, App. B) and Kass and Raftery (1995).

Formula (2) or (2a) cannot, however provide a value for the absolute probability of any hypothesis being true – something that Earman (1992:171-3) considers as a serious flaw, one close to causing the "giving up inductivism altogether." But, as noted above, it is questionable whether we can meaningfully speak of an absolute value for our degree of belief in a hypothesis or a theory. More realistically, "at any time, the most favored theories are simply those with the highest subjective probabilities" (Strevens 2006).

2.2 **Some issues of Bayesian confirmation**

The Bayesian formalism is widely used in practice,[3] but several fundamental problems have led some philosophers to reject it as a proper (let alone *the* rational) approach for evaluating scientific hypotheses. Some issues, relevant to this work, are:

a) Inability to accommodate novel hypotheses: Many currently accepted theories were not even thought of for formerly. Yet by Bayesian formalism, the introduction of new hypothesis requires an exogenous (i.e. not derived by conditionalization) change of all other probabilities (Talbott 2015:11; Henderson et al 2010:20). So it seems that the emergence of new hypotheses – arguably the essence of scientific advance – is outside the Bayesian mechanism. On a slightly more practical side, even if a new hypothesis is somehow admitted, all the relevant facts known before its formulation (some of which may have even motivated it) are automatically considered to be "old evidence" (see below) and therefore cannot contribute to its evaluation.

[3] For use in Archaeology, see Buck et al. (1996)

b) The problem of old evidence: Since the probability of a known fact under any hypothesis equals one, it follows from 1(a) that if we conditionalize our beliefs on known facts we get $P_i(H) = P_f(H)$. It appears that Bayesian formalism requires that we update our belief only using evidence discovered after a hypothesis' formulation.

There is hardly any treatise on Bayesian inference that does not discuss "The Problem of Old Evidence." This issue, forcefully raised by Glymour (1980:85-93) is indeed disconcerting, because the history of science includes numerous examples of old evidence being used to support or refute hypotheses.

Of the responses offered to the problem, two are relevant to the cases discussed here. The "structural" approach, mentioned affirmatively by Glymour and elaborated (in different versions) by Garber (1983), Jeffrey (1983b) and Niiniluoto (1983) posits that the *learning* of the relevance of old evidence - the "structural connection between a piece of evidence and a piece of theory" – constitutes *new* evidence on which beliefs can be conditionalized. The "counterfactual" approach suggested by Howson (1991) and endorsed (somewhat halfheartedly) by Earman (1992:119-135), suggests that that the change in degree of belief (from $P_i(H)$ to $P_f(H) = P(H|E)$) should be computed *as if* the agent's knowledge *K* at the time hypothesis *H* was formulated did not include evidence *E*.

Old evidence, and new theories that explain old evidence, abound in archaeology. Both play an important part in the case studies discussed below.

c) The problem of disputed evidence: No evidence is beyond doubt. The scenario described below includes several examples of evidentiary assertions that were later revised, and the history of science provides many more. This uncertainty can be handled within Bayesian formalism either by assigning moderate likelihoods to each piece of evidence, as I do here or by using the more sophisticated formalism of "Jeffrey's conditionalization" (Jeffrey 1983a).[4]

A more serious problem occurs when scholars do not agree about the evidence – its relevance, its likelihood under various hypotheses, or even its content. Godfrey-

[4] Aside from its computational difficulty, Jeffrey's conditionalization requires that we know the probability of both the evidential statement and its negation, "something that it is doubtful that anybody has ever done" (Talbott, 2015).

Smith (2003:209) wonders "why should two people, who disagree massively on many things, have the same likelihoods for all possible evidence? Why don't their disagreements affect their views on the relevance of possible observations?" Other scholars, as we have seen, are more categorical and deny the possibility objective appraisal of evidence altogether.

The case study below includes examples of both agreement and disagreement about the evidential content of archaeological findings. Lessons can be learned from both, as I shall point out in Sections 6d and 7.

d) Surprising evidence and diverse evidence: From (1) it follows that the smaller the *a priori* probability of evidence *P(E*), the greater the posterior probability when *E* is discovered to be true. This "surprising evidence effect" is sometimes equated to the "diverse evidence effect" (Talbott 2015), namely, that the weight of a piece of evidence for confirmation or disconfirmation of a hypothesis is diminished if earlier similar evidence is already present. Several scholars (Horwich 1982:118-122; Strevens 2012:73-78) emphasize that in order to be useful, the diversity of the evidence has to be meaningful with respect to the hypotheses being evaluated, something that is hard to pin down. I shall argue below that under certain circumstances diversity may not be entirely beneficial.

3. Historiographic hypotheses and archaeological evidence

3.1 The competing hypotheses

The question of the "emergence of Israel," namely, the historical sequence, the causal factors, and the demographic underpinnings that led to the later appearance of the territorial monarchies of Judea and Israel had been a focus of interest for archaeologists, biblical scholars, and historians since the nineteenth century. Of specific attention were the passages in the biblical books of Joshua and Judges that describe a military conquest, followed by a series of conflicts whereby the land of Canaan came to be settled by the tribes of Israel. The subject has remained "hot" until today, but the hypotheses landscape has changed substantially: Hypotheses that were once dominant within the scientific community are currently assigned a negligible degree of belief, while one that was not even considered is now dominant.

Four[5] hypotheses were advanced[6] to account for the relevant developments. For the purpose of this analysis they can be summarized as follows:

a. The Conquest hypothesis: The books of Joshua and Judges provide a generally correct description (though not accurate in all its details) of the events by which the Israelites established themselves in Canaan. A chronological anchor is provided by the stele of Pharaoh Merneptah;[7] thus the conquest and destruction of Canaanite cities by the tribes of Israel occurred via a coordinated military campaign of relatively short duration in the latter part of the 13th century B.C.E.. Thenceforth, a settlement process, splattered with occasional conflicts, begins, as described in the book of Judges.

The Conquest hypothesis was championed by the American archaeologist William Foxwell Albright (1939, 1940, 1949, 1956) and advanced by Ernst Wright (1946, 1958) and Yigael Yadin (1965, 1982, 1984). Advocates of the Conquest hypothesis maintain (Albright 1956, Wright 1958) that their thesis is strongly supported by archeological findings. Until the 1970s, this claim was undisputed by most archaeologists.

b. The Immigration (or "peaceful infiltration") hypothesis: Starting from the late 14th century B.C.E (Alt 1939:163) and perhaps even earlier (Alt 1925; Aharoni 1957:115), a protracted process of seasonal transhumance of nomadic Israelite tribes between the eastern desert and the sown western land led to gradual settlement in non-occupied areas between Canaanite cities. During the 13th century B.C.E, concurrent with the weakening of Egyptian rule, ensuing conflicts with local inhabitants resulted in the conquest and destruction of some cities. The battles described in the book of Judges were carried out, starting from the first half of the 12th century BCE (Noth 1958:81) by coalitions of tribes ("amphictyonic leagues") that formed around cultic centers like Beth-el and Shiloh.

[5] I do not discuss here the "minimalist" school of thought (e.g., Davies 1992) that considers both historical events and archaeological findings irrelevant to the understanding of biblical narrative.

[6] Naturally, variations and shades of opinions exist among supporters of each of these hypotheses, but giving them due description is outside the scope of this paper and is not pertinent to my attempt to analyze the change of scientific opinion in Bayesian terms. See for example Dever (1993, Ch. 2) Finkelstein (1988:295-314), Moorey (1991) or Junkkaala (2006:11-36) for a fuller summary of the hypotheses and the history of their development.

[7] The pronouncement: "Israel is laid waste" found on this stele was interpreted to "prove that Israel was already in Western Palestine in force, but had not yet settled down" (Albright, 1940:194) at ca. 1230 B.C.E.; a similar chronological estimate is given by Yadin (1965).

The Immigration hypothesis was formulated by German biblical scholars, most notably Albrecht Alt (1925, 1939) and Martin Noth (1938, 1958). They grounded their thesis on interpretation of biblical text and analogies to modern herding nomads (Bedouins) in the Levant. Yohanan Aharoni (1957, 1982) was the first archaeologist to adopt the Immigration hypothesis, presenting archaeological evidence to support it since the 1950s. Initially a minority, "iconoclastic" opinion among archaeologists, the Immigration hypothesis gathered support during the 1970s and became dominant by the 1980s.

c. The Revolt hypothesis: The early Israelite population was composed of people from the urban and/or agricultural lower strata that withdrew from the feudal and oppressive Canaanite society of the Late Bronze Age (Mendenhall 1962). They had at least a similarity and perhaps an affinity to the H'abiru mentioned in the 14th century B.C.E. Al-Amarna letters. The Yahwistic faith, either formed indigenously or adapted from a group of mutinous slaves that escaped Egypt (Gottwald 1979:214) provided this population with a unifying ideological-religious zeal that empowered them to attack and destroy the cities of their former oppressors, a process that took place over a prolonged period between the mid-13th to the mid-11th century B.C.E.

The Revolt hypothesis was formulated by the American biblical scholar George Mendenhall (1962, 1974) and expounded by Martin Gottwald (1979, 1985). Based upon sociological theories and a novel interpretation of the biblical texts, its proponents (Gottwald 1985) doubted whether it could be supported by archaeological findings, but maintained that such findings discredited the Conquest hypothesis. Against the Immigration hypothesis they argued, *inter alia* (Mendenhall 1962:68) that the analogy to modern Bedouins was misleading because the behavioral repertoire of long-range nomadism and transhumance could not have existed before the domestication of camels, something that occurred much later than the relevant period.

The Revolt hypothesis never gained much support in the archaeological community, but one crucial element of it – the indigenousness of the "origin of Israel" - did, as shown below.

d. The Autochthonic hypothesis: Indigenous inhabitants of Late-Bronze Canaan were the major origin of the [proto-]Israelite population. The demographic source of this population were local agrarian residents (Dever 1998, 2003) or "internal nomads" that existed in Palestine for hundreds of years as a part of a dimorphic society (Finkelstein 1995, 1998a) and not outsiders who penetrated the land either by military conquest or by peaceful migration. They were driven to settle in the hill country of Palestine by the instability of the Late Bronze Age that followed the weakening and eventual withdrawal of Egyptian rule during the 12th century B.C.E. Rather than a revolt against the established order this process was a reaction to its disappearance. The coalescence of this diverse population was prolonged and gradual, and a national identity with more-or-less shared narratives did not materialized until later in the Iron Age.

Formulated in the 1990s, the Autochthonic hypothesis attempts to reconcile data available *then*, and it incorporates elements from earlier hypotheses. While its main expounders, William Dever and Israel Finkelstein disagree about the sources and background of the settlers in the hill country during the Bronze/Iron transition, the nature of their incipient culture, and several other points, the commonalities in their viewpoint, as outlined above, are arguably the dominant position held by biblical archaeologists today. A label in the Israel Museum in Jerusalem, for example, tells visitors that "While the biblical story of the Exodus relates that the Israelite came from Egypt, many archaeologists believe that they actually originated [here] in the land…".

3.2 **Archaeological evidence**

Out of hundreds of archaeological works in Palestine I chose 24 "data points" (Table 1) that span the period between the late 1920s and the late 1980s and had pronounced influence upon the debate among the above mentioned hypotheses.[8]

I confine myself to evidence derived from material findings because my aim is to see if the changes that occurred in the belief distribution can be attributed to such evidence *alone*. Besides, although all camps in the debate tended to find support for their view in the biblical texts and to invoke arguments based upon them, all accepted

[8] Since hypotheses seeking to make sense of the biblical narrative about the conquest of Canaan cannot be tested in places and regions claimed in the text *not* to have been conquered, the list does not include sites in "the remaining land" (Josh. 13).

the (essentially Wellhausenian) view that these texts originated from several sources, were written and edited several centuries after the events described therein, and cannot be expected to provide a full and accurate report of what actually happened. Therefore, a wide degree of freedom was available to each scholar to select textual "evidence" supporting his own view, to deny the evidential relevance of any contradicting textual passage, or to interpret the text in a manner different from its literal meaning.[9] As to archaeological evidence, it is by nature fragmentary and its interpretation is theory-laden no less than in any other scientific discipline. But I think that the cases described here substantiate the view that "the strategies archaeologists developed for exploiting a range of background knowledge can be very effective in establishing a network of evidential constrains" (Wylie 2002:217).

As a matter of fact, most of the evidential results mentioned below were undisputed, not only in their "low-level" content – that such and such material remains were found at a certain site – but also in their "middle-level" aspect ─ "what was here when": That a particular site was destroyed at a certain time, that another one was uninhabited throughout a specific period, etc. Scholars that held completely differing opinions concerning the overall processes usually accepted that the discovery of a reference to a certain Pharaoh at a site entails a *Terminus Post Quem* to its destruction, or that artifacts from the Early, Middle, and Late Bronze periods can be safely differentiated. With few exceptions (which will be specifically mentioned and discussed below), disagreements concerned historiographic interpretations of the findings – that is, their implications (or lack thereof) to the understanding of the period under discussion - and not their factual content *per se*.

This does not imply, of course, that archaeological evidential claims are infallible or irrevocable. As in every science, results are subject to revision by new discoveries or new interpretation. In Table 1, for example, Data point 7 was revised in Data point 9 and Data point 10 was challenged by Data point 16. Each of these results affected in turn the beliefs of scholars, as described below.

Table 1 lists the 24 data points for the Bayesian model. For simplicity and brevity, reference is made to two comprehensive books (Mazar 1990 and Finkelstein 1988b) whenever possible. References to the original publications are found therein.

[9] Biblical texts describing later periods (monarchic, exilic etc.) were interpreted more consensually, but their evidential status is not my concern here.

Table 1: Data points for the Bayesian model

Data point No.	Year (apr.)	Site / Region	Researcher(s)	Findings	Reference
1	1929	Tell Beit Mirsim	Albright	Destruction layer dated to the 2nd half of the 13th century BCE (identified by the excavator as the biblical Dvir)	F54; M 290
2	1930	Beit-El	Albright	Destruction layer dated to the 2nd half of the 13th century BCE	F 72-3; M 333
3	1934	A-Tell ('Ai)	Market-Krause	No Late-Bronze occupation in a "conquered town"	F 72; M 331-2
4	1935	Tell Lachish	Starkey	Egyptian rule (Ramesses II) in "a conquered city" until the last quarter of 13th century BCE. (later revised by 17)	T 36-7
5	1936	Heshbon	Glueck	No Late-Bronze occupation in a "conquered town"	F 113; M 330
6	1936	Transjordan	Glueck	Dozens of simple, unfortified settlements dated to 13th or 12th century BCE	F 114-6; M 334
7	1948	Jericho	Garstang	Identification of Late-Bronze walls (later falsified by 9)	G 130
8	1953	Upper Galilee	Aharoni	Dozens of simple, unfortified settlements	F 106; M 334
9	1954	Jericho	Kenyon	No Late-Bronze fortifications (Cf. Josh. 2, 6)	F 296-7; M 331
10	1956	Hazor	Yadin	Violent destruction and sacking, dated to ca. 1230 BCE (later revised by 16)	F 98; M 288
11	1960	Gibeon	Pritchard	Negligible Late Bronze remains (Cf. Josh.10:2)	F 60-61; M 353
12	1960	Shechem	Wright	An occupational continuum from Late Bronze to the Iron Age II (Cf. Josh. 24)	F 81; M 333-4
13	1965	Arad	Aharoni	No Late-Bronze occupation in a "conquered city"	F 39; M 329-30
14	1967	Emergency survey	Kochavi et al.	Dozens of "settlement sites" in the central hilly region	Incorporate in later surveys
15	1962	General	Mendenhall	Long-range nomadism and transhumance impossible before the domestication of camels	Mn 67; F 307
16	1972	Aphek (implications for Hazor)	Beck & Kochavi	Ceramic typology indicates that Hazor was destroyed in the beginning of 13th century	B&K 38; M 294n

				B.C.E.	
17	1975	Tell Lachish	Ussishkin	Egyptian (Ramesses III) rule in "a conquered city" until the mid-12th century B.C.E.	F 301; M 299, 332
18	1976	Beer-Sheba Valley	Aharoni	Several "settlement sites"	F 37-47; M 336
19	1978	Upper Galilee	Frankel	About 40 "settlement sites" in the central hilly region	Fr 25
20	1982	Lower Galilee	Gal	About15 "settlement sites" in the central hilly region	F 94-97; M 335
21	1984	Hebron	Ofer	No Late-Bronze occupation (cemeteries only) in a "conquered town"	F 47-8; M 332
22	1985	"Land of Menasseh"	Zertal	About 100 "settlement sites"	F 89-71; M 335
23	1985	"Land of Ephraim"	Finkelstein	About 100 "settlement sites" in the central hilly region	F 119-204; M 335
24	1985	Judean Mountain	Ofer	Scores of "settlement sites"	F 51; M 336

References code for the table: B&K – Beck and Kochavi 1985; F – Finkelstein 1988b; Fr – Frankel 1994; G – Garstang 1931; M – Mazar 1990; Mn – Mendenhall 1962; T – Tufnell 1958.

4. Methodology

The following section is comprised of three diachronic, contrastive simulations that attempt to reconstruct in Bayesian terms the scholarly debate about what happened in the Bronze/Iron Age transition in Palestine. Following Salmon's (1990:191-2, 207n.) suggestion (and also, approximately, the historical sequence as played out in the 20th century), the simulations compare pairwise the Conquest hypothesis to the Immigration hypothesis, then the Immigration hypothesis to the Revolt hypothesis and again the Immigration hypothesis to the Autochthonic hypothesis.

Each simulation begins with the assumption that the degree of belief in the "incumbent" (the current dominant) hypothesis is one hundred times stronger than

that in the "usurper" one,[10] an assumption the sensitivity to which is subsequently examined.

The simulation runs diachronically over the data points in Table 1, so that when each data point is "entered," it causes an update in the belief ratio according to formula (2a). The result of each update is the basis for the next one, until the entire list of data points is exhausted. The final result is the estimate for the relative degree of belief in the two hypotheses toward the end of the 1990s. Subsequent to each "run" of the simulation I examine the sensitivity of the result to the model's assumptions.

Bayes' Factors: I use values after Jeffreys (1961: Appx B) for the influence of evidence on the relative probabilities of two competing hypotheses by evidence.

Table 2: Updating factors

Strength of the evidence	B(H1, H2, E) = P(E|H1)/P(E|H2)	
	From Jeffreys 1961:431	Used here
Decisive support against H1	$0.01 > B$	not used
Very strong support against H1	$0.03 > B \geq 0.01$	not used
Strong support against H1	$0.1 > B \geq 0.03$	0.1
Substantial support against H1	$0.3 > B \geq 0.1$	0.3
Anecdotal[11] support against H1	$1 > B \geq 0.3$	0.67
Neutral	1	1
Anecdotal support for H1	$3 > B \geq 1.5$	1.5
Substantial support for H1	$10 > B \geq 3$	3
Strong support for H1	$30 > B \geq 10$	10
Very strong support for H1	$100 > B \geq 30$	not used
Decisive support for H1	>100	not used

Moderate values: No evidence and no inference is indisputable; and archaeology, known for the fragmentary nature of its results is certainly no exception. I use the lower bound of the values recommended in Jeffreys to reflect this element of

[10] This can, for example, be the result of assigning a probability of 90% to the first hypothesis, 0.9% to the second, and allowing 9.1% to the "catchall hypothesis." But an infinity of other combinations give the same ratio and, as said above, I doubt if an absolute figure for the "degree of belief in hypothesis X" is meaningful here, and in any case do not attempt to compute any.

[11] "Not worth more than a bare mention" in the original.

ambiguity and avoid designating any piece of evidence as "decisive" or "very strong" in support of or against any hypothesis. Most data points are counted as either "substantial" or "anecdotal" and only few (usually, those that were exceptionally surprising and "sensational" when they were first announced) are considered as "strong" evidence for or against any hypothesis.[12]

Moderate or not, my choice of updating factors represents the subjectivist element in the model. I try to take cues from the way the scholars themselves reacted to the data: For example, when a discovery was followed by a flurry of auxiliary (often rather *ad hoc*) assumptions to reconcile it with one's favorite hypothesis, I assume it to be strong evidence against *that* hypothesis.[13] But this does not eliminate the subjective element. As a defense against "pure unadulterated subjectivism" (Salmon 1990:183-4), each "run" of the simulation is followed by a sensitivity test, whereby the "nominal" updating factors are modified to see under which modifications the overall result is stable.

5. Paired Comparisons of Hypotheses

5.1 **Conquest vs. Immigration hypothesis**

Findings that were interpreted as evidence of Late Bronze Age cities conquered and sacked "at the right time" (i.e., in the second half of the 13th century B.C.E) and "at the right place" (i.e., sites identified as remains of Canaanite cities mentioned in the book of Joshua as conquered by the Israelites) were heralded as confirmation of the Conquest hypothesis (e.g. Albright 1956). Supporters of the Immigration hypothesis demurred, pointing out (Alt 1939:156; also Gottwald 1979:199) that the destruction layers carried no signature and therefore could have been caused by other forces that operated during that tumultuous era. Nevertheless, looking at the issue from a Bayesian perspective, it seems reasonable to consider such evidence as providing

[12] It is worth noting that researchers' own appreciations of the evidential strength of their findings were often much stronger. Only rarely would a scholar say that his results "increase (diminish) the plausibility of hypothesis X by some degree." Expressions like "*there can be no doubt* that this destruction was the deed of the Israelite tribes" (Yadin 1965) or "*there is not the slightest doubt* that we are now witnessing the beginning of the settlement of the Israelite tribes in the Negev" (Aharoni 1976) (italics mine) are much more frequent. But as we shall see, such strong claims were not always corroborated by later discoveries.

[13] "Thus, attempting to salvage a hypothesis by inventing numerous ad hoc excuses for all the evidence it doesn't fit will rapidly diminish the probability of that hypothesis being true." (Carrier 2012: 80)

strong support for the Conquest hypothesis (sensitivity to this assumption is examined below).

But other excavations provided contravening results. Failure to find evidence of a destruction layer at a site assumed to have been conquered and sacked by the Israelites could be (and was) explained as an inaccuracy or an exaggeration in the scriptures[14] and hence is considered in my analysis as only *anecdotal against* the Conquest hypothesis. However, Late-Bronze destruction layers whose dating significantly diverges from the circumscribed "window of opportunity" posited in the Conquest hypothesis point to continued Egyptian presence in the "conquered land" – a state-of-affaire unmentioned in the bible and difficult to reconcile with a conquest scenario - when they are "too late" and jeopardize the hypothesis' chronological scenario when they are "too early." Therefore, the analysis considers these data points as *substantial against* the Conquest hypothesis.

Most damaging to the Conquest hypothesis was the failure to discover an occupation layer at locations identified as sites of Canaanite cities. Such findings were explained by an assortment of *ad hoc* assumptions.[15] Therefore, it seems justified to consider such evidence as *strong against* the Conquest hypothesis.

As to the large area surveys, one should distinguish between the evidential import of the early (Glueck's surveys in Transjordan and Aharony's work in the upper Galilee) and the later ones (the "emergency survey" of 1967/8 and afterwards). The early discovery of scores of Early Iron Age settlements in the Hill regions of Palestine could be reconciled with the Conquest hypothesis by evoking the Biblical passage (Josh. 17: 18) in which some Israelite tribes are told to deforest the mountainous region and settle therein; I therefore consider them *neutral* to both hypotheses. Only when many hundreds of small, simple and unfortified settlements in the hill regions were discovered during the late large area surveys did it become apparent that this phenomenon ─ barely mentioned in the Bible and by its very nature congruous with the premises of the Immigration hypothesis ─ is far more significant to the Late Bronze/Early Iron Age transformation in Palestine than whatever happened or didn't

[14] Recall that the Conquest hypothesis was not obligated to a literal interpretation of the Biblical narrative, only to its overall adequacy

[15] E.g. the suggestion that the 'Ai story actually refers to Beit-El (Albright 1934), or that Jericho's Late-Bronze walls were completely consumed by later use (Yeivin 1971).

happen to the Canaanite cities (the record from which, as was by then known, is ambiguous anyway, see section 6c below). So evidence from these late surveys is considered to be *substantially against* the Conquest hypothesis, subject to sensitivity analysis.

Results:

The "run" under the assumptions above is shown in Table 3:

Table 3: The Conquest vs. the Immigration hypotheses - Bayesian Model Results

Data point No.	Year (apr.)	Site / Region	Implications for HC	Updated Beliefs ratio P(Hc)/P(Hi)
N/A	Start	N/A	N/A	100
1	1929	Tell Beit Mirsim	strong for	1000
2	1930	Beit-El	strong for	10000
3	1934	A-Tell ('Ai)	strong against	1000
4	1935	Tell Lachish	substantial against	300
5	1936	Heshbon	strong against	30
6	1936	Transjordan	Neutral	30
7	1948	Jericho	strong for	300
8	1953	Upper Galilee	Neutral	300
9	1954	Jericho	strong against	30
10	1956	Hazor	strong for	300
11	1960	Gibeon	strong against	30
12	1960	Shechem	anecdotal against	20
13	1961	Arad	strong against	2.0
14	1967	Emergency survey	substantial against	0.6
15	1962	General	Neutral	0.6

16	1972	Aphek (implications for Hazor)	substantial against	0.2
17	1975	Tell Lachish	substantial against	0.05
18	1976	Beer-Sheba Valley	substantial against	0.02
19	1978	Upper Galilee	substantial against	0.005
20	1982	Lower Galilee	substantial against	0.001
21	1984	Hebron	strong against	0.0001
22	1985	"Land of Menasseh"	substantial against	0.00004
23	1985	"Land of Ephraim"	substantial against	0.00001
24	1985	Judean Mountain	substantial against	0.000004

The model reconstructs the decline of the Conquest hypothesis from clear dominance to a negligible degree of confidence. Considering its crude and simplified assumptions, the model even does a fairly good job in estimating the "inflection point" in the mid-1970s when the Conquest hypothesis became less favored and the Immigration hypothesis (temporarily) rose to dominance in the disciplinary community.

Sensitivity checks:

It is quite easy to see that the result above is insensitive to assumptions about prior beliefs: Even allotting a miniscule initial credibility of 0.01% (i.e., multiplying the results in the right-hand column of Table 1 by one hundred) to the Immigration hypothesis still leaves it more than hundred times stronger than the Conquest hypothesis at the end of the conditionalization run.

The result is also fairly stable against changes in assumptions about the strength of the evidence embodied in the Bayes factors: Even if, for example, we demote *both* the findings from the late surveys and the evidence of destruction layers "with the wrong timing" to the status of being *anecdotally* instead of *substantially against* the Conquest hypothesis, the final ratio of beliefs would still be about 0.01; that is, the Immigration hypothesis still has the upper hand. Similarly, granting evidence for destruction layers "at the right time" an increased weight of being "*very strong f*or"

the Conquest hypothesis *plus* lowering the evidential significance of the "non-existent cities" to just "*substantially against*" instead of "*strongly against"* the Conquest hypothesis, a similar result would obtain. Only a combination of *all* the above, essentially downplaying any evidence that did not comport with the Conquest hypothesis (something that the archaeological community evidently did not do) would leave this hypothesis with some non-negligible degree of belief.

One possible sensitivity check, which is also pertinent to the other pairwise comparisons below, concerns the large area surveys: Each of these data points (6, 8, 14, 18-20 and 22-24) generalizes regional evidence from scores of "settlement sites" into one salient conclusion: That many simple, small, unfortified settlements appeared in mountainous or arid regions that were mostly uninhabited during the Late Bronze age. One could argue either for each site to be counted separately or, vice versa, for all of them to be included as one "evidential phenomenon" (or perhaps for the first survey to be counted as evidence and the rest to be discarded as "old evidence").

Let me first note that the procedure of considering each large-area survey as a separate data point is the method adopted by archaeological textbooks like those cited in Table 1, so such a grouping is by no mean arbitrary. Nor would the results above (as well as these in the next two sections) change appreciably should we consider each site as a single data point: The number of "settlement sites" by now discovered approaches 500 and considering each one as providing only *very marginal support* of 1% for or against a hypothesis would produce a similar outcome.

Things are different if one regards all the data from the "settlement sites" as just "one piece of evidence." While the Immigration hypothesis still wins, albeit by a much smaller margin, the results of Section 5.3 below would be reversed. The significance of this is discussed in Section 6b under "Surprising, diverse and mundane evidence."

Disputed evidence: Data point 17 (a revised dating for Hazor's destruction) was not universally agreed upon (e.g., Mazar (1990: 294n) is unconvinced). But elimination of this single data point from the simulation only slightly changes the final result. The same holds if one accepts one of the many explanations offered for the absence of Late-Bronze fortifications in Jericho and eliminates Data point 9. A more cogent case of disputed evidence is considered in 5.3 below.

5.2 **Immigration vs. Revolt hypothesis**

The Revolt hypothesis was formulated at the time when the Immigration hypothesis was making inroads into the archaeological community and quickly gaining dominance. Since protagonists of both hypotheses (Alt 139:156; Noth 1958:82; Gottwald 1979:199; 1985:46) thought that destruction layers in Canaanite cities could not point to the identity of their executors, all data points from these sites are therefore *neutral* concerning the comparison between them. For reasons similar to those mentioned above, the early surveys are also considered neutral.

But both sides (e.g., Noth 1958:82; Gottwald 1979:202) assumed that the hill settlements discovered in the large-area surveys were the locations of the population that later became transformed into the kingdoms of Judea and Israel, i.e., Israelites or proto-Israelites. Supporters of the Immigration hypothesis used the results of the late, more comprehensive surveys to point out (e.g., Finkelstein 1988b:307-8; Zertal 1994:54) that the geographic settings of these settlements do not accord with what should be expected from the Revolt hypothesis. Quite a few of the them appear in the vicinity of Canaanite cities and seem to have maintained a mutually beneficial relationship with them, something hard to reconcile with the idea of "two forms of political economy that could not coexist" (Gottwald 1985:36). Evidence of violent conflict between these settlements and the Canaanite cities are lacking. Therefore, I consider the late surveys as providing at least *substantial* evidence *against* the Revolt hypothesis (but see sensitivity check below)[16].

There was one argument of the promoters of the Revolt hypothesis that supporters of the Immigration hypothesis were ready to admit: that the phenomenon of transhumance "aus der Wüste in die Kulturländer" (Alt 1939:140-142) which plays a crucial part in the immigration hypothesis is based upon an analogy that does not hold for the southern Levant of the relevant era. This line of reasoning was recognized as pertinent by scholars (e.g., Finkelstein, 1988b:307) who rejected the Revolt hypothesis itself. Hence the model weights this argument (at Data point 15) as *substantially against* the Immigration hypothesis, subject to sensitivity analysis.

Results:

Table 4. The Immigration vs. the Revolt hypotheses - Bayesian Model Results

[16] Some scholars (e.g., Zertal (1991:36), Finkelstein (1998a:27)) pointed to expansion of the hill settlement from east to west as a further argument against the Revolt hypothesis. This claim is however not generally accepted (Dever 1998:227).

Data point No.	Year (apr.)	Site / Region	Implications for Hi	Updated Beliefs ratio P(Hi)/P(Hr)
N/A	Start	N/A	N/A	100
1	1929	Tell Beit Mirsim	Neutral	100
2	1930	Beit-El	Neutral	100
3	1934	A-Tell ('Ai)	Neutral	100
4	1935	Tell Lachish	Neutral	100
5	1936	Heshbon	Neutral	100
6	1936	Transjordan	Neutral	100
7	1948	Jericho	Neutral	100
8	1953	Upper Galilee	Neutral	100
9	1954	Jericho	Neutral	100
10	1956	Hazor	Neutral	100
11	1960	Gibeon	Neutral	100
12	1960	Shechem	Neutral	100
13	1961	Arad	Neutral	100
14	1967	Emergency survey	substantial for	300
15	1962	General	substantial against	90
16	1972	Aphek (implications for Hazor)	Neutral	90
17	1975	Tell Lachish	Neutral	90
18	1976	Beer-Sheba Valley	substantial for	270
19	1978	Upper Galilee	substantial for	810
20	1982	Lower Galilee	substantial for	2,430
21	1984	Hebron	Neutral	2,430
22	1985	"Land of Menasseh"	substantial for	7,290

23	1985	"Land of Ephraim"	substantial for	21,870
24	1985	Judean Mountain	substantial for	65,610

The model clearly shows the "incumbent" Immigration hypothesis trumping the "usurper" Revolt hypothesis as evidence from the large area surveys accumulate.

Sensitivity checks:

The result is strong enough to withstand a reversal of the ratio of priors: Even if we start the simulation by assuming the Revolt hypothesis to be 100 times stronger that the Immigration hypothesis, the series of successive conditionalizations terminates with it being seven times weaker, illustrating the "washing out" effect desired by Bayesians.

This qualitative result – namely that evidence from the late surveys shows the Revolt hypothesis to be untenable – is also quite resistive to modifications of the likelihood ratios intended to revise it: Taking the argument against Bronze-age transhumance to be a *very strong* against the Immigration hypothesis *and* the evidence from the late surveys to be only *anecdotally for* it still leaves the likelihood of the Immigration hypothesis nearly fifty times stronger than the Revolt hypothesis. Only by tilting both the ratio of prior beliefs and the ratios of likelihoods of the evidence to the benefit of the Revolt hypothesis ─ essentially assuming the Revolt hypothesis to be true and denying the relevance of all archeological findings against it ─ does this hypothesis become dominant.

5.3 **Immigration vs. Autochthonic hypothesis**

Like the Immigration and Revolt hypotheses that influenced it, the Autochthonic hypothesis considers the archeological evidence from Canaanite cities as immaterial for the question of "the emergence of Israel." It differs from the Immigration hypothesis in pointing out (Dever 1998:228; Finkelstein 1988a:16-17) that findings from "settlement sites" discovered in both early and late large-area surveys show no evidence for an out-of-country origin for their inhabitants: Although the material repertoire exposed in these sites is distinct from that found at sites of Late Bronze Canaanite cities, the origin of every material-culture-attribute in the Hill sites is indigenous rather than foreign.

Another and perhaps more important point was the dating of the hill settlements: Early appearance (13th century B.C.E or earlier) of these sites is essential to the Immigration hypothesis which postulates a lengthy settlement period as a prelude to the conglomeration and "Landnahme" of the Israelites in Canaan. Now, these "settlement sites" are notoriously difficult to date. Radiocarbon results from them were not available through the 20th century (and are very hard to come by even today) and dating was based upon the typology of ceramics. Several characteristics of the assemblages found in the hill settlements[17] convinced most researchers that their appearance is a phenomenon of the 12th century B.C.E (But see the discussion of an opposing opinion below).

On the strength of these arguments, the findings from each large–area survey can be regarded as providing evidence at least *substantially against* the Immigration hypothesis. As mentioned above, many archaeologists were also influenced by the argument against the likelihood of transhumance between the deserts and western Palestine during the relevant period.

Results

The use of archeological discoveries from the 1930s - 1980s to evaluate a hypothesis formulated during the 1990s raises the problem of old evidence and new theory. Let us disregard these problems for the time being (Cf. 6a) and look at the result from the model's run under the above assumptions:

Table 5: The Immigration vs. the Autochthonic hypotheses - Bayesian Model Results

Data point No.	Year (apr.)	Site / Region	Implications for Hi	Updated Beliefs ratio P(Hi)/P(Ha)
N/A	Start	N/A	N/A	100
1	1929	Tell Beit Mirsim	Neutral	100
2	1930	Beit-El	Neutral	100
3	1934	A-Tell ('Ai)	Neutral	100

[17] For example, these sites conspicuously lack remains of imported ceramic ware. Imports from Cyprus and the Aegean reached Canaan during most of the 13th century B.C.E, but ceased later due to regional disturbances that prevented that commerce.

4	1935	Tell Lachish	Neutral	100
5	1936	Heshbon	Neutral	100
6	1936	Transjordan	Substantial against	30
7	1948	Jericho	Neutral	30
8	1953	Upper Galilee	Substantial against	9
9	1954	Jericho	Neutral	9
10	1956	Hazor	Neutral	9
11	1960	Gibeon	Neutral	9
12	1960	Shechem	Neutral	9
13	1961	Arad	Neutral	9
14	1967	Emergency survey	Substantial against	3
15	1962	General	Substantial against	0.8
16	1972	Aphek (implications for Hazor)	Neutral	0.8
17	1975	Tell Lachish	Neutral	0.8
18	1976	Beer-Sheba Valley	Substantial against	0.2
19	1978	Upper Galilee	Substantial against	0.1
20	1982	Lower Galilee	Substantial against	0.02
21	1984	Hebron	Neutral	0.02
22	1985	"Land of Menasseh"	Substantial against	0.01
23	1985	"Land of Ephraim"	Substantial against	0.002
24	1985	Judean Mountain	Substantial against	0.0006

The simulation exhibits the rapid decline of belief in the Immigration hypothesis vis-à-vis that in the Autochthonic one, once evidence from the surveys is admitted. The sensitivity analysis in this case, however, involves several fundamental issues.

Sensitivity checks:

The dominance of the Autochthonic hypothesis at the end of the conditionalization cycle holds even if we assign it a nearly negligible prior probability of 0.01 % (a hundred times lower than the one used), and also if we consider the results from the survey as only *anecdotally* (in lieu of *substantially*) *against* it.

Disputed evidence: However, in this case – unlike the others so far discussed – there was strong debate within the archaeological community about the nature and meaning of evidence. The ongoing disagreement relates to the dating of the small, simple "settlement sites" that are believed by supporters of all hypotheses to have been inhabited by the early [proto-]Israelites in Canaan. Two distinguished archaeologists - Yohanan Aharoni (1957, 1971, 1976) during the third quarter of the twentieth century and Adam Zertal (1991, 1994) during the 1990s - have presented evidential support for precocious existence of the hill settlements (early 13th century B.C.E or even earlier)[18].

While these evidential claims remain disputed on methodological and other grounds,[19] if one accepts them, then the late large area surveys support, rather than challenge, the Immigration hypothesis, causing a dramatic change in the model's result.

As Table 6 shows, just considering the late surveys as lending *anecdotal* support *for* the Immigration hypothesis is sufficient to retain it and buttress its dominance:

Table 6: **The Immigration vs. the Autochthonic hypotheses - Bayesian Model Results (Alternate parameters)**

Data point No.	Year (apr.)	Site / Region	Implications for Hi	Updated Beliefs ratio P(Hi)/P(Ha)
N/A	Start	N/A	N/A	100
1	1929	Tell Beit Mirsim	Neutral	100

[18] As for the absence of material of foreign origin in general and of imported Aegean/Cyprian ware in particular, it can be explained (Faust 2006:55-63) as the result of the norms and ideology of the relevant population.

[19] See Aharoni (1957:119; 1971; 1976:60) and Zertal (1991; 1994:65-66) for the "early settlement" argument and Finkelstein (1988b:90; 2007) for its rebuttal. A similar chronology was also offered by Gal (1982, Ph.D. thesis) and contested by Finkelstein (1988b:96).

2	1930	Beit-El	Neutral	100
3	1934	A-Tell ('Ai)	Neutral	100
4	1935	Tell Lachish	Neutral	100
5	1936	Heshbon	Neutral	100
6	1936	Transjordan	Anecdotal for	150
7	1948	Jericho	Neutral	150
8	1953	Upper Galilee	Anecdotal for	225
9	1954	Jericho	Neutral	225
10	1956	Hazor	Neutral	225
11	1960	Gibeon	Neutral	225
12	1960	Shechem	Neutral	225
13	1961	Arad	Neutral	225
14	1967	Emergency survey	Anecdotal for	338
15	1962	General	Substantial against	101
16	1972	Aphek (implications for Hazor)	Neutral	101
17	1975	Tell Lachish	Neutral	101
18	1976	Beer-Sheba Valley	Anecdotal for	152
19	1978	Upper Galilee	Anecdotal for	228
20	1982	Lower Galilee	Anecdotal for	342
21	1984	Hebron	Neutral	342
22	1985	Menasseh Mountain	Anecdotal for	513
23	1985	"Land of Ephraim"	Anecdotal for	769
24	1985	Judean Mountain	Anecdotal for	1,153

Acceptance of Aharoni's 1971 assertion that his analysis "furnishes a clear *terminus ad quem* for the early waves of the settlement in the hilly region in the fourteenth century B.C" and therefore considering the surveys as lending *strong* or even *substantial* support *for* the Immigration hypothesis would make it even more prominent.

This simulation retrial illustrates the profound effect of disputed evidence, the significance of which is discussed in Section 6d below.

6. Discussion

Using fairly moderate assumptions, a Bayesian model has been constructed for a two-generation process that led to a significant change in the distribution of beliefs within a scientific community. In the model as well as in the actual case, large differences in prior assumed probabilities were "washed out" by the flow of evidence.

Most of the model's results are only weakly sensitive to its assumptions. In particular, extensive variations in the Bayes factors (the ratio of likelihoods of evidence under competing hypotheses) cannot "resurrect" the Conquest hypothesis that was so dominant during the first half of the previous century nor relegate the once-unimaginable Autochthonic hypothesis to negligible credibility. Also reproduced with reasonable fidelity is the initial rise in belief in the Immigration hypothesis and its subsequent decline when many scholars found that the accumulation of evidence did not cohere with what should have been expected if it was correct and the failure of the Revolt hypothesis to establish itself as a credible alternative for similar reasons.

Analysis of the model's results also serves to illustrate characteristics of Bayesian inference, as well as few of its known problems:

a. Old evidence and new theories:

That long-range nomadism and transhumance in the Middle East was a product of the Iron and not the Bronze Age was known at least since the 1930s (e.g., Albright 1940:196), many years before it was cited as an argument against the Immigration hypothesis. This, therefore, is a typical case of the "Problem of Old Evidence:" A piece of already known information is used to confirm or disconfirm a theory, even though under the Bayesian formulation it cannot have any influence upon the agent's degree of belief. It is a "diachronic" old evidence (*sensu* Christensen 1999) or "old

new evidence" (*sensu* Eells 1985) because the agent (the scientific community) knew of it, but only in hindsight learned of its relevance to an already formulated theory. As such, the issue can be resolved by considering the *learning* of the relevance of the "old" information as a reason for an agent to update her beliefs as advocated by Glymour (1980), Garber (1983), Jeffrey (1983b) and Niiniluoto (1983). The "counterfactual" approach advocated by Howson (1991) and Earman (1992:134) that scholars should update their beliefs relative to background knowledge *sans* the new evidence is also possible, but seems superfluous here.

A more serious problem is illustrated by the emergence of the Autochthonic hypothesis and its rise to dominance long after all the relevant evidence was at hand and indeed largely as an attempt to "make sense" of that body of evidence. The "learning as evidence" approach simply does not apply to this situation because knowledge of the evidence *and* its relevance to the hypothesis were synchronous with the hypothesis' formulation. Actually some information – like the proximity and inferred mutual coexistence of some "hill settlements" and Canaanite cities – acquired their evidential significance only as a result of the formulation of the Revolt and the Autochthonic hypotheses.[20]

It seems to me that the only way to cast this in Bayesian terms is counterfactual: Scholars conditionalized on the evidence "as if they did not know" it already existed. I posit that this would also be an apt description of what many scientists actually did in this case and often do:[21] weighing whether old evidence is better explained by a new hypothesis.

Admittedly, this approach is fraught with theoretical difficulties[22]: The very introduction of new theories illustrates that we humans lack theoretical omniscience, considered by some to be a cornerstone of Bayesianism. Both the Autochthonic and the Revolt hypotheses were not even considered during most of the 20th century, but

[20] In a manner that recalls Wylie's (2002: 162-8) "cables and tacking" and Currie's (2015) "investigating scaffolding" between hypotheses and evidence in historical sciences.

[21] Consider, e.g., Lyell using previously known data to support uniformitarianism, van Vleck using quantum theory to explain the anomaly of the specific heat of hydrogen, known since the 19th century, or the much elaborated example of Einstein demonstrating how general relativity explains the perihelion of Mercury.

[22] See Howson (1991:553), Earman (1992:131), Christensen (1999: 441-448) and Eells and Fitelson (2000) for more fundamental discussions.

Bayesian formalism does not allow genuinely novel hypotheses to gain ground via conditionalization (Cf.2.1). The previous section demonstrates both the strength and weakness of this approach: It works well, *provided* one is allowed to introduce novel hypotheses by some non-Bayesian means.

An alternative approach, suggested in Henderson et al. (2010) would be to construct a *hierarchic Bayesian model*, wherein hypotheses that are tested against data are derived from higher-level theories which "may represent more abstract or general knowledge." In such models not only the evidence, but also the hypotheses have likelihoods: a hypothesis' likelihood is influenced by the likelihood of the evidence underlying it. Hierarchic Bayesian formalism is said to have the potential to accommodate novel hypotheses (and also to answer other problems of Bayesian formalism, which are beyond the scope of this paper). In the case considered here, a higher-level theory could be centered on the premise that Biblical texts pertaining to the 13^{th} - 11^{th} centuries B.C.E contain factual elements that archaeological discoveries can expose and explain, with the "Conquest," "Immigration," and "Revolt" hypotheses as explanatory sub-theories. An alternative high-level theory might regard the period as essentially pre-historic, so that archeological findings should be interpreted without recourse to textual sources.[23] It would be interesting to see if such a hierarchic model could spawn the "Autochthonic" hypothesis and predict its rise, but such an attempt must be left for another day.

b. Surprising evidence, diverse evidence, and mundane evidence:

The model has no difficulty in representing the effect of surprising evidence. For example, that a town reported to have been conquered and sacked simply did not exist at the relevant time is naturally regarded as *strong against* the Conquest hypothesis, markedly influencing its posterior degrees of belief relative to a hypothesis that is not sensitive to such a discovery.

The effect of surprising evidence upon Bayesian conditionalization is sometimes equated with *diverse evidence* (Cf. 2.2 d), in that evidence that varies in ways relevant to the hypotheses is considered to have a stronger influence than evidence "of the same kind."

[23] I am grateful to Ilan Sharon for suggesting this classification of the hypotheses to me.

I posit that the situation discussed herein demonstrates that diversity of evidence is not always a virtue: Due to the fragmentary nature of archaeological findings and the always existent possibility of intrusive findings,[24] accumulation of evidence of a similar nature can contribute to the "stability and autonomy" of the evidence (Wylie 2002:192) thus increasing its confirmational value. What is important is not so much the *diversity* of the evidence but its *independence* from the hypothesis being probed and from other evidential claims (Kosso 1989, 2001:75-80) and the consilience of several independent lines of evidence (Forber and Griffith 2011).

It was the accumulation of many *similar* findings from the large-area surveys that raised awareness of the significance of the Hill settlements in the Bronze/Iron Age transformation in Palestine. As the above analysis shows, even if each survey lends a hypothesis only *anecdotal* support, that is sufficient to tilt the scales toward that hypothesis. In such cases the weighting of similar evidence as "diminishing returns" would be a wrong confirmatory strategy.

c. <u>The importance of the (shifting) background:</u>

All probabilities in the Bayesian formula depend upon the background knowledge of the agent. Background knowledge is often assumed to be static so that the term indicating it is sometimes omitted under the assumption that it is "built into" the probability distribution (e.g., Strevens 2006:5).

However, background knowledge is bound to change. Most case studies of Bayesian confirmation involve short periods of conditionalization, so a change in background knowledge may be considered negligible. A protracted conditionalization process complicates the matter, because earlier evidence becomes part of the knowledge base and can influence subjective likelihoods.

It is, for example, reasonable to surmise that it was previously attained knowledge from excavations of Canaanite cities, with its equivocal verdict about the Conquest hypothesis, that directed attention to the hill settlements which in turn bolstered the Immigration hypothesis. Here, this effect was handled by assigning the late large-area

[24] An artifact that somehow (e.g. through a morphological changes or human intervention) found its way into an archaeological context, even though it was not created there.

surveys a higher Bayes factor (Cf. 5.1) than the earlier ones. In more complex cases a subtler, stochastic model may be required.

d. Disputed evidence:

Dissent and disagreement are part of every scholarly endeavor and the archaeological research discussed here is no exception. It is significant, therefore, that almost all the evidential claims cited above were accepted undisputedly (Cf. 3.2). Disagreements - sometimes respectful (Albright 1956) and sometime acrimonious (as described in Silberman 1993) - revolved around interpretations of this evidence and not their content[25]. More often than not, the thesis that scholars who hold different convictions will be unable to agree about the content of the evidence and their relevance to the hypotheses under discussion (Godfrey-Smith 2003:209, Ullmann-Margalit 2006:22) was simply not borne out.

However, as Section 5.3 above demonstrates, when disagreement about evidential claims does exist, Bayesian conditionalization may diverge rather than converge. Accepting Aharoni's and Zertal's estimates for the dating of the earlier hill settlements totally reverses the ranking of degrees-of-belief of the Immigration and the Autochthonic hypotheses, making the former look much more plausible than the latter, while accepting other archaeologists' view gives the opposite result.

Both Aharoni and Zertal were supporters of the Immigration hypothesis. Do we have here an example of a "hermeneutic circle" which is not amenable to a rational resolution? I do not think so. While these scholars' judgments were most likely *influenced* by the hypothesis they adhered to, it was by no means *derived* from this hypothesis.[26] Moreover, one cannot preclude the possibility that new evidence – possibly from an independent methodology such as radiocarbon dating– will resolve the issue one way or another.

e. Eliminative inference:

Earman (1992:165-185) endorses eliminative induction, not in the Sherlockian sense of deductively disconfirming each hypothesis in turn until only one remains, but in the

[25] Cf. section 3.2 for the meaning of "content" and "interpretation" as used here.

[26] In this respect the case discussed here differs from explications given to the ruins in Qumran (Ullmann-Margalit 2006) that were derived from scholars' opinions as to whether the site was or was not inhabited by a sect of hermits.

Bayesian context whereby conditionalization drives the probability of a hypothesis to values so low as to be disregarded.

If one grants that a probability lower than, say a tenth of a percent is "low enough," then the results above show the Conquest and Revolt hypotheses to have been eliminated (a conclusion which accords with the prevailing scientific opinion). One might also consider either the Immigration or the Autochthonic hypothesis as having been eliminated, or close to being so, depending upon one's opinion on the dating of the hill settlements (Cf. 5.3).

Earman's analysis of eliminative Bayesianism stipulates the availability of a partition {Hi} of *all* observationally distinguishable alternatives. This requirement has clearly not been met in the process discussed above: The Revolt and Autochthonic hypotheses were not even conceived at the time that the Conquest hypothesis was being eliminated. As Earman himself notes (1992:182), omniscience is not common in science; but availability of a complete hypotheses space is, by Earman's analysis, a perquisite for the accumulation of evidence to drive the (absolute) probability of any one hypothesis to unity. While we may say that the Conquest and Revolt hypotheses have been eliminated, we cannot say that either the Immigration or the Autochthonic hypotheses have been "accepted" – not even as a shortcut to the condition of having a degree-of-belief close to one. So it seems to me that in all cases where a complete enumeration and partition of hypotheses cannot be done – arguably, most of science – Earman is close to accepting Salmon's recommendation for comparative Bayesian evaluation of competing theories, a proposition which he strongly criticizes (*ibid* 171-173)[27].

Norton (1995) suggests that that the introduction of new hypotheses can be part of *eliminative* induction: As more and more hypotheses are discredited and a smaller and smaller subset of not-yet-eliminated theories receive more complete articulation, and this can point to missing elements in the former set of alternatives and form the basis of a new one. A similar view is given by Kitcher (1993:237-247): As theories are eliminated, evidence can draw our attention to theories that were not considered; but when one round of elimination is exhausted, a change in scientific practice – which

[27] Earman has other reservations about Salmon's suggestion which are not relevant here.

may include changes in methodology and even in linguistics - may result in new alternatives.

Both Norton's and Kitcher's portrayal of eliminativism do not match the process described above. Norton speaks of eliminations that "conclude with the full articulation of the final theory" – something that clearly is not present here (if it ever is). Kitcher's rich view of eliminative inference is non-Bayesian and essentially deductive. Regardless of whether it is appropriate to other cases, it is hard to reconcile with the fragmentary nature of archeological evidence, where typically only an accumulation of many instances leads to a reasonably safe conclusion. But Norton's and Kitcher's observations about the formulation of new hypotheses as being driven by the process of testing and elimination do conform to the process described above. In particular, it was the failure of the (by then dominant) Immigration hypothesis to accord with data gathered from the late surveys that drove scholars to expand the scope of possible hypotheses, a move that included the introduction of terms like "internal nomadism" and "proto-Israelites" into the explanatory discourse.

7. Conclusion

Using fairly moderate assumptions, a diachronic and contrastive Bayesian model has been constructed simulating a multi-decade process that resulted in a momentous change in the distribution of beliefs within a scientific community. Analysis shows that the model's results are only weakly sensitive to its assumptions.

This does not, of course, prove that the scholars involved cast their thoughts and debates in Bayesian terms. They did not (and scientists rarely do). But it does show that the overall process can be so construed. If one accepts that Bayesian updating is a rational method for evaluating hypotheses and adjudicating between rival theories these results can serve as a signal for rationality of these particular debates, or of the discipline of archaeology, or of science in general. The fact that the subject matter of these scholarly debates involved (as it still does) deeply entrenched emotions and ideologies may reinforce this comforting conclusion.

An important observation to be made is that this convergence toward consensus was possible because scholars of different persuasions generally agreed upon the essential attributes of the findings and their archaeological (even if not the historical) significance. This ability of archeological methods to "unambiguously disprove

entrenched claims and assumptions" (Wylie 2002:170) contravenes assertions (as, e.g., in Hodder 1997; Shanks and Tilley 1987; Bloor 1991 and Ullmann-Margalit 2006) that the relation between observations, evidence and hypotheses – in archaeology, in the human sciences, and in science in general – are essentially hermeneutic and inextricably tied to worldviews and theoretical assumptions. But it is also important to note that the existence of such agreement is not guaranteed. It depends upon the survival and discovery of evidence, as well as the existence of a developed and stable theoretical and methodological base on which to interpret the evidence (Tucker 2004: 181-184) and when these are absent convergence is threatened and may be impossible.

This treatise also sheds light on several known issues in Bayesian confirmation. It demonstrates that the problems of "old evidence" and "new theories" are not equivalent: For the former, it is possible to adopt a solution wherein the learning of the evidence's significance is itself (new) evidence, while the latter admits only counterfactual confirmation by pre-existing evidence with all its difficulties. There is also asymmetry in the effects of "surprising evidence" and "diverse evidence": Depending upon the subject matter involved, many similar pieces of evidence may be essential for establishing the genuineness and significance of each single one.

I use a methodology of pairwise contrastive comparisons between competing hypotheses that results in a series of successive eliminations, in which one alternative ends up with a negligibly small probability in comparison to the other. This approach fits the actual historical scenario and is dictated by our inability to list all potential alternative hypotheses, but has the drawback of never being able to obtain an absolute measure for the degree-of-belief in any specific hypothesis, whether or not such absolute figures are meaningful.

I posit that what was shown above undermines the notion that Bayesian updating of hypotheses and beliefs is impossible in archaeology and in human sciences in general. Aside from this, the above results are by their very nature descriptive and not normative. But descriptive case studies abound in Bayesian literature. This one is unique in that it looks at an often neglected discipline over a lengthy period and as such, I think, is no less valuable than case studies of Mercury's perihelion, the blackness of ravens, or the grueness of emeralds.

Acknowledgments

In title page.

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