The stability of Bose gases near resonance has been a puzzling problem in recent years. We demonstrate that in addition to generating thermal pressure, thermal atoms enhance the repulsiveness of the scale-dependent interactions between condensed atoms due to renormalization effect and further stabilize the Bose gases. Consequently, we find that, as a precursor of instability, the compressibility develops an anomalous structure as a function of scattering length and is drastically reduced compared with the mean-field value. Furthermore, as a potential smoking gun for probing such an effect, the density profile of a Bose gas in a harmonic trap is found to develop a flat top near the center due to the anomalous behavior of compressibility.